

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



## *User Guide*

Version 1.0 - July 2007

Rodrigo Archondo-Callao





*SSATP Working Paper No. 85-A*

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**Road Network Evaluation Tools  
(RONET)**

**Version 1.0, July 2007**

**User's Guide**

**Rodrigo Archondo-Callao**

**October 2007**

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## Acknowledgments

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## List of Acronyms and Abbreviations

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AADT	Average Annual Daily Traffic
ANE	National Roads Administration in Mozambique
ESA	Equivalent Standard Axles
ETWTR	Energy, Transport & Water Department's Transport Unit (The World Bank)
GDP	Gross Domestic Product
HDM	Highway Development & Management
HNMS	Highway Network Management System (Mozambique)
IQL	Information Quality Level
IRI	International Roughness Index
Km	Kilometer
PAM	Performance Assessment Model
PMORALG	Prime Ministers Office Regional Administration and Local Government
PMS	Pavement Management System
RAFU	Road Agency Formation Unit
RAI	Rural Access Indicator
RED	Road Economic Decision Model
RMI	Road Management Initiative
RMMS	Road Maintenance Management System (Tanzania)
ROCKS	Road Cost Knowledge System
RONET	Road Network Evaluation Tools
RSSS	Road Sector Strategy Study (Mozambique)
RUC	Road User Charges Model
RUCKS	Road User Costs Knowledge System
SAM	Social Accounting Matrix
SSATP	Sub-Saharan Africa Transport Policy Program
ST	Surface Treatment
TANROADS	Tanzania National Roads Agency
TTC	Total Transport Costs
UNRA	Uganda National Roads Authority
USD	United States Dollar
VOC	Vehicle operating cost



## Part A – Overview

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### INTRODUCTION

The Road Network Evaluation Tools (RONET) model is being developed for the Sub-Saharan Africa Transport Policy Program<sup>1</sup> (SSATP) by the Energy, Transport and Water Department, Transport Anchor (ETWTR), of the World Bank to assist decision makers to accomplish the following:

- Monitor the current condition of the road network
- Plan allocation of resources
- Assess the consequences of macropolicies on the road network

RONET is a tool for assessing the performance of road maintenance and rehabilitation policies and the importance of the road sector for the economy, to demonstrate to stakeholders the importance of continued support for road maintenance initiatives. It assesses the current network condition and traffic, computing the asset value of the network and road network monitoring indicators. It uses country-specific relationships between maintenance spending and road condition, and between road condition and road user costs, to assess the performance over time of the network under different road works standards, determining, for example, the minimum cost for sustaining the network in its current condition. It also shows the savings or the costs to the economy to be obtained from maintaining the network at different levels of road condition. It further determines the proper allocation of expenditures among recurrent maintenance, periodic maintenance, and rehabilitation road works. Finally it determines the “funding gap,” defined as the difference between current maintenance spending and required maintenance spending (to maintain the network at a given level of road condition), and the effect of under spending on increased transport costs.

The model is developed from the same principles underlying the accepted economic evaluation, engineering, and design model Highway Development and Management Model<sup>2</sup> (HDM-4), adopting the same road user costs relationships of the HDM-4 and simplified road deterioration equations derived from the HDM-4 research. However, the primary audience for RONET is decision makers in the road sector, for whom it is designed as a tool for advocacy of specific revenue enhancing or cost recovery measures.

RONET is being developed for use in the Africa region, but there are no impediments to its application in 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 (i)

functional classification, (ii) surface type, (iii) traffic level, (iv) road condition, (v) terrain, (vi) climate, and (vii) geographical region.

In the past SSATP has developed two other software tools, also designed to evaluate an entire road network by evaluating a series of representative road classes, as follows:

- The Road User Charges Model Version 3.0<sup>3</sup> (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 functions of traffic, percent of cars, trucks loading, pavement strength, environment, level of agency costs, and vehicle operating costs.
- The Performance Assessment Model Version 1.0<sup>4</sup> (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 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. RONET is being developed in a modular form, characterizes the entire road network of a country by allowing the definition of a maximum of 625 road classes, and includes simplified road deterioration models based on HDM-4 research. 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 could be enhanced in the future by adding the following evaluation modules, for example: (i) road user charges evaluation, (ii) life-cycle economic evaluation, (iii) axle loading impacts evaluation, (iv) accidents impacts evaluation, and (v) network improvements evaluation.

## MODEL STRUCTURE

To run RONET you first review the Configuration pages and modify any configuration data, if necessary. Cells with a bright yellow background indicate country-specific inputs that you are expected to modify, whereas cells with dim yellow backgrounds indicate user-defined RONET defaults that most likely you will not need to modify. Then you enter the country-specific inputs at the following Input Data pages:

- *Country Data* that collects land area, total population, rural population, gross domestic product at current prices, total vehicle fleet, discount rate, traffic growth rates, pavement widths, capital works unit costs, recurrent maintenance works unit costs, traffic level characteristics, and vehicle fleet unit road user costs relationship to roughness
- *Road Network Length* that collects the road network length distribution by road classes that are functions of network type, surface type, traffic category and condition category
- *Historical Data* that collects historical average road expenditures and road works during the last five years per surface class and road work type

The RONET road network length can cover the entire road network system of the country (roads, highways, expressways, streets, avenues, and so forth), or a partial road network; for example, the road network of a state or province of the country, or the road network managed by the main road agency. The road network is represented by road classes that are a function of (i) five network types, (ii) five surface types, (iii) five traffic categories, and (iv) five condition categories, which total a maximum of 625 road classes. Table 1 illustrates the representative road classes.

Table 1. Matrix of Road Classes: Overall Network Evaluation

Matrix of Road Classes: Overall Network Evaluation					
Network Type	Surface Type				
	Concrete	Asphalt	S.T.	Gravel	Earth
Primary					
Secondary					
Tertiary					
Unclassified					
Urban					

Traffic Category	Condition Category				
	Very Good	Good	Fair	Poor	Very Poor
Traffic I					
Traffic II					
Traffic III					
Traffic IV					
Traffic V					

## Network Types

The road network is subdivided into as many as five network types that are user defined. The RONET default configuration subdivides the network into five network types characterized by functional classification, but you have the option to change the default configuration and redefine the characteristics of each road network type. For example, each network type can represent a different, region, terrain type, or climate type. Table 2 below shows the default configuration and sample user-defined configurations.

Table 2. Default Configuration and Alternative Configurations

Network Type	Default Configuration	Alternative Configurations Examples	
	Types by Functional Class	Types by Geographic Region	Types by Terrain Type
1	Primary	North Region	Flat Terrain
2	Secondary	South Region	Hilly Terrain
3	Tertiary	Eastern Region	Mountainous Terrain
4	Unclassified	Western Region	NA
5	Urban	Central Region	NA

The default RONET road network types are based on the functional classification of the roads. The default network types are as follows:

- Primary:* Arterial, main, trunk, or national roads, which are roads outside urban areas that belong to the top-level road network and generally, have higher design standards than other roads. These roads generally provide the highest level of mobility, at the highest speed, for long interrupted traffic. These roads form the principal avenue of communication between and through major regions of the country, between regional capitals and key towns that have significant national economic and social interaction, and between the country and adjoining countries, whose main function is to provide access to major freight terminals, including ports.
- Secondary:* Collectors, classified as rural or regional roads, which are the main feeder routes into primary roads, and provide the main links between primary roads. These roads generally provide a lower degree of mobility than primary roads, being designed for travel at lower speeds and for shorter distances. These roads form the principal avenue of communication between primary roads and key towns and between primary roads and important centers, which have a significant economic, social tourist, or recreation role (for example, tourism and resource development).
- Tertiary:* Local roads, which are classified as rural or local roads. The roads are characterized by a comparatively low-level design standard and traffic. These roads provide basic access between residential and commercial properties, connecting with

higher-order roads. The function of these roads is to provide the only access to scattered rural settlements and primarily serve local social services, as well as provide access to markets and generally form the first phase of the journey for commuters.

- *Unclassified*: Unclassified roads, which are roads that do not fall into any of the previous categories. These roads comprise special-purpose public roads that cannot be assigned to any other class above, and which are provided almost exclusively for one specific activity or function, such as recreational, forestry, mining, national parks, or dam access.
- *Urban*: Urban roads, streets, and avenues, which are located within the boundaries of cities or towns.

On different countries, different road networks are managed by different road agencies or entities; therefore, RONET allows for definition of the management responsibility type of each road network. On the RONET Basic Configuration page, you assign one possible management type or entity (management and funding responsibility) to each road network type. The default user-defined management types are the following:

- *Private sector*: roads that are under the jurisdiction of concessionaires
- *National road agency*: roads that are under the jurisdiction of the national road agency
- *Regional road agencies*: roads that are under the jurisdiction of regional, provincial, or state governments
- *Local road agencies*: roads under the jurisdiction of district or local governments
- *Urban municipalities*: roads, streets and avenues that are under the jurisdiction of city or town governments.

## **Surface Types**

Each network type is subdivided into the following five possible surface types:

- Concrete pavement
- Asphalt mix pavement
- Surface treatment pavement
- Gravel road
- Earth road

The country-specific characteristics of each surface type are defined on the RONET Basic Configuration page.

## **Traffic Categories**

Each surface type is subdivided into five possible traffic categories (Traffic I, Traffic II, Traffic III, Traffic IV, Traffic V). To each traffic category, you assign one of nine possible traffic lev-

els (T1 to T9) defined on the RNET Basic Configuration page. Table 3 presents the default nine RNET traffic levels, based on a logarithmic scale. The table presents the traffic characteristics of each traffic level and corresponding illustrative geometric and pavement standards. Proper geometric and pavement standards are country-specific and are the product of an economic evaluation; therefore, the standards presented in table 3 are given only for illustrative purposes.

Table 3. RNET Default Traffic Levels

Traffic Level	Average Annual Daily Traffic (AADT)		Average (veh/day)	Illustrative Standards	
	Minimum (veh/day)	Maximum (veh/day)		Geometry Standard	Pavement Standard
T1	0	10	5	1-lane warranted	Formation not warranted
T2	10	30	20	1-lane warranted	Formation warranted
T3	30	100	65	2-lane warranted	Gravel warranted
T4	100	300	200	2-lane warranted	Gravel warranted
T5	300	1,000	650	2-lane warranted	Paved Surface warranted
T6	1,000	3,000	2,000	2-lane warranted	Paved Surface warranted
T7	3,000	10,000	6,500	2-lane warranted	Paved Surface warranted
T8	10,000	30,000	20,000	4-lane warranted	Paved Surface warranted
T9	30,000	100,000	65,000	multi-lane warranted	Paved Surface warranted

- Standard given for illustration purposes. Proper standards are country specific.

- AADT of motorized 4-tires or more 2-way traffic

Table 4 presents the RNET default assignment of traffic levels to each traffic category per surface type. Most likely, you will not need to change the characteristics of each traffic level and the default RNET traffic level assignments to each traffic category.



Table 4. RNET Default Assignment of Traffic Levels

Surface Type	Traffic Category	Traffic Level	Average Annual Daily Traffic (AADT)			Illustrative Standards	
			Minimum (veh/day)	Maximum (veh/day)	Average (veh/day)	Geometry Standard	Pavement Standard
Earth	Traffic I	T1	0	10	5	1-lane warranted	Formation not warranted
	Traffic II	T2	10	30	20	1-lane warranted	Formation warranted
	Traffic III	T3	30	100	65	2-lane warranted	Gravel warranted
	Traffic IV	T4	100	300	200	2-lane warranted	Gravel warranted
	Traffic V	T5	300	1,000	650	2-lane warranted	Paved Surface warranted
Gravel	Traffic I	T2	10	30	20	1-lane warranted	Formation warranted
	Traffic II	T3	30	100	65	2-lane warranted	Gravel warranted
	Traffic III	T4	100	300	200	2-lane warranted	Gravel warranted
	Traffic IV	T5	300	1,000	650	2-lane warranted	Paved Surface warranted
	Traffic V	T6	1,000	3,000	2,000	2-lane warranted	Paved Surface warranted
Paved	Traffic I	T4	100	300	200	2-lane warranted	Gravel warranted
	Traffic II	T5	300	1,000	650	2-lane warranted	Paved Surface warranted
	Traffic III	T6	1,000	3,000	2,000	2-lane warranted	Paved Surface warranted
	Traffic IV	T7	3,000	10,000	6,500	2-lane warranted	Paved Surface warranted
	Traffic V	T8	10,000	30,000	20,000	4-lane warranted	Paved Surface warranted

- Standard given for illustration purposes. Proper standards are country specific.

