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DEPARTMENT OF CIVIL ENGINEERING AND ENVIRONMENTAL TECHNOLOGY

A THESIS

ON

DEVELOPING ALTERNATIVE CONSTRUCTION AND MAINTENANCE STANDARDS FOR EFFICIENT AND JUSTIFIED INVESTMENTS IN RURAL UNPAVED ROADS IN RWANDA

Submitted by

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Submitted in partial fulfillment of the requirements for the award of

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TRANSPORTATION ENGINEERING AND ECONOMICS

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DECLARATION

I hereby declare that the thesis entitled "***DEVELOPING ALTERNATIVE CONSTRUCTION AND MAINTENANCE STANDARDS FOR EFFICIENT AND JUSTIFIED INVESTMENTS IN RURAL UNPAVED ROADS IN RWANDA"*** submitted for the Degree of Master of Science is my original work and the thesis has not formed the basis for the award of any Degree, Diploma, Associateship, Fellowship of similar other titles. It has not been submitted to any other University or Institution for the award of any Degree or Diploma.

Place: Kigali – Rwanda Signature of the Scholar………………………..

Date: December 2013 RUTAGARAMA Aimable

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BONAFIDE CERTIFICATE

Certified that this thesis titled "***DEVELOPING ALTERNATIVE CONSTRUCTION AND MAINTENANCE STANDARDS FOR EFFICIENT AND JUSTIFIED INVESTMENTS IN RURAL UNPAVED ROADS IN RWANDA***" is the bonafide work of **RUTAGARAMA Aimable (REG.NO: PG 2011-616)** who carried out the research under my supervision. Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion for this or any other candidate.

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ABSTRACT

Road transport is the most commonly used means of transport in Rwanda since the country is landlocked. Unpaved roads represent 78% of the whole classified Rwandan road network and the majority of the unpaved roads are located in remote rural areas with low to very low traffic volumes. Investments made in the construction and maintenance of unpaved low volume roads in Rwanda are subjected to big technical, financial, institutional and managerial challenges that need to be addressed in a special manner.

A sustainable solution to these challenges is an unpaved road investment that would provide acceptable design standards suitable to Rwandan condition, cost effective, institutionally applicable and easy to maintain.

The present research was about to identify the challenges that are being observed in the construction and maintenance of rural unpaved roads in Rwanda due to lack of proper project planning, poor policing and standardisation that leads sometimes to unjustified investments and no value for money due to the fact that construction and/or maintenance costs are very high and the traffic volume is very low.

The specific objective of this research was to develop and propose alternative engineering design standards, policies and practices that are cost effective and suitable to local conditions for the construction and maintenance of unpaved low volume roads in Rwanda.

The study was carried out using a series of methodological steps including data collection on traffic, geometric and structural design characteristics and construction costs on three case studied roads (National, District and unclassified roads). Data analysis in terms of investments efficiency compared to the resulting level of service was carried out using HDM-4.

The results of analysis were then used to develop and propose alternative design standards and techniques for the construction and maintenance of low volume unpaved roads.

The analysis of the gaps existing between the commonly used policies and practices in Rwanda and International Best Management Practices for the construction and maintenance of unpaved roads helped to develop and propose alternative

institutional policing and practices to be adopted for effective and efficient investments in unpaved roads in Rwanda.
The research has proved that widening the case studied unpaved roads results into increased Total Road Agency Costs and insignificantly decreased Total Road User Costs and, thus making higher Total Transport Costs compared to the base scenario of maintaining the existing unpaved road widths and finally leading to negative NPV and IRR. Negative values of these economic indicators show that all proposed projects of widening the three unpaved roads are not cost effective and not viable.
By conducting sensitivity analysis, the main reason for cost ineffectiveness was found to be high initial investment costs related to the works of widening of roads together with high maintenance costs of such wide roads.
Alternative road construction and maintenance techniques that can reduce Total Transport Costs like minimizing road width, avoiding steep road grade by selecting good location, providing adequate drainage system and surfacing unpaved road with gravel where it is necessary were found to be the best options for assuring good road condition, minimizing Road Agency costs and thus making investments economically viable.
The research recommended among many others the following alternative practices and policies for appropriate maintenance management of unpaved roads: improved road surveys before designing: inspection during the rains to observe the movement of water, Study reviews before starting the works, decentralisation of unpaved road funding schemes, objective prioritization of road works by optimizing maintenance activities instead of constructing new roads, increasing road maintenance financing by creating additional sources of funds like road use charging where possible and complementing recurrent budget by development budgets.
Further research using additional analysis tools like Road Economic Development was recommended.