- AADT of motorized 4-tires or more 2-way traffic

### Road Condition Categories

Each network type, road type, and traffic category is subdivided into five possible road condition categories defined as a function of the engineering assessment of the capital road works (periodic maintenance or rehabilitation works) needed to bring a road to very good condition. Routine maintenance road works are needed by all roads every year; therefore, they are not considered on the definition of the road condition classes.

For paved roads, the road condition classes are defined as follows:

- a) *Very Good*: Roads in very good condition require no capital road works.
- b) *Good*: Roads in good condition are largely free of defects, requiring some minor maintenance works, such as preventive treatment or crack sealing.
- c) *Fair*: Roads in fair condition are roads with defects and weakened structural resistance, requiring resurfacing of the pavement (periodic maintenance), but without the need to demolish the existing pavement.

- d) *Poor*: Roads in poor condition require rehabilitation (strengthening or partial reconstruction).
- e) *Very Poor*: Roads in very poor condition require full reconstruction, almost equivalent to new construction.

For gravel roads, the road condition classes are defined as follows:

- a) *Very Good*: Roads in very good condition require no capital road works.
- b) *Good*: Roads in good condition are roads that require only spot regravelling.
- c) *Fair*: Roads in fair condition require regravelling (periodic maintenance).
- d) *Poor*: Roads in poor condition require partial reconstruction.
- e) *Very Poor*: Roads in very poor condition require full reconstruction, almost equivalent to new construction.

For earth roads, the road condition classes are defined as follows:

- a) *Very Good*: Roads in very good condition require no capital road works.
- b) *Good*: Roads in good condition are roads that require only spot repairs.
- c) *Fair*: Roads in fair condition require heavy grading (periodic maintenance).
- d) *Poor*: Roads in poor condition require partial reconstruction.
- e) *Very Poor*: Roads in very poor condition require full reconstruction, almost equivalent to new construction.

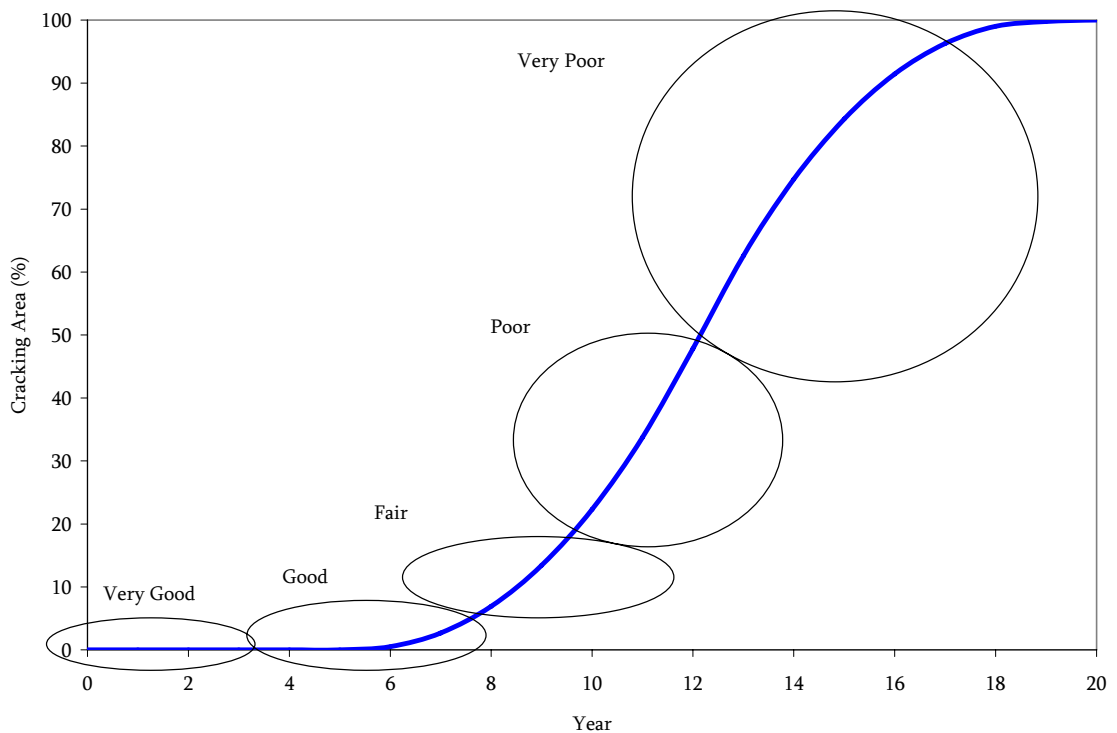
Table 5 presents a summary of the capital road works needed to bring a road to very good condition by surface type.

**Table 5. Capital Road Works Needed to Bring a Road to Very Good Condition**

Capital Road Works Needed to Bring a Road to Very Good Condition			
Condition Category	Bituminous Roads	Gravel Roads	Earth Roads
Very Good	None	None	None
Good	Preventive Treatment	Spot Regravelling	Spot Repairs
Fair	Resurfacing	Regravelling	Heavy Grading
Poor	Strengthening	Partial Reconstruction	Partial Reconstruction
Very Poor	Full Reconstruction	Full Reconstruction	Full Reconstruction

Figure 1 presents the road condition categories of bituminous roads, taking into account the area of cracking and the pavement age.

Figure 1. Road Condition Categories of Bituminous Roads



To assess the consequences to the road agency, the infrastructure, and the economy of applying different maintenance and rehabilitation standards, RONET needs to associate an average roughness value to each road condition category. Table 6 presents the default RONET basic characteristics of each road condition class in terms of roughness and the corresponding car speeds on a flat terrain for unpaved roads. The roughness values are country-specific and user-defined at the RONET Basic Configuration page. Note that the car speeds are given for illustrative purposes and are not being used by the RONET model.

RONET is by default configured to reflect average road characteristics that are applicable to African conditions. If needed, RONET can be configured to reflect other local conditions. On the configuration pages, cells with bright yellow backgrounds indicate country-specific inputs that you are expected to modify, whereas cells with dim yellow background indicate user-defined RONET defaults that most likely you will not modify.

**Table 6. Default RONET Basic Characteristics of Each Road Condition Class**

Surface Type	Condition Category	Roughness (IRI m/km)			Speeds (km/hr)
		Minimum	Maximum	Average	
Concrete	Very Good	1.0	2.5	2.0	
	Good	2.5	3.5	3.0	
	Fair	3.5	6.0	4.0	
	Poor	6.0	10.0	8.0	
	Very Poor	10.0	16.0	12.0	
Asphalt	Very Good	1.0	2.5	2.0	
	Good	2.5	3.5	3.0	
	Fair	3.5	5.5	4.5	
	Poor	5.5	10.5	8.0	
	Very Poor	10.5	16.0	12.0	
S.T.	Very Good	1.0	3.5	3.0	
	Good	3.5	4.5	4.0	
	Fair	4.5	6.5	5.5	
	Poor	6.5	11.5	9.0	
	Very Poor	11.5	16.0	13.0	
Gravel Roads	Very Good	1.0	6.0	5.0	90-110
	Good	6.0	9.0	7.0	70-90
	Fair	9.0	13.5	11.0	40-70
	Poor	13.5	18.0	16.0	30-40
	Very Poor	18.0	25.0	20.0	20-30
Earth Roads	Very Good	1.0	8.0	7.0	90-110
	Good	8.0	11.0	9.0	70-90
	Fair	11.0	15.5	13.0	40-70
	Poor	15.5	20.0	18.0	30-40
	Very Poor	20.0	25.0	22.0	20-30

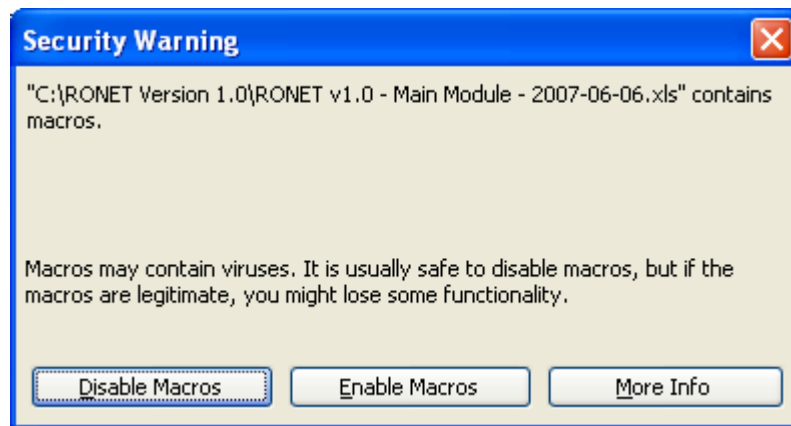
Speeds represent range of car speeds at the dry season on a flat terrain

## SOFTWARE CHARACTERISTICS

RONET is implemented on a Microsoft Office Excel 2003 workbook. To run RONET, open the following Excel workbook:

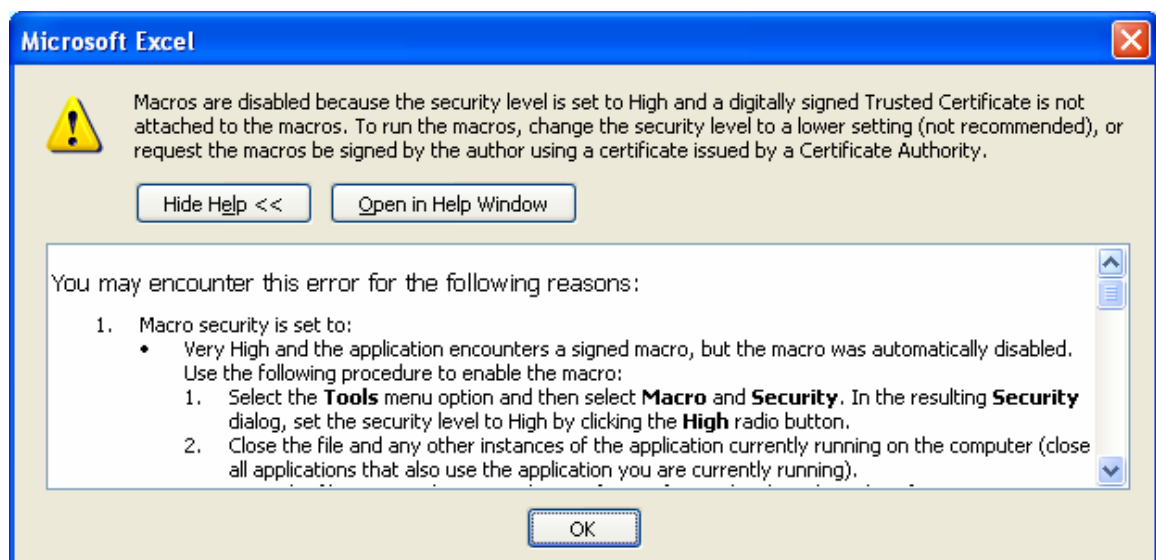
RONET v1.0 - Main Module - 2007-06-06.xls

RONET relies on Excel macros to perform its calculations; therefore, Excel has to be configured to enable Excel macros. If Excel is properly configured, you will get the following message when opening the RONET Excel workbook.



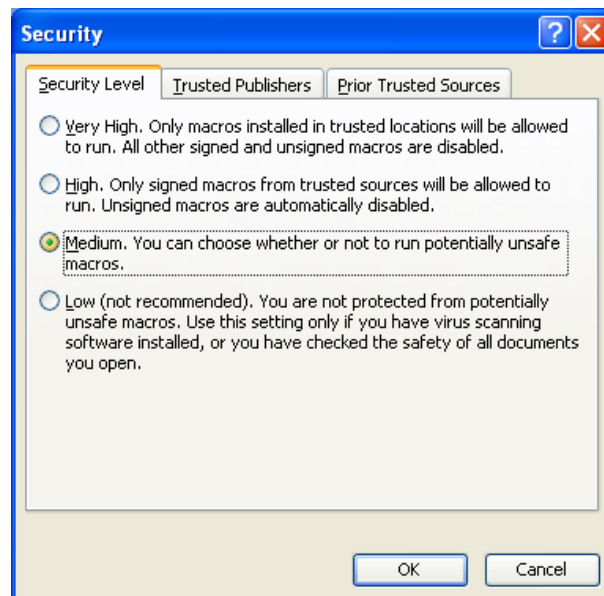
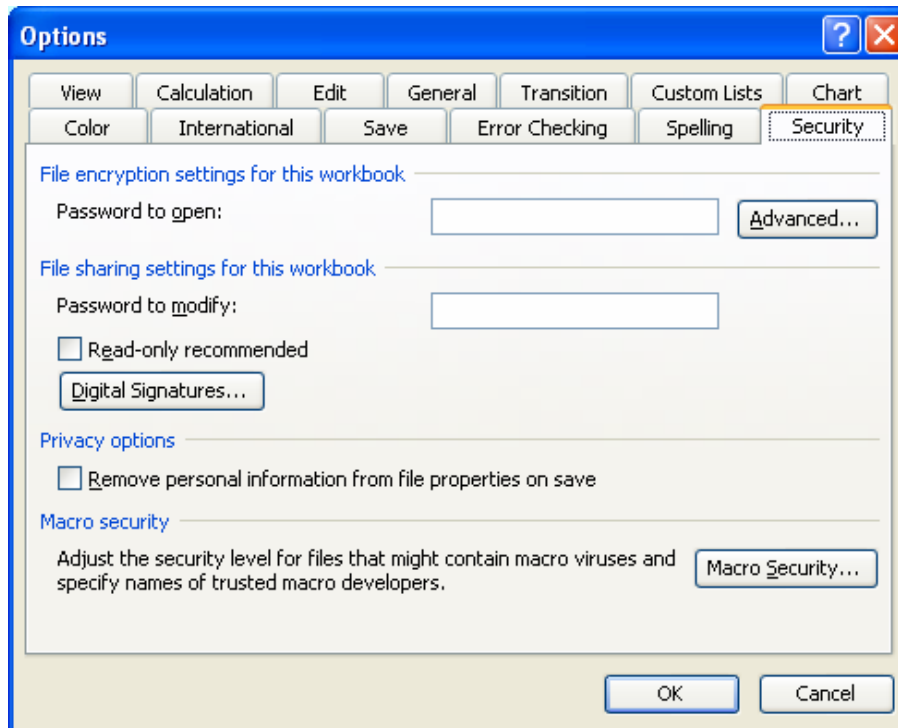
In this case, select the option “Enable Macros” to go to the RONET main menu.

If Excel is not properly configured, you will get the following message when opening the RONET Excel workbook, indicating that the Excel security level is set to high.



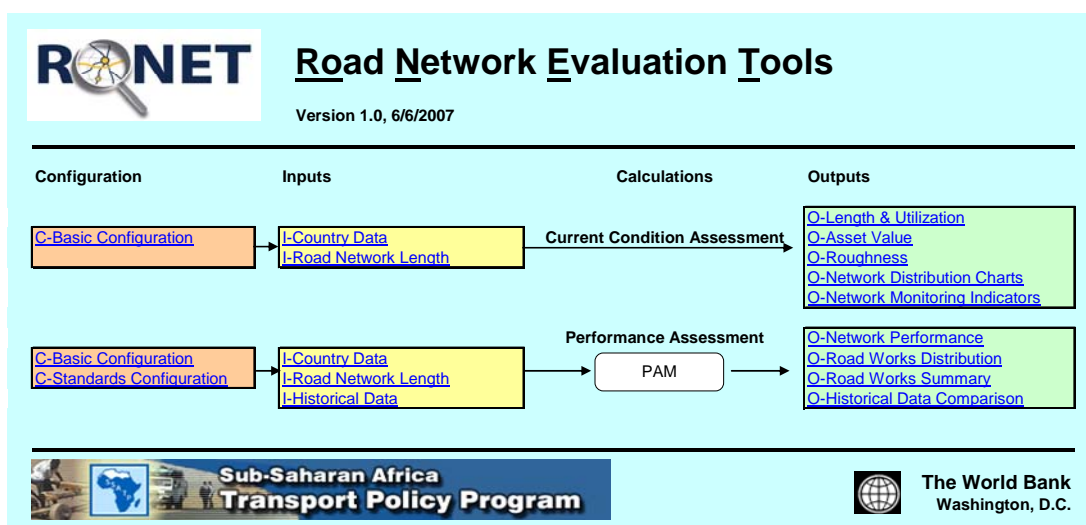
To be able to run the RONET macros, you should change the Excel security level to a medium setting by following the steps below:

1. Select the **Tools** menu option of Excel and then select **Options**. At the Options tabs, select the **Security** tab and press the button **Macro Security**. In the resulting **Security** dialog, set the security level to Medium by clicking the Medium radio button. See the screenshots below.



2. Close the Excel workbook and any other instances of the Excel application currently running on the computer.
3. Open the RONET Excel workbook again and click the Enable Macros button at the Security Warning dialog, to allow for the macros to run.

When you open RONET, you are presented with the following RONET main menu:



The menu is subdivided into the following areas:

- Configuration: presents pages where you can configure the model
- Inputs: presents pages where you enter the model input parameters
- Calculations: presents buttons that you press to perform calculations
- Outputs: presents pages that store the results of the calculations

To view a particular page, press the corresponding hyperlink (page name) and you will be directed to that page. If you are viewing a Configuration, Input, or Output page and want to return to the main menu, press the M hyperlink that is placed on the top left corner of the page (cell A1). All pages are formatted to be printed; therefore, if needed, use the Excel print options to print any page.

The first RONET module is the module that performs the network current condition assessment. On this module, there is no need to press any button to compute the results, which are all computed with Excel formulas.

The second RONET module is the module that performs the network performance assessment. On this module, there is a need to press the corresponding “Performance Assessment” button to compute the results, which are computed using Excel macros. Note the following:

- When you press the Performance Assessment button, RONET asks if you want to keep the intermediate results of the calculations on a temporary workbook. If you select Yes, all the intermediate results are stored on a new workbook created automati-

cally by RONET. The new workbooks are named “Book1,” “Book2,” “Book3,” and so on. Once you are done reviewing a temporary workbook, you can close it or save it if necessary (saving with a different name if necessary). If you select No, then no temporary workbook is created.

- To compute the results takes between two and five minutes, depending on the computer processing speed. The status of the calculations is presented on the Excel status line at the bottom left corner of the screen. When all the calculations are done, the model presents a message indicating the end of the calculations and the duration of the calculations.

When you are displaying a Configuration, Input, or Output page, you will notice that some cells have a yellow background. These cells with the yellow backgrounds are input cells where you enter your input data or your model output choices. Cells with bright yellow backgrounds indicate country-specific inputs that you are expected to modify, whereas cells with dim yellow backgrounds indicate user-defined RONET defaults that most likely you will not need to modify. All the cells with a white background contain labels (black font) or formulas (blue font). You are only allowed to edit the input cells with yellow backgrounds because all other cells are protected. If you need to unprotect a page, select the Tools menu option of Excel, and then select Protection and Unprotect Sheet.

RONET can be used with any currency, but the numerical fields and decimal places are set up to fit U.S. dollars and all RONET default values are provided in U.S. dollars. If you decide to use any other currency, you have to be careful to enter all the inputs and default values using the same currency on all RONET configuration and input pages. In that case, all the results will be presented in that currency.

To carry out a current condition assessment, follow the steps below.

- If necessary, modify the basic configuration
- Enter the country data
- Enter the network data
- View and the corresponding output pages

To carry out a performance assessment, follow the steps below.

- If necessary, modify the basic configuration, if you had not done that before
- If necessary, modify the standards configuration
- Enter the country data, if you had not done that before
- Enter the network data, if you had not done that before
- Enter the historical data
- View and the corresponding output pages, selecting on row 1 a corresponding surface class, standard, road work type, or period



## Part B – Configuration

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### BASIC CONFIGURATION

#### Management Types

On the Basic Configuration page, the first option is to define the possible management responsibility types present in the country. RONET shows, as one of its outputs, the required road agency costs and other indicators summarized by these management types. The default management types are given below:

- *Private* sector: roads that are under the jurisdiction of concessionaires
- *National* road agency: roads that are under the jurisdiction of the national road agency
- *Regional* road agencies: roads that are under the jurisdiction of regional, provincial or state governments
- *Local* road agencies: roads under the jurisdiction of district or local governments
- *Urban* municipalities: roads, streets and avenues that are under the jurisdiction of city or town governments

#### Network Types

The second option defines the names of the five network types characterized for the country or partial road network. For example, one can subdivide a network by functional classification, geographical region, or terrain. The default values define the network types by functional classification (Primary, Secondary, Tertiary, Unclassified, or Urban) as shown in table 7.

Table 7. 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	Local Government
Urban	2	12	Urban Roads

The network types can be defined differently on different countries. For example, in China, the network types could be defined as: Expressway, Class I, Class II, Class III, and Class IV

roads, and on another country, where all roads are managed by only one road entity, the network types could represent different regions of the country: North, South, Center, East, and West. Therefore, it is expected that most users will configure the definition of the network types to reflect local conditions. Some examples are given in table 8.

**Table 8. Default and Alternative Configurations**

	Default Configuration	Alternative Configurations Examples	
Network Type	Types by Functional Class	Types by Geographic Region	Types by Terrain Type
1	Primary	North Region	Flat Terrain
2	Secondary	South Region	Hilly Terrain
3	Tertiary	Eastern Region	Mountainous Terrain
4	Unclassified	Western Region	NA
5	Urban	Central Region	NA

Once the network types are defined, you then define, for each network type, the average terrain type (1 to 3), environment type (1 to 23), and the management entity (management type) responsible for management of the network type. Each terrain type and environment type is identified by an identification number.

### Terrain Types

The average physical characteristics of the three possible terrain types (1-flat, 2-hilly or 3-mountainous) vary by country; therefore, they are defined at the Basic Configuration page. Here you enter the corresponding average Rise & Fall, in m/km, and Horizontal Curvature, in degrees/km, of each terrain type, following the HDM-4 definitions of Rise & Fall and Horizontal Curvature. The default RNET values given in table 9 are based on worldwide averages. It is expected that you will adjust these values to reflect local conditions only if local data are readily available on existing HDM-4 studies.

**Table 9. Terrain Types**

Terrain Type (1 to 3)	Terrain Classification	Rise & Fall (m/km)	Horizontal Curvature (deg/km)
1	Flat	0	0
2	Hilly	40	100
3	Mountainous	80	300

## Environmental Types

The Basic Configuration page allows for the definition of 23 possible environment types defined by function of the moisture and temperature classification. Here you can enter, for each environment type, the average rainfall, in mm/month, and the HDM-4 environment coefficient of road deterioration for paved roads. The default values are given below in figure 9. It is expected that very few users will modify the environmental coefficients of road deterioration for paved roads. These coefficients can only be adjusted after a detailed calibration of the HDM-4 road deterioration equations, which typically is not readily available.

Table 10. Environment Types

Environment Type (1 to 23)	Moisture Classification	Temperature Classification	Rainfall (mm/month)	Environment Coefficient (#)
1	Arid	Tropical	15	0.005
2	Arid	Sub-tropical Hot	15	0.100
3	Arid	Sub-tropical Cool	15	0.015
4	Arid	Temperate Cool	15	0.025
5	Arid	Temperate Freeze	15	0.040
6	Semi-arid	Tropical	50	0.010
7	Semi-arid	Sub-tropical Hot	50	0.015
8	Semi-arid	Sub-tropical Cool	50	0.025
9	Semi-arid	Temperate Cool	50	0.035
10	Semi-arid	Temperate Freeze	50	0.060
11	Sub-humid	Tropical	100	0.020
12	Sub-humid	Sub-tropical Hot	100	0.025
13	Sub-humid	Sub-tropical Cool	100	0.040
14	Sub-humid	Temperate Cool	100	0.060
15	Sub-humid	Temperate Freeze	100	0.100
16	Humid	Tropical	175	0.025
17	Humid	Sub-tropical Hot	175	0.030
18	Humid	Sub-tropical Cool	175	0.060
19	Humid	Temperate Cool	175	0.100
20	Humid	Temperate Freeze	175	0.200
21	Per-humid	Tropical	210	0.030
22	Per-humid	Sub-tropical Hot	210	0.040
23	Per-humid	Sub-tropical Cool	210	0.070

## Road Condition Classes

The next Basic Configuration page option is to define (per surface type) for each of the five road condition categories (Very Good, Good, Fair, Poor and Very Poor), the roughness characteristics (average, minimum, and maximum), the number of years since the last periodic maintenance or rehabilitation road work, and the estimate of the percent of roads that are seasonal. The default values are given in table 11. It is expected that few users in Africa will modify the default roughness values and the years since the last periodic maintenance or rehabilitation road work. Users in other regions might adjust these values to reflect local conditions. Users might want to adjust the percent of roads that are seasonal, which is a rough estimate of the percent of the road in each road condition class that are not all-weather roads, because this is a country-specific input.

Table 11. Default Values for Road Condition Classes

Surface Type	Condition Category	Avg. Roughness (IRI)	Min. Roughness (IRI)	Max. Roughness (IRI)	Last Periodic Maint. (years)
Concrete	Very Good	2.0	1.0	2.5	1
	Good	3.0	2.5	3.5	5
	Fair	4.0	3.5	6.0	10
	Poor	8.0	6.0	10.0	15
	Very Poor	12.0	10.0	16.0	20
Asphalt	Very Good	2.0	1.0	2.5	1
	Good	3.0	2.5	3.5	5
	Fair	4.5	3.5	5.5	10
	Poor	8.0	5.5	10.5	15
	Very Poor	12.0	10.5	16.0	20
S.T.	Very Good	3.0	1.0	3.5	1
	Good	4.0	3.5	4.5	5
	Fair	5.5	4.5	6.5	10
	Poor	9.0	6.5	11.5	15
	Very Poor	13.0	11.5	16.0	20
Gravel	Very Good	5.0	1.0	6.0	NA
	Good	7.0	6.0	9.0	NA
	Fair	11.0	9.0	13.5	NA
	Poor	16.0	13.5	18.0	NA
	Very Poor	20.0	18.0	25.0	NA
Earth	Very Good	7.0	1.0	8.0	1
	Good	9.0	8.0	11.0	2
	Fair	13.0	11.0	15.5	3
	Poor	18.0	15.5	20.0	4
	Very Poor	22.0	20.0	25.0	5

## Traffic Levels

RONET considers nine possible traffic levels (T1 to T9). At the Basic Configuration page, you define the average, minimum and maximum daily traffic of each traffic level. The default values are given in table 12. It is expected that few users will modify these default values.

Table 12. Default Values for Traffic Levels

Traffic Level	Avg. Traffic (AADT)	Min. Traffic (AADT)	Max. Traffic (AADT)
T1	5	0	10
T2	20	10	30
T3	65	30	100
T4	200	100	300
T5	650	300	1,000
T6	2,000	1,000	3,000
T7	6,500	3,000	10,000
T8	20,000	10,000	30,000
T9	65,000	30,000	100,000

## Traffic Categories

Finally, you define the traffic level that is associated to each of the five traffic category (Traffic I, Traffic II, Traffic III, Traffic IV, and Traffic V), per surface type, and the structural number of each traffic category for paved roads. The structural number represents the modified structural number at the time of construction or last rehabilitation of the road, computed as defined on the HDM-III<sup>2</sup> documentation, equal to the structural number computed following American Association of State Highway & Transportation Officials (AASHTO) guidelines, plus adding the strength contribution of sub-grade. The default values are given in table 13. It is expected that very few users will modify these default traffic levels per traffic category.

Table 13. Default Values for Traffic Categories

Surface Type	Traffic Category	Traffic Level (T1 to T9)	Avg. Traffic (AADT)	Min. Traffic (AADT)	Max. Traffic (AADT)	Structural Number for Paved Roads (#)
Concrete	Traffic I	T4	200	100	300	6.0
	Traffic II	T5	650	300	1000	6.0
	Traffic III	T6	2000	1000	3000	6.0
	Traffic IV	T7	6500	3000	10000	6.0
	Traffic V	T8	20000	10000	30000	8.0
Asphalt	Traffic I	T4	200	100	300	1.5
	Traffic II	T5	650	300	1000	2.0
	Traffic III	T6	2000	1000	3000	3.0
	Traffic IV	T7	6500	3000	10000	5.0
	Traffic V	T8	20000	10000	30000	8.0
S.T.	Traffic I	T4	200	100	300	1.5
	Traffic II	T5	650	300	1000	2.0
	Traffic III	T6	2000	1000	3000	3.0
	Traffic IV	T7	6500	3000	10000	5.0
	Traffic V	T8	20000	10000	30000	8.0
Gravel	Traffic I	T2	20	10	30	NA
	Traffic II	T3	65	30	100	NA
	Traffic III	T4	200	100	300	NA
	Traffic IV	T5	650	300	1000	NA
	Traffic V	T6	2000	1000	3000	NA
Earth	Traffic I	T1	5	0	10	NA
	Traffic II	T2	20	10	30	NA
	Traffic III	T3	65	30	100	NA
	Traffic IV	T4	200	100	300	NA
	Traffic V	T5	650	300	1000	NA

## STANDARDS CONFIGURATION

The Standards Configuration page defines the characteristics of the road work standards to be evaluated at the Performance Assessment Module. Therefore, the inputs on this page do not affect the results of any other RNET module. On this page, you configure the following parameters.

- Custom Standard
- Capital Road Works Standards
- Recurrent Maintenance Works Standards

## Custom Standard Configuration

The custom standards definition table is used to describe the custom standard to be evaluated. On this table, you define for each network type the road work standard that will be applied under this overall custom standard. For example, one can define to apply the high standard on primary and urban roads, the medium standard on secondary and tertiary roads, and the very low standard on unclassified roads. The custom standard summarizes the overall results of applying the selected standards on the corresponding network types. The default values are given in table 14. These are country- or study-specific values; therefore, it is expected that you will change these values.

Table 14. Custom Standards Definition

Code	Network Type	Select a Standard per Network Type	
		Standard Name	Standard No.
R	Primary	High Standard	2
S	Secondary	Medium Standard	3
T	Tertiary	Medium Standard	3
U	Unclassified	Very Low Standard	5
V	Urban	High Standard	2

## Capital Road Works Standards Configuration

This table defines the capital road works (periodic maintenance and rehabilitation works) to be applied on each standard to be evaluated. The default values for concrete and asphalt concrete roads are given below in table 15. Most likely these default values are applicable for most countries worldwide; therefore, it is expected that few users will modify these default values.

Table 15. Concrete and Asphalt Roads Default Values

### Roughness Thresholds to Apply Recommended Road Works (IRI, m/km)

Scenario		Roughness Range and Required Road Work				
		IRI<=4.0 Overlay	4.0<IRI<=6.0 Overlay	6.0<IRI<=8.0 Strengthening	8.0<IRI<=10.0 Reconstruction	10<IRI Reconstruction
Code	Name	Roughness Threshold (IRI)				
A	Very High Standard	3.00	4.00	6.00	8.00	10.00
B	High Standard	3.25	4.50	6.50	8.50	10.50
C	Medium Standard	3.50	5.00	7.00	9.00	11.00
D	Low Standard	3.75	5.50	7.50	9.50	11.50
E	Very Low Standard	4.00	6.00	8.00	10.00	12.00
F	Do Minimum	99.00	99.00	99.00	99.00	14.00
G	Do Nothing	99.00	99.00	99.00	99.00	99.00

On this table you define, for each roughness range, the roughness thresholds when the required capital road works will be applied. For example, for a road with current roughness of less than 4.0 IRI, on a very high standard scenario, the required overlay (periodic maintenance) will be applied when the road reaches 3.0 IRI, and on a very low standard scenario, when the road reaches 4.0 IRI. For roads with less than 6.0 IRI, the required road works are overlays; for roads between 6.0 and 8.0 IRI, the required road works are thick overlays (strengthening), and for roads with roughness higher than 8.0 IRI, the required road works are reconstructions.

The default values for surface treatment roads are given in table 16. Most likely these default values are applicable for most countries worldwide; therefore, it is expected that few users will modify these default values.

Table 16. Default Values for Surface Treatment Roads

**Time Interval and Roughness Thresholds to Apply Recommended Road Works (IRI, m/km)**

Scenario		Roughness Range and Required Road Work				10<IRI Reconstruction
		IRI<=4.0 Reseal	4.0<IRI<=6.0 Reseal	6.0<IRI<=8.0 Strengthening	8.0<IRI<=10.0 Reconstruction	
Code	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	99.00	99.00	99.00
G	Do Nothing	99	99	99.00	99.00	99.00

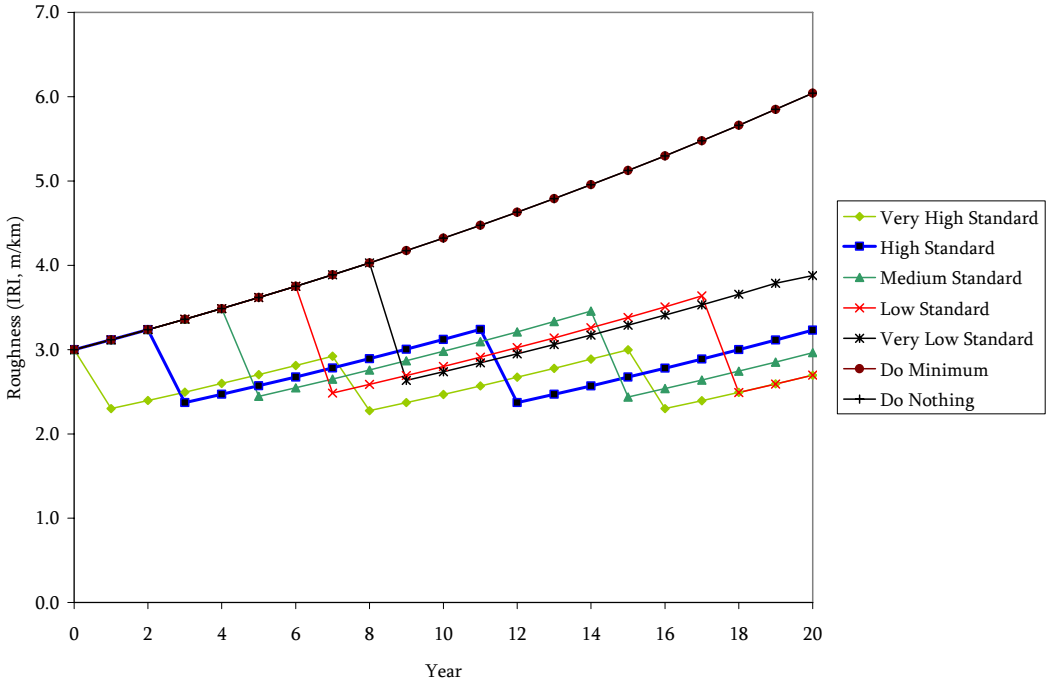
In this case, reseals are the work required for roads with roughness less than 6.0 IRI, and the reseals are scheduled at a fixed time interval in years. On this table, you define, for each roughness range, the roughness thresholds when the required capital road works will be applied for roads with roughness higher than 6.0 IRI, and the frequency of the reseals for roads with roughness less than 6.0 IRI. For example, for a road with current roughness less than 4.0 IRI, on a very high standard scenario, the required reseal (periodic maintenance) will be applied every seven years, and on a very low standard scenario, every 15 years.

RONET uses a simplified HDM-4 road deterioration equation to estimate the roughness progression over time as a function of the following road characteristics: (i) current roughness, (ii) road strength (modified structural number), (iii) pavement age, (iv) traffic loading (annual equivalent standard axles), and (v) environment coefficient (see annex 1). The capital road works are applied when the corresponding roughness or pavement age thresholds are



reached. Figure 2 presents, for example, the road deterioration of a road with 3.0 IRI under different standards.

Figure 2. Road Deterioration under Different Standards



The default values for gravel roads are given below in table 17. The left sub-table defines the regreveling postponement, in years, for each standard scenario. Most likely, these default values are applicable for most countries worldwide. The right sub-table defines the corresponding country specific average roughness of each standard scenario, and the bottom sub-table defines the average gravel characteristics, which are country-specific inputs.

Table 17. Default Values for Gravel Roads

Regreveling Postponement (years)			Average Yearly Roughness Level (IRI, m/km)		
Scenario		Postponement	Scenario		Roughness
Code	Name	(years)	Code	Name	(IRI)
A	Very High Standard	0	A	Very High Standard	5
B	High Standard	1	B	High Standard	7
C	Medium Standard	2	C	Medium Standard	11
D	Low Standard	3	D	Low Standard	16
E	Very Low Standard	4	E	Very Low Standard	20
F	Do Minimum	5	F	Do Minimum	22
G	Do Nothing	999	G	Do Nothing	25

### Gravel Characteristics

Characteristic	Value	Suggested Values for Different Gravel Types			
		Quartzitic	Lateritic	Coral	Volcanic
Gravel Plasticity Index (%)	10.1	9.1	10.1	13.0	17.0
Gravel Material Passing 0.075 mm Sieve (%)	25.5	24.2	25.5	25.0	23.5

### Gravel Characteristics

Characteristic	Value	Suggested Values for Different Gravel Types			
		Quartzitic	Lateritic	Coral	Volcanic
Gravel Plasticity Index (%)	10.1	9.1	10.1	13.0	17.0
Gravel Material Passing 0.075 mm Sieve (%)	25.5	24.2	25.5	25.0	23.5

RONET uses the HDM-4 gravel loss deterioration equation to estimate the gravel loss over time as a function of the following road characteristics: (i) gravel characteristics, (ii) road geometry, (iii) road rainfall, and (iv) average daily traffic (see annex 2). On a very high standard scenario, the regravelling is applied when the gravel thickness reaches 50 mm (optimal case without budget constraints). On the other scenarios, the regravelling is applied after the user-defined years of postponement has elapsed after the regravelling year estimated for the very high standard. For example, if under the very high standard, the optimal year is year 6 (computed based on the HDM-4 equations), then under the very low standard, the regravelling is applied on year 10 after the user-defined four years of postponement. The regravelling frequency and the recurrent maintenance determine the average roughness of gravel roads. On RONET, the average roughness of gravel roads for each standard is not computed using some equations; it is user-defined in the right sub-table.

The default values for earth roads are given below in table 18. The left sub-table defines the heavy grading interval, in years, for each standard scenario. Most likely, these default values are applicable for most countries worldwide. The right sub-table defines the corresponding average roughness of each standard scenario. These are country-specific inputs.

Table 18. Default Values for Earth Roads

Earth Roads Heavy Grading Interval (years)			Average Yearly Roughness Level (IRI, m/km)		
Scenario		Interval	Scenario		Roughness
Code	Name	Years	Code	Name	(IRI)
A	Very High Standard	2	A	Very High Standard	7
B	High Standard	4	B	High Standard	9
C	Medium Standard	6	C	Medium Standard	13
D	Low Standard	8	D	Low Standard	18
E	Very Low Standard	10	E	Very Low Standard	22
F	Do Minimum	12	F	Do Minimum	24
G	Do Nothing	999	G	Do Nothing	25

RONET adopts the user-defined time interval of heavy grading to characterize each standard scenario. The interval of heavy grading and the recurrent maintenance determine the average roughness of earth roads. On RONET, the average roughness of earth roads for each standard is not computed using some equations; it is user-defined in the right sub-table.

### Recurrent Maintenance Works Standards Configuration

Table 19 defines the recurrent maintenance works costs multipliers to be applied on each of the standards to be evaluated. The default values are given in table 19. Most likely these default values are applicable for most countries worldwide; therefore, it is expected that few users will modify these default values.

Table 19. Recurrent Maintenance Works Standards Configuration

<b>Recurrent Maintenance Costs Multipliers</b>						
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

On this table you define, for each surface type, the recurrent maintenance cost multipliers applicable to each standard scenario. For example, for the very high standard scenario, for asphalt roads, the recurrent maintenance costs defined at the Country Data page are multiplied by 1.00, whereas for the very low standard scenario, the recurrent maintenance costs defined at the Country Data page are multiplied by 0.25. Note that the average roughness of unpaved roads (defined before) is greatly related to the level of expenditures for recurrent maintenance of unpaved roads; therefore, you have to enter coherent values in both tables.

### Paved Roads Deterioration Calibration Coefficients

This table allows for configuring the paved roads deterioration calibration coefficients for concrete, asphalt, and surface treatment roads. The a1 coefficient multiplies the modified structural number of the road, and the a2 coefficient multiplies the pavement age to replace the surface distress and rutting components of the roughness deterioration (see annex 1). It is expected that few users will modify these default values, and will do so only after performing an HDM-4 roughness progression calibration effort.



## Part C - Input Data

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### COUNTRY DATA

On this page you enter the basic country data that is composed of the following elements:

- Name and Year
- Basic Characteristics
- Traffic Growth and Pavement Width
- Capital Road Works Unit Costs
- Recurrent Maintenance Works Unit Costs
- Traffic Levels Characteristics
- Vehicle Fleet Unit Road User Costs Relationship to Roughness

#### **Name and Year**

Here you enter the name of the country, or the name of the region of the country or road agency being evaluated. RONE is set up to evaluate an entire road network of a country, but in some circumstances RONE can be used to evaluate only a region of a country; for example, a state or a province of a country or a partial network managed by a road agency. Here you also enter the year of the road network data and basic country characteristics. The year is entered for reference purposes; it is not used in the calculations.

#### **Basic Characteristics**

At this table, you enter the country figures that are used by the network performance assessment module (discount rate), as well as used to compute the network monitoring indicators:

- Land area (sq km): a country's total area, excluding areas under inland bodies of water and some coastal waterways
- Total population (million persons): the mid-year estimates of all residents regardless of legal status or citizenship
- Rural population (million persons): the mid-year population of areas defined as rural in each country and reported to the United Nations
- GDP at current prices (\$ billion): the gross domestic product at current 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): 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 (%): the planning discount rate adopted by the country

The first four of these indicators can be found at the following World Bank Website:

<http://go.worldbank.org/45B5H20NV0>

### **Traffic Growth and Pavement Width**

You define the expected annual traffic growth rate over the 20-year evaluation period and the average pavement width per network type. Currently the pavement widths are not being used in the calculations.

The RONET default values for basic characteristics and for traffic growth and pavement width are for a *fictitious country*; therefore, you must change them to reflect local conditions.

### **Capital Road Works Unit Costs**

On RONET, the road agency road works are classified in the following manner:

- Capital Road Works
  - Periodic Maintenance
  - Rehabilitation
  - New Construction
- Recurrent Maintenance Works
  - Annual Works on Carriageway
  - Annual Works outside Carriageway

Here you enter the unit costs of the capital road works defined for each surface type, in \$ per km for a two-lane road. RONET works with two-lane equivalent road classes. The possible capital road works, which are a function of the current road condition and network type, are shown in table 20.

Strengthening and reconstruction of paved roads and partial reconstruction, or full reconstruction of unpaved roads are considered as rehabilitation works. The road works applied to roads in good and fair condition are considered periodic maintenance works.

Table 20. Possible Capital Road Works

Surface	Current Condition	Road Work	Road Work Type
Concrete	Good Condition	Preventive Treatment	Periodic Maintenance
	Fair Condition	Resurfacing (Overlay)	Periodic Maintenance
	Poor Condition	Strengthening (Overlay)	Rehabilitation
	Very Poor Condition	Reconstruction	Rehabilitation
	No Road	New Construction	New Construction
Asphalt	Good Condition	Preventive Treatment	Periodic Maintenance
	Fair Condition	Resurfacing (Overlay)	Periodic Maintenance
	Poor Condition	Strengthening (Overlay)	Rehabilitation
	Very Poor Condition	Reconstruction	Rehabilitation
	No Road	New Construction	New Construction
S.T.	Good Condition	Preventive Treatment	Periodic Maintenance
	Fair Condition	Resurfacing (Reseal)	Periodic Maintenance
	Poor Condition	Strengthening (Overlay)	Rehabilitation
	Very Poor Condition	Reconstruction	Rehabilitation
	No Road	New Construction	New Construction
Gravel Roads	Good Condition	Spot Regravelling	Periodic Maintenance
	Fair Condition	Regravelling	Periodic Maintenance
	Poor Condition	Partial Reconstruction	Rehabilitation
	Very Poor Condition	Full Reconstruction	Rehabilitation
	No Road	New Construction	New Construction
Earth Roads	Good Condition	Spot Repairs	Periodic Maintenance
	Fair Condition	Heavy Grading	Periodic Maintenance
	Poor Condition	Partial Reconstruction	Rehabilitation
	Very Poor Condition	Full Reconstruction	Rehabilitation
	No Road	New Construction	New Construction

The unit costs of the capital works could vary by network type (different functional classification or different region of the country), for example, because of different design standards; therefore, if necessary, you can enter different values by network type. Here you also need to define the basic characteristics of the regravelling, resurfacing, strengthening, and reconstruction options in terms of surface layer thickness for regravelling, resurfacing, and strengthening, and resulting modified structural number and roughness for reconstruction.

The default values are given in table 21. It is expected that you will modify these default values to reflect local conditions. The default values reflect broadly African conditions and were derived by evaluating the World Bank's Road Costs Knowledge System<sup>2</sup> (ROCKS) that stores and evaluates information on unit road works unit costs worldwide, and can be download at the following World Bank Web site: <http://worldbank.org/roadsoftwaretools/>.

**Table 21. Default Values in 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 Mi	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 Tre	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			

## Recurrent Road Works Unit Costs

Here you enter the unit costs of the recurrent road works for each surface type, in \$ per km per year for a two-lane road. The recurrent road works unit costs vary by current road condition and network type; therefore, if necessary, you can enter different values by road condition and network type. Here you enter the total recurrent costs that are the sum of the annual road works done on the carriageway (for example, grading, pothole patching, and so forth), and the annual road works done outside the carriageway (for example, shoulder repairs, grass mowing, and so forth). The default values, which reflect broadly African conditions, are given in table 22. It is expected that you will modify these default values to reflect local conditions.



Table 22. Default Values for 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
Asphalt Mix	Very Poor	Recurrent Maintenance	750	563	375	375	750
	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
Surface Treatment	Poor	Recurrent Maintenance	750	563	375	375	750
	Very Poor	Recurrent Maintenance	750	563	375	375	750
	Very Good	Recurrent Maintenance	1,000	750	500	500	1,000
	Good	Recurrent Maintenance	1,250	938	625	625	1,250
Gravel	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
	Very Good	Recurrent Maintenance	500	375	250	250	500
Earth	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
Earth	Very Poor	Recurrent Maintenance	150	150	50	50	150

### Traffic Levels Characteristics

On the Basic Configuration page, nine possible traffic levels (T1 to T9) are defined by characterizing their average, minimum, and maximum Average Annual Daily Traffic (AADT). Here you define the average traffic composition of each traffic level and define for each vehicle type: (i) the equivalent standard axles (ESA per vehicle), (ii) the average cargo payload per vehicle (tons per vehicle), and (iii) the average number of passengers per vehicle (passengers per vehicle). Based on this information, RNET computes for each traffic level: (i) the total equivalent standard axles per year, in million ESA per year, (ii) the average cargo payload per vehicle, in tons per vehicle, and (iii) the average number of passengers per vehicle, in passengers per vehicle. The ESA loading is used to compute the road deterioration of paved roads and the average payload and passengers per vehicle are used to compute the network monitoring indicators: annual freight carried over road network (annual ton-km) and annual passengers carried over road network (annual passenger-km).

The default values, which reflect broadly African conditions, are given in table 23. It is expected that you will modify these default values to reflect local conditions.

Table 23. Default Values for Traffic Levels Characteristics

Average Annual Daily Traffic (AADT) =				T1	T2	T3	T4	T5	T6	T7	T8	T9
				5	20	65	200	650	2,000	6,500	20,000	65,000
Vehicle Type	Equivalent Standard Axles (ESA/vehicle)	Cargo Payload (Tons/vehicle)	Passengers/vehicle	Typical Traffic Composition (%)								
				(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Motorcycle	0.00	0.20	1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Car Small	0.00	0.10	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Car Medium	0.00	0.30	2	24.4%	24.4%	24.4%	24.4%	29.8%	29.8%	29.8%	34.1%	34.1%
Delivery Vehicle	0.01	0.90	2	33.3%	33.3%	33.3%	33.3%	27.2%	27.2%	27.2%	26.8%	26.8%
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	8.9%	8.9%	8.9%	8.9%	6.7%	6.7%	6.7%	4.5%	4.5%
Truck Medium	1.25	5.70	1	10.5%	10.5%	10.5%	10.5%	7.8%	7.8%	7.8%	4.9%	4.9%
Truck Heavy	2.28	10.60	1	3.3%	3.3%	3.3%	3.3%	3.4%	3.4%	3.4%	2.5%	2.5%
Truck Articulated	4.63	22.30	1	2.7%	2.7%	2.7%	2.7%	4.5%	4.5%	4.5%	3.0%	3.0%
Bus Light	0.04	1.25	12	10.6%	10.6%	10.6%	10.6%	15.0%	15.0%	15.0%	16.4%	16.4%
Bus Medium	0.70	2.50	30	3.2%	3.2%	3.2%	3.2%	2.8%	2.8%	2.8%	3.9%	3.9%
Bus Heavy	0.80	3.20	40	3.2%	3.2%	3.2%	3.2%	2.8%	2.8%	2.8%	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) =				0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Payload/Vehicle (tons/vehicle) =				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Passengers/Vehicle (persons/vehicle) =				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

### Vehicle Fleet Unit Road User Costs Relationship to Roughness

RONET computes the network road user costs for different maintenance and rehabilitation standards at the performance assessment module. Road user costs are a function of road roughness; therefore, there is a need to define the relationship between unit road user costs and roughness for a particular country. On RONET, this relationship takes the form of the following cubic polynomial.

$$\text{Unit Road User Costs (\$/vehicle-km)} = a_0 + a_1 \cdot \text{IRI} + a_2 \cdot \text{IRI}^2 + a_3 \cdot \text{IRI}^3$$

Where “Unit Road User Costs” represents the unit road use costs of the vehicle fleet, “IRI” is the roughness of the road, in IRI, m/km, and a<sub>0</sub>, a<sub>1</sub>, a<sub>2</sub> and a<sub>3</sub> are coefficients of the cubic polynomial.

Here you need to define the coefficients of the cubic polynomial for each traffic level based on local conditions. To compute these coefficients effortlessly, you can use the World Bank’s Road User Costs Knowledge System (RUCKS)<sup>6</sup> version 1.2 that contains an Excel model designed for this purpose, and presents representative vehicle fleet characteristics for different regions of the World. RUCKS can be downloaded at the following World Bank Website: <http://worldbank.org/roadssoftwaretools/>.

When you compute unit user costs with RUCKS or with any other model, you compute either financial (market costs) or economic (without taxes and subsidies) road user costs. RONET requires financial road user costs; therefore, there is an input factor that represents the factor to multiply the defined unit road user costs by the cubic polynomials to convert them to financial costs. The default values, which reflect broadly African conditions, are given below in table 24. It is expected that you will modify these default values to reflect local conditions.

**Table 24. Vehicle Fleet Unit Road User Costs Default Values**

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		0.27966	0.27966	0.27966	0.27966	0.28871	0.28871	0.28840	0.27267	0.41310
a0 coefficient		0.27966	0.27966	0.27966	0.27966	0.28871	0.28871	0.28840	0.27267	0.41310
a1 coefficient		-0.00028	-0.00028	-0.00028	-0.00028	-0.00055	-0.00055	-0.00060	-0.00222	0.00613
a2 coefficient		0.00144	0.00144	0.00144	0.00144	0.00148	0.00148	0.00151	0.00173	0.00049
a3 coefficient		-0.00003	-0.00003	-0.00003	-0.00003	-0.00003	-0.00003	-0.00003	-0.00004	-0.00002
Factor to multiply defined unit road user costs above to convert them to	1.00									

## ROAD NETWORK LENGTH

On this page you enter the network length distribution by network type, surface type, traffic category, and road condition category. You should enter the two-lane equivalent network length belonging to each road class, in kilometers. That means if there is a four-lane road, you should enter the corresponding two-lane equivalent length, which is twice the length of the four-lane road. If there are no kilometers on the network represented by a road class, you can enter zero kilometers or leave the cell blank. Figure 3 presents the structure of this page.

**Figure 3. Road Network Length Default Values (Country XYZ)**

### Country XYZ - 2007

#### Road Network Two-Lane Equivalent Length (km)

##### Primary

##### Concrete

Condition (IRI)		Very Good	Good	Fair	Poor	Very Poor	Total
		2	3	4	8	12	
Traffic (AADT)							
Traffic I	<300						0
Traffic II	300-1000						0
Traffic III	1000-3000						0
Traffic IV	3000-10000						0
Traffic V	>10000						0
Total		0	0	0	0	0	0

##### Primary

##### Asphalt

Condition (IRI)		Very Good	Good	Fair	Poor	Very Poor	Total
		2	3	4.5	8	12	
Traffic (AADT)							
Traffic I	<300	0	0	0	0	0	0
Traffic II	300-1000	0	184	39	31	10	264
Traffic III	1000-3000	370	341	61	22	0	794
Traffic IV	3000-10000	0	0	0	0	0	0
Traffic V	>10000	2	97	16	2	0	117
Total		372	622	116	55	10	1,175

##### Secondary

##### Concrete

Condition (IRI)		Very Good	Good	Fair	Poor	Very Poor	Total
		2	3	4	8	12	
Traffic (AADT)							
Traffic I	<300						0
Traffic II	300-1000						0
Traffic III	1000-3000						0
Traffic IV	3000-10000						0
Traffic V	>10000						0
Total		0	0	0	0	0	0

##### Secondary

##### Asphalt

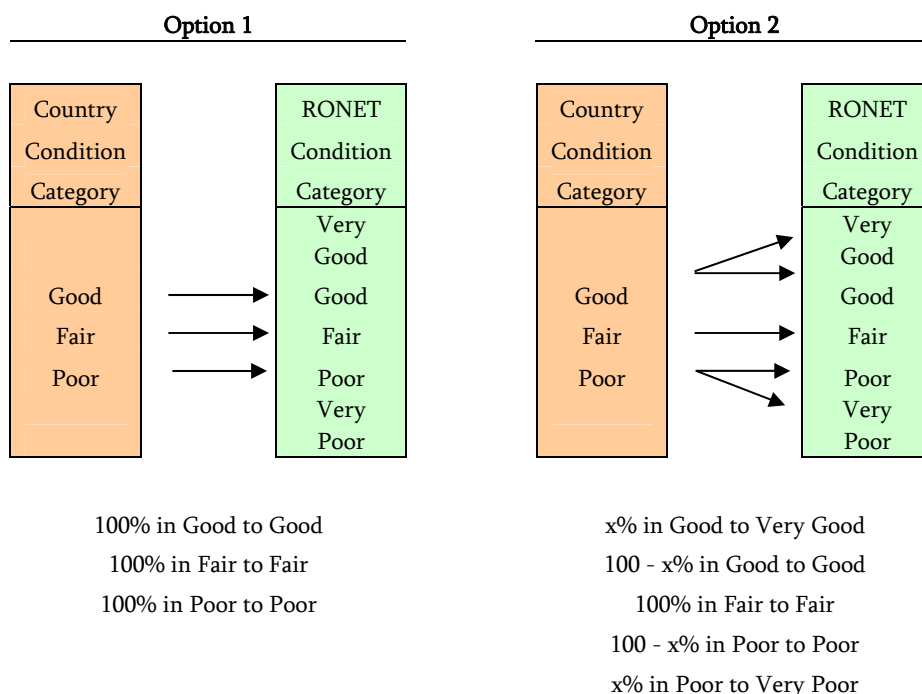
Condition (IRI)		Very Good	Good	Fair	Poor	Very Poor	Total
		2	3	4.5	8	12	
Traffic (AADT)							
Traffic I	<300	0	0	0	0	0	0
Traffic II	300-1000	0	41	32	17	0	90
Traffic III	1000-3000	0	0	21	6	0	27
Traffic IV	3000-10000	0	0	0	0	0	0
Traffic V	>10000	0	0	0	0	0	0
Total		0	41	53	23	0	117

The default values are values for a *fictitious country*; therefore, you must change them.

RONET defines five road condition categories (Very Good, Good, Fair, Poor, and Very Poor), but in some countries roads are classified in only three or four condition categories. You will have to judge how best to define the network on RONET, based on the network data you have available. For example, if you have only three categories (Good, Fair, and Poor), you can consider the following options: (i) assign 100 percent of the road in Good, Fair, and Poor condition to the corresponding RONET Good, Fair, and Poor condition categories and

leave the RONET Very Good and Very Poor categories blank, or (ii) assign a percentage of the roads in Good condition to the RONET Very Good condition category, and the remaining percentage of the roads in Good condition to the RONET Good condition category; assign 100 percent of the roads in Fair condition to the corresponding RONET Fair condition category; assign a percentage of the roads in Poor condition to the RONET Poor condition category; and the remaining percentage of the roads in Poor condition to the RONET Very Poor condition category (recommended option). The options are outlined in figure 4.

Figure 4. Options for Assigning Road Condition Categories



The network length distribution can be originated from (i) aggregating the outputs of a Pavement Management System (PMS) or Road Database that presents for each homogeneous road section the section length, network type, surface type, traffic category, and condition category, if needed, transforming the outputs of the PMS to the units of RONET; or (ii) an engineering estimate of the network length distribution, based on secondary information and good judgment. Most likely, for primary and secondary roads, a PMS or a Road Database is available or is under development; therefore, an effort should be made to collect the network data from these sources of information. Most likely, for tertiary roads, unclassified roads, and urban roads, engineering estimates will be needed.

## **HISTORICAL DATA**

On this page you enter (i) the historical average road works expenditures during the last five years, in M\$ per year, and (ii) the historical average road works during last five years, in km per year. You can enter this information by network type, road work type (rehabilitation, periodic maintenance, routine maintenance, and total), and surface class (paved, unpaved, and total). RNET computes on this page the corresponding average road works expenditures during the last five years, in \$ per km, for the different road work types and surface classes.

The information entered into this page is used by the Performance Assessment Module to compare the required expenditure under different road work standards with the historical expenditures in the country.



## Part D – Current Condition Assessment Module

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### CURRENT CONDITION ASSESSMENT OVERVIEW

This RNET module evaluates the current network condition and presents summary network statistics and network monitoring indicators. The outputs of this module are the following.

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

All the results are computed using Excel formulas; therefore, there is no button to press to compute the results which are recomputed automatically when you change any configuration data or input data. The Output pages contain tables and charts and are formatted to be printed; therefore, if necessary, use the Excel print options to print these pages.

### LENGTH & UTILIZATION

This output page presents the total network length (km) and total network utilization (million vehicle-km) and the distribution by network type, surface type, surface class (paved or unpaved), road condition category, and traffic category. At the top of the page, there is a table of contents where you can select among:

- [Distribution by Network Type](#)
- [Distribution by Surface Type](#)
- [Distribution by Surface Class](#)

Once you select an option, you can view the corresponding distribution by surface type, road condition and traffic categories. The network length tables are located on the right side and the utilization tables on the left. To return to the table of contents, press the [T](#) hyperlinks (“T” for Top) located on column B, or use the Excel features to go to the top of the page.

The network length values are computed by just summarizing the network length input data. The network utilization values are computed by multiplying, for each road class, the road class length times the average daily traffic of the road class. We have the following.

Utilization in Million vehicle-km = Length (km) X Average Daily Traffic (vehicles per day) x 365 (days) / 1,000,000

## ASSET VALUE

This output page presents the total network maximum asset value (M \$) and total network current asset value (M \$), and the distribution by network type, road type, road condition category, and traffic category. At the top of the page, there is a table of contents where you can select among:

- Distribution by Network Type
- Distribution by Surface Type
- Distribution by Surface Class

Once you select an option, you can view the corresponding distribution by surface type, road condition category, and traffic category. The maximum asset value tables are located on the right side and the current asset value tables at the left. To return to the table of contents, press the [T](#) hyperlinks located on column B, or use the Excel features to go to the top of the page.

The asset value computed by RNET refers mostly to the asset value of the pavement. The maximum asset value is computed by multiplying, for each road class, the road class length times the new construction unit cost of the corresponding surface type, which was entered at the Country Data page. We have the following.

Maximum Asset Value in Million \$ = Length (km) x New Construction Unit Cost (\$/km)/1,000,000

The current asset value is computed by multiplying, for each road class, the road class length times the current asset value unit costs, which is a defined function of the surface type and current road condition as given in table 25.



Table 25. Surface Type and Current Road Condition

Road Type	Current Condition	Current Asset Value Unit Cost
Paved Roads	Very Good	Construction Unit Cost
	Good	Construction Unit Cost - Preventive Treatment Unit Cost
	Fair	Construction Unit Cost - Resurfacing Unit Cost
	Poor	Construction Unit Cost - Strengthening Unit Cost
	Very Poor	Construction Unit Cost - Full Reconstruction Unit Cost
Gravel Roads	Very Good	Construction Unit Cost
	Good	Construction Unit Cost - Spot Regraveling Unit Cost
	Fair	Construction Unit Cost - Regraveling Unit Cost
	Poor	Construction Unit Cost - Partial Reconstruction Unit Cost
	Very Poor	Construction Unit Cost - Full Reconstruction Unit Cost
Earth Roads	Very Good	Construction Unit Cost
	Good	Construction Unit Cost - Spot Repairs Unit Cost
	Fair	Construction Unit Cost - Heavy Grading Unit Cost
	Poor	Construction Unit Cost - Partial Reconstruction Unit Cost
	Very Poor	Construction Unit Cost - Full Reconstruction Unit Cost

We have the following:

Current Asset Value in Million \$ = Length (km) X Current Asset Value Unit Cost (\$/km) /1,000,000.

## ROUGHNESS

This output page presents the network average roughness weighted by km (IRI, m/km) and network average roughness weighted by vehicle-km (IRI, m/km) by network type, surface type, road condition category, and traffic category. At the top of the page, there is a table of contents where you can select among:

- Roughness by Network Type
- Roughness by Surface Type
- Roughness by Surface Class

Once you select an option, you can view the corresponding roughness by surface type, road condition category, and traffic category. The average roughness tables weighted by km are located on the right and the average roughness tables weighted by vehicle-km tables are on the left. To return to the table of contents, press the [T](#) hyperlinks located on column B, or use the Excel features to go to the top of the page.

The network average roughness is computed by assigning to each road class the user- defined average roughness of the road class that was entered at the Basic Configuration page. The roughness values of each road class are weighted either by the road class length (km), or by the road class utilization (vehicle-km) computed by multiplying the road class length by the average traffic of the road class defined at the Basic Configuration page.

## **NETWORK DISTRIBUTION CHARTS**

This output page presents network distribution charts of the network length, utilization, and maximum and current asset value by network type and surface type. The charts are produced from the results presented on the previous output pages.

## **NETWORK MONITORING INDICATORS**

This page presents a road network monitoring indicators table and two user-defined charts. The road network monitoring indicators table presents monitoring indicators by network type, subdivided into the following categories.

- Network Length
- Network Density
- Network Condition
- Network Standards
- Network Utilization
- Network Asset

You define the two charts to be presented below the network monitoring indicators table. Select the two indicators to chart using the drop-down lists on cells B59 and B61, which have a yellow background. Figure 6 shows the network monitoring indicators computed by RNET.

Figure 6. Network Monitoring Indicators Computed by RONET

<b>Network Monitoring Indicators</b>	
Monitoring Indicator	
<b>Network length</b>	
Road network length	km
Road network length that is unpaved	km
Road network length that is paved	km
Road network length that is paved	%
<b>Network Density</b>	
Road network per thousand land area	km/1000 sq km
Road network per thousand total population	km/1000 persons
Road network per thousand rural population	km/1000 persons
Road network per thousand vehicles	km/1000 vehicles
Road network per \$ million GDP	km/million \$
Paved road network per thousand land area	km/1000 sq km
Paved road network per thousand total population	km/1000 persons
Paved road network per thousand rural population	km/1000 persons
Paved road network per thousand vehicles	km/1000 vehicles
Paved road network per \$ million GDP	km/million \$
<b>Network Condition</b>	
Percentage of road network in good and fair condition	%
Percentage of paved road network in good and fair condition	%
Percentage of paved road network with roughness 4 m/km IRI or less	%
Paved roads average roughness weighted by km	IRI, m/km
Paved roads average roughness weighted by vehicle-km	IRI, m/km
Percentage of unpaved roads that are all-weather roads	%
<b>Network Standards</b>	
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	%
<b>Network Utilization</b>	
Annual motorized vehicle utilization	million vehicle-km
Annual freight carried over road network	million ton-km
Annual passengers carried over road network	million ton-km
Average network annual average daily traffic	vehicles/day
<b>Network Asset</b>	
Current Road asset value	million \$
Current Road asset value as a share of maximum road asset value	%
Current Road asset value as a share of GDP	%

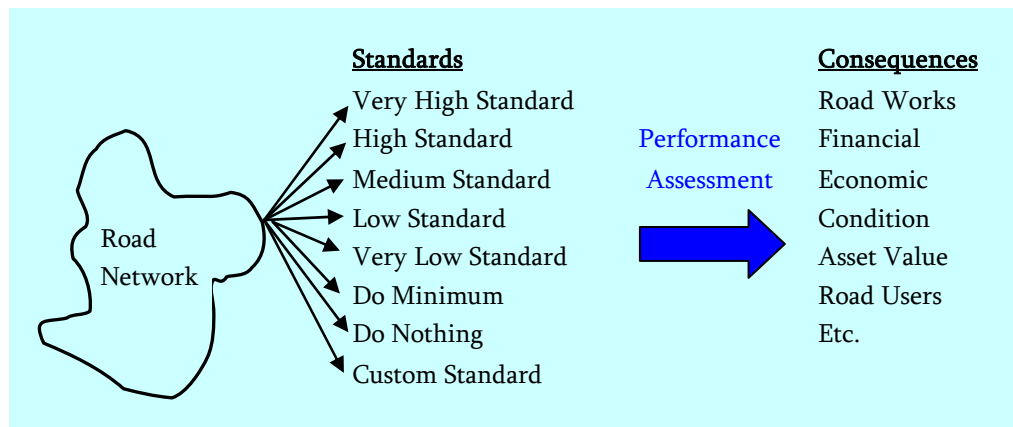


## Part E – Performance Assessment Module

### PERFORMANCE ASSESSMENT OVERVIEW

The objective of this module is to assess the consequences of applying different road works standards that represent different levels of road works expenditures over time. The consequences are presented on the road works requirements, financial cost, road condition, asset value, and so on. Figure 7 illustrates the process.

Figure 7. Consequences of Applying Different Road Works Standards



This module evaluates the performance of the network under different road works standards over a 20-year evaluation period. The user-defined road works standards are the following:

- Very High Standard
- High Standard
- Medium Standard
- Low Standard
- Very Low Standard
- Do Minimum
- Do Nothing
- Custom Standard

The very high standard represents a scenario without budget constraints but with an optimal level of periodic maintenance and rehabilitation works. The high, medium, low and very low standards represent scenarios of decreasing levels of road works expenditures. The “do minimum” standard represents a scenario where the only capital road work applied over the evaluation period is reconstruction, at a very high roughness. The “do nothing” standard represents a scenario where no capital road works are applied over the evaluation period. On

all these cases, the defined standard is applied to all road networks types. On the custom standard, you define, at the Standards Configuration Page, the standard (Very High, High, Medium, Low, Very Low, Do Minimum or Do Nothing) to apply to each road network type.

The outputs of this module are the following.

- Network Performance: presents the consequences to the total, paved or unpaved network of applying the different road works standards (road expenditure levels). Consequences are presented in terms of:
  - Road Agency Costs
  - Society Costs
  - Road Users Costs
  - Network Asset Value
  - Network Roughness
  - Network Condition
  - Annual Road Agency Costs
  - Annual Road Agency Costs by GDP
- Road Works Distribution: presents, for a user-selected standard, the distribution of the recurrent maintenance, periodic maintenance and rehabilitation costs, and road works length by network type, management type, surface type, and surface class, for years 1 to 5, 6 to 20 and 1 to 20. The output tables present: (i) total road works costs (M\$); (ii) annual road works costs (M\$/year); (iii) annual road works costs per km (\$/km-year); and (iv) annual road works length (km/year).
- Road Works Summary: presents for a user-selected standard, period (years 1 to 5, 6 to 20 or 1 to 20), and road work type (recurrent maintenance, periodic maintenance, rehabilitation, or all works), a summary of the distribution, by network type, management type and surface type, of the following: (i) road works costs; (ii) current network length, (iii) current network utilization; and (iv) current network asset value.
- Historical Data Comparison: presents, for a user-selected standard, each network type and road work type: (i) the historic expenditures over the last five years, (ii) the required expenditures over the next five years, and (iii) the ratio between the required per historic expenditures.

All the results are computed using Excel macros; therefore, you have to press the button “Performance Assessment” located at the main menu to compute the results. The results *are not* recomputed automatically when you change any configuration data or input data. When you press the button “Performance Assessment,” RNET asks if you want to keep the intermediate results of the calculations in a temporary workbook. If you select Yes, all the intermediate results are stored in a new workbook that is created every time you select Yes at this option. The new workbooks are named “Book1,” “Book2,” “Book3,” and so on. Once you have reviewed one of the temporary workbooks, you can close it or save it if necessary (saving with a different name if necessary). If you select No, then no temporary workbook is cre-

ated. To compute the results can take between 2 and 5 minutes, depending on the computer processing speed. The status of the calculations is presented on the Excel status line at the bottom left corner of the screen. When all the calculations are done, the model presents a message indicating the end of the calculations and the duration of the calculations.

The characteristics of the road works standards are country-specific; therefore, you define the characteristics of the road works standards at the Standards Configuration page.

## NETWORK PERFORMANCE

This page presents the consequences of applying different road works standards (road expenditure levels). The consequences are presented in terms of:

- Road Agency Costs
- Society Costs
- Road Users Costs
- Network Asset Value
- Network Roughness
- Network Condition
- Annual Road Agency Costs
- Annual Road Agency Costs by GDP

On cell D1, you select, from the list of available choices, whether you want to view the consequences to the paved, unpaved, or total network. At the top of the page, there is a table of contents where you can select among:

- Consequences to Road Agency
- Consequences to Society
- Consequences to Road Users
- Consequences to Network Asset Value and Network Roughness
- Consequences to Network Condition 1/2
- Consequences to Network Condition 2/2
- Consequences to Annual Road Agency Costs
- Consequences to Annual Road Agency Costs by GDP

Once you select an option, you can view the corresponding tables and charts (left side of the tables). To return to the table of contents, press the T hyperlinks located on column B or use the Excel features to go to the top of the page.

The available tables are the following:

- Consequences to Road Agency
  - Road Agency Costs (Years 1-20)
  - Road Agency Costs Breakdown (Years 1-20)
  - Recurrent Maintenance as a Percent of Total Maintenance Costs

- Consequences to Society
  - Society Costs (Total Costs Years 1-20)
  - Society Net Loss Compared to Very High Standard (Total Costs Years 1-20)
  - Society Net Benefits Compared to Do Minimum Standard (Total Costs Years 1-20)
- Consequences to Road Users
  - Impact of Road Agency Deficit on Road User Costs
  - Unit Road User Costs
- Consequences to Network Asset Value and Network Roughness
  - Network Asset Value
  - Roughness Weighted by Km
  - Roughness Weighted by Vehicle-Km
- Consequences to Network Condition 1/2
  - Network Length in Very Good Condition
  - Network Length in Good Condition
  - Network Length in Fair Condition
- Consequences to Network Condition 2/2
  - Network Length in Poor Condition
  - Network Length in Very Poor Condition
  - Network Length by Road Condition (select the standard for this table on cell D342)
- Consequences to Annual Road Agency Costs
  - Annual Road Agency Costs Years 1-5 (Annual Costs Years 1-5)
  - Annual Road Agency Costs Years 6-20 (Annual Costs Years 6-20)
  - Annual Road Agency Costs Years 1-20 (Annual Costs Years 1-20)
- Consequences to Annual Road Agency Costs by GDP
  - Annual Road Agency Costs Years 1-5 (Percentage of GDP)
  - Annual Road Agency Costs Years 6-20 (Percentage of GDP)
  - Annual Road Agency Costs Years 1-20 (Percentage of GDP)

## **ROAD WORKS DISTRIBUTION**

This page presents for the recurrent maintenance works, periodic maintenance works, rehabilitation works, and all works, the following information:

- Total road works costs (M\$)
- Annual road works costs (M\$/year)
- Annual road works costs per km (\$/km-year)
- Annual road works length (km/year)



The information is presented by network type, management type, surface class and surface type, and for years 1 to 5, 6 to 20 and 1 to 20.

On cell C1, you select, from the list of available choices, one standard to view the corresponding tables on this page and on the Road Works Summary and Historical Data among:

- Total Road Works Costs (M\$) by Network Type and Surface Class
- Annual Road Works Costs (M\$/year) by Network Type and Surface Class
- Annual Road Works Costs per Km (\$/km-year) by Network Type and Surface Class
- Annual Road Works Length (km/year) by Network Type and Surface Class
- Total Road Works Costs (M\$) by Management Type and Surface Class
- Annual Road Works Costs (M\$/year) by Management Type and Surface Class
- Annual Road Works Costs per Km (\$/km-year) by Management Type and Surface Class
- Annual Road Works Length (km/year) by Management Type and Surface Class
- Total Road Works Costs (M\$) by Network Type and Surface Type
- Annual Road Works Costs (M\$/year) by Network Type and Surface Type
- Annual Road Works Costs per Km (\$/km-year) by Network Type and Surface Type
- Annual Road Works Length (km/year) by Network Type and Surface Type
- Total Road Works Costs (M\$) by Management Type and Surface Type
- Annual Road Works Costs (M\$/year) by Management Type and Surface Type
- Annual Road Works Costs per Km (\$/km-year) by Management Type and Surface Type
- Annual Road Works Length (km/year) by Management Type and Surface Type

Once you select an option, you can view the corresponding tables. To return to the table of contents, press the [T](#) hyperlinks located on columns B or T, or use the Excel features to go to the top of the page.

## **ROAD WORKS SUMMARY**

This page presents a summary of the distribution of the network:

- Road works costs
- Current network length
- Current network utilization
- Current network asset value

The distribution is presented by network type, management type, and surface type.

On cell C1, you select a road works type (recurrent maintenance works, periodic maintenance works, rehabilitation works, capital works, or all works) and on cell F1 you select a period (year 1 to 5, 6 to 20 or 1 to 20). Select your choice from the lists of available choices. You select the standard to view at cell C1 of the Road Works Distribution page (previous page). At the top of the page, there is a table of contents where you can select among:

- Information by Network Type
- Information by Surface Type
- Information by Management Type

Once you select an option, you can view the corresponding tables. To return to the table of contents, press the T hyperlinks located on column B, or use the Excel features to go to the top of the page.

## **HISTORICAL DATA COMPARISON**

This page presents, for a user-selected standard, each network type and road work type: (i) the historic expenditures over the last five years, (ii) the required expenditures over the next five years, and (iii) the ratio between the required per historic expenditures.

## Annexes

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### ANNEX 1: PAVED ROADS ROUGHNESS PROGRESSION MODEL

An analysis of the HDM-4 roughness deterioration model for bituminous roads indicates that the deterioration of bituminous roads is a function of (i) current pavement strength taking into account current surface distress; (ii) equivalent standard axle loading; (iii) pavement age; (iv) environment coefficient; (v) roughness; (vi) increase during a year of rut depth standard deviation, cracking, and potholing; and (vii) deterioration factors. The RNET roughness progression model for paved road simplifies the HDM-4 model by (i) adopting the modified structural number at construction or last rehabilitation, to define the pavement strength by adding a strength reduction coefficient (a1) that multiplies the modified structural number to take into account the surface distress impact on the pavement strength; (ii) substituting the cracking, rutting, and potholing parameters of the HDM-4 model by a coefficient (a2) that multiplies the pavement age; (iii) considering that the K deterioration factors are equal to 1; and (iv) considering that pothole patching is always done on the roads. The simplified RNET model is given by the following equation:

$$dIRI = K_{gp} * (a_0 * \text{Exp} (K_{gm} * m * AGE_3) * [(1 + SNC * a_1)]^{-5} * YE_4 + a_2 * AGE_3) + (K_{gm} * m * RI_a) \quad (1)$$

and:

$$RI_b = \text{minimum} (RI_a + dRI, 16) \quad (2)$$

where:

$K_{gp} = 1$ , calibration factor of roughness progression

$a_0 = 134$ , which is the original  $a_0$  coefficient of the HDM-4 model

$K_{gm} = 1$ , calibration factor for environmental coefficient

$m =$  environmental coefficient (see table 2)

$AGE_3 =$  pavement age since last overlay, reconstruction or new construction (years)

$SNC =$  modified structural number of pavement at construction, reconstruction, or last rehabilitation (modified structural number as defined on the HDM-III<sup>2</sup> documentation equal to the structural number computed following AASHTO guidelines, plus adding the strength contribution of sub-grade)

$YE_4 =$  annual number of equivalent standard axles (million ESA/lane/year)

RIa = roughness at the start of the analysis year (IRI, m/km)

RIb = roughness at the end of the analysis year (IRI, m/km)

dIRI = increment in roughness during one year

a1 = 0.7947, which is a coefficient derived on the RONET study to reflect the reduction of the strength of the pavement due to the presence of surface distress

a2 = 0.0054, which is a coefficient derived on the RONET study to reflect the increase in roughness progression of the pavement due to the presence of cracking, rutting, and potholes

The coefficients a1 and a2 and the K calibration coefficients can be configured at the Standard Configuration page.

### RONET Roughness Progression Model Coefficients

The approach used to develop the RONET roughness progression model uses the full empirical simulation model of HDM-4 to generate roughness data for a wide range of the primary input data parameters, and estimates the parameters of the simple model by best fitting the generated data. Roughness data was generated for an array of the three primary variables (pavement strength, annual traffic loading, and environment) for the combinations shown on table A-1. Loading ranged from 10,000 to 1 million ESAL/lane-yr and strength from modified structural number 2 to 8. Three environments were considered with an m environmental coefficient of 0.025, 0.040, and 0.100, which correspond to different moisture and temperature classifications (see table 1A-2). All roads were considered to have an asphalt concrete surface, because the impact of the surface type classification (asphalt concrete or surface treatment) on the roughness progression is negligible. There were 48 possible combinations and a 20-year analysis period, resulting in a total of 960 observations.

Table 1A-1. Combinations of Primary Parameters Used to Generate Roughness Data

Environmental Factor	Structural Number	Thickness (mm)	Traffic Loading (million ESAL/year-lane)						
			0.01	0.03	0.10	0.20	0.30	0.50	1.00
0.025	2	30	X	X	X	X			
	3	50		X	X	X	X		
	5	80			X	X	X	X	
	8	100				X	X	X	X
0.040	2	30	X	X	X	X			
	3	50		X	X	X	X		
	5	80			X	X	X	X	
	8	100				X	X	X	X
0.100	2	30	X	X	X	X			
	3	50		X	X	X	X		
	5	80			X	X	X	X	
	8	100				X	X	X	X

Table 1A-2 presents the default HDM-4 m environmental coefficients for different moisture and temperature classifications.

Table 1A-2. m Environmental Coefficients

Moisture Classification	Temperature Classification				
	Tropical	Sub-tropical hot	Sub-tropical cool	Temperate cool	Temperate freeze
Arid	0.005	0.010	0.015	0.025	0.040
Semi-arid	0.010	0.015	0.025	0.035	0.060
Sub-humid	0.020	0.025	0.040	0.060	0.100
Humid	0.025	0.030	0.060	0.100	0.200
Per-humid	0.030	0.040	0.070		

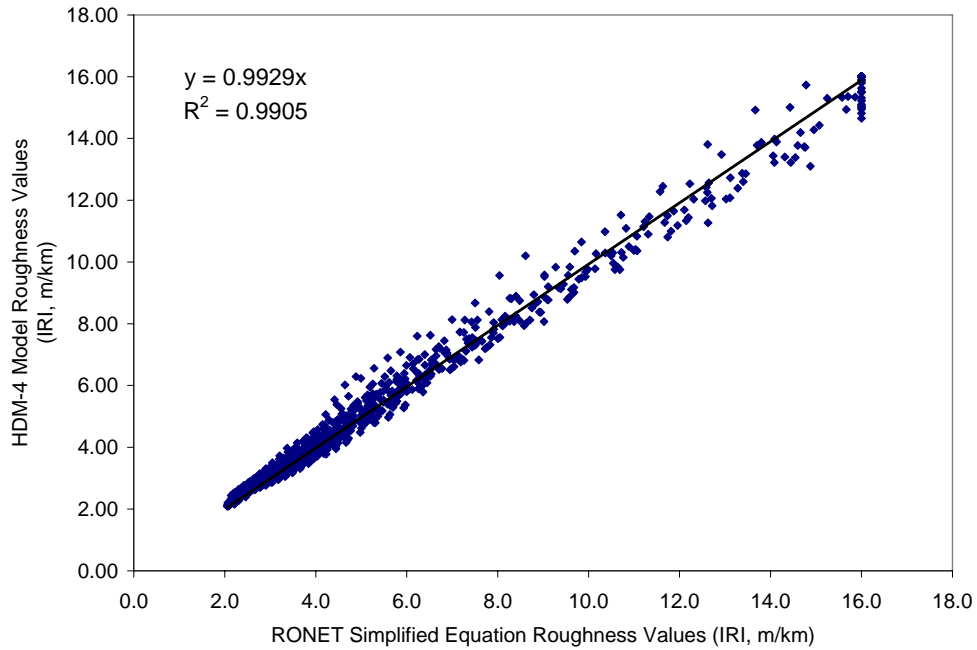
The 960 observations of roughness at different years for the different road strength, loading, and environment classes, obtained by executing the HDM-4 model, were compared on an Excel workbook with the roughness progression results of the simplified RNET roughness progression model (equation 1) for different scenarios of coefficients a1 and a2. The Excel optimization routine was then used to find the optimal set of a1 and a2 coefficients that minimizes the sum of the square of the differences. The optimal a1 and a2 coefficients for equation 1 are as follows:

$$a1 = 0.7947$$

$$a2 = 0.0054$$

Figure 1A-1 below shows the comparison between the roughness values predicted by the HDM-4 model, and the roughness values predicted with the RNET model adopting the optimal a1 and a2 coefficients, which shows the good fit of the RNET model with an R2 of 0.99.

Figure 1A-1. RONET Simplified Equation Roughness Values (IRI, m/km)



The RONET paved roads deterioration equation 1 was derived evaluating the deterioration of bituminous roads. The same exercise was not done evaluating the deterioration of concrete roads; therefore, at the moment, RONET does not have road deterioration equations specific for concrete roads. To roughly estimate the roughness progression of concrete roads using the current version of RONET, you will need to use equation 1 and define a pavement strength (modified structural number) representative of a concrete road.

## ANNEX 2: GRAVEL ROADS GRAVEL LOSS MODEL

RONET estimates the material loss of gravel loss using the HDM-4 relationships for predicting the annual quantity of material loss as a function of monthly rainfall, traffic volume, road geometry, and characteristics of the gravel. The RONET model for gravel loss is given by the following equation:

$$MLA = K_{gi} * 365 * (3.46 + 2.46 * MMP * RF * 10^{-4} + KT * AADT) \quad (3)$$

Where:

MLA = the predicted annual material loss (mm/year)

RF = average rise plus fall of the road (m/km)

MMP = mean monthly precipitation (mm/month)

AADT = annual average daily traffic (veh/day)

KT = the traffic-induced material whip-off coefficient

$K_{gi}$  = gravel material loss calibration factor

The traffic-induced material whip-off coefficient is expressed as a function of rainfall, road geometry, and material characteristics, as follows.

$$KT = K_{kt} * \text{maximum} \{0, (0.022 + (0.969 * C)/57300) + 3.42 * MMP * P_{075j} * 10^{-6} - 9.2 * MMP * P_{Ij} * 10^{-6} - 1.01 * MMP * 10^{-4}\} \quad (4)$$

Where:

C = average horizontal curvature of the road (deg/km)

$P_{Ij}$  = Plasticity index of material

$P_{075j}$  = Gravel material passing 0.075 mm sieve (%)

$K_{kt}$  = traffic-induced material loss calibration factor

### ANNEX 3: ROAD WORKS EFFECTS

RONET estimates the road works effects using the HDM-4 relationships that are given below.

#### Reseal

The roughness after a reseal is computed by the following equation.

$$RI_{aw} = RI_{bw} - \text{maximum} (0, \text{minimum} (0.3 * (RI_{bw} - 5.4), 0.5) ) \quad (5)$$

Where:

$RI_{aw}$  = Roughness after reseal (IRI, m/km)

$RI_{bw}$  = Roughness before reseal (IRI, m/km)

The structural number after a reseal is computed by the following equation.

$$SN_{aw} = SN_{bw} + RE_{th} * 0.2 * 0.0394 \quad (6)$$

Where:

$SN_{aw}$  = Structural number after reseal

$SN_{bw}$  = Structural number before reseal

$RE_{th}$  = Reseal thickness (mm)

#### Overlay

The roughness after an overlay is computed by the following equation.

$$RI_{aw} = 2.0 + 0.01 * \text{maximum} (0, (RI_{ap} - 2.0) * \text{maximum} (0, (80 - OV_{th})) ) \quad (7)$$

Where:

$RI_{aw}$  = Roughness after overlay (IRI, m/km)

$RI_{bw}$  = Roughness before overlay (IRI, m/km)

$OV_{th}$  = Overlay thickness (mm)

The structural number after a reseal is computed by the following equation.

$$SN_{aw} = SN_{bw} + OV_{th} * 0.4 * 0.0394 \quad (8)$$

$SN_{aw}$  = Structural number after overlay



SNbw = Structural number before overlay

### **Reconstruction**

The roughness and the structural number of paved roads after a reconstruction is user defined at the Country Data page.

### **Gravel Thickness**

The gravel thickness after regravelling is computed by the following equation.

$$GTaw = GTbw + GTth \quad (9)$$

Where:

GTaw = Gravel thickness after regravelling (mm)

GTbw = Gravel thickness before regravelling (mm)

GTth = Regravelling thickness (mm)



## References

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