Keywords: investment efficiency, cost effectiveness, widening the roads, Net Present Value, unpaved road construction and maintenance, alternative techniques, policies and practices

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List of Symbols and Abbreviations

AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
AMS	Asset Management System
BCR	Benefit Cost Ratio
BMP’s	Best Management Practices
CDF	Common Development Fund
CEA	Cost Effectiveness Analysis
CoK	City of Kigali
CS	Case Study
DR	District Road
EDPRS	Economic Development and Poverty Reduction Strategy
FER	Fonds d’Entretien Routier
GoR	Government of Rwanda
HDM – 4	A new version of HDM models
HDM	Highway Development and Management software initially
IRI	International Roughness Index
Km	Kilometer
MCA	Multi Criteria Analysis
MDG’s	Millennium Development Goals
MINAGRI	Ministry of Agriculture and Animal Resources
MINECOFIN	Ministry of Finance and Economic planning
MININFRA	Ministry of Infrastructure
MMS	Maintenance Management System
NPV	Net Present Value
NR	National Road
PCU	Passenger Car Unit
PMS	Pavement Management System
RAC	Road Agency Costs
RD	Route de District
RED	Road Economic Model
RLDSF	Rwanda Local Development Support Fund
RMF	Road Maintenance Fund
RN	Route Nationale
RTDA	Rwanda Transportation Development Agency
RTI	Rural Transport Infrastructure
RUC	Road User Costs
RWF	Rwanda Francs
SF	Seasonal Factor
SSA	Sub-Saharan Africa
SSATP	Sub-Saharan Africa Transport Policy Program
TRRL	Transport and Road Research Laboratory
USD	United States Dollar
VOCs	Vehicle Operating Costs
VPD	Vehicle per day

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Rwanda being a landlocked country, road transport is the most commonly used means of transport. The Rwandan road network is currently mainly composed of unpaved roads: 4,514.1 km of unpaved roads compared to 1,227.9 km of paved roads [1].Approximately 78% are unpaved roads and major parts of these unpaved roads are located in rural areas with low to very low traffic volumes.

The road transport network of any country plays a vital role in its economy, and the physical condition of its infrastructure is critical. Without adequate and timely maintenance, highways and rural roads alike inexorably deteriorate, leading to higher vehicle operating costs, increased numbers of accidents, and reduced reliability of transport services.

The Government of Rwanda (GoR) through its various development programmes like the Millenium Development Goals (MDG's), Vision 2020, the Economic Development and Poverty Reduction Strategy (EDPRS) etc…, has put forward infrastructure development as a key to success and among the infrastructures required, the transport sector should play an important role.

It is in this regards that the GOR invests a lot of money in rural roads construction and maintenance since 2000 when most of these development programmes were initiated and it will still have to invest in them considered their role for overall economic development and growth.

The rapid deterioration of rural roads is one of the more challenging issues facing many countries in the developing world today including Rwanda [3] currently technical, financial and managerial are the known constraints that make the problem so difficult.

From an asset management perspective, the dynamic nature of road condition is the most significant feature of unpaved roads, distinguishing their management from paved roads. The condition of an unpaved roads is highly sensitive to weather, traffic and maintenance strategy and implementation.

Therefore, in order to support these initiatives from the GoR, we need to undertake a research in this area so as to detect the process of appraisal used as decision tool for investing in rural unpaved roads (low volume) and if there is a clear national policy on investing in rural roads in Rwanda.

As a Transport Engineer on one hand, we need to evaluate and assess if the techniques used in constructing rural roads in Rwanda are the most appropriate and check if other alternatives which are technically better and economically justified are available; on the other hand, as a Transport Economist, we will have to assess the process being used in appraising road projects and conduct a diagnosis on the efficiency of investment decisions in rural unpaved roads in Rwanda.

It was noted that gravel loss is the most important condition parameter to predict in managing a network of unpaved roads.

This research will assist road asset manager to face the challenges for asset management of unpaved road, particularly to be able to respond to quick on changes in condition, and to deal with the environmental impacts associated with unpaved roads, in a tight financial climate.

1.2. PROBLEM DESCRIPTION

In the process of constructing and maintaining unpaved rural roads in Rwanda, there are many challenges that need to be addressed for effective and efficient investments in this area. This research paper is an attempt to review what is currently known about the technical, financial and managerial constraints that make the problem of rapid deterioration so difficult to handle.

(i) ***Technical***; Many developing and tropical countries including Rwanda, do not have their specifications of their own and use specifications developed in temperate zone together with pavement design procedure developed in Europe and America, for instance AASHTO specifications.

At the end, the final result of design is always a monotonous set of activities or works that are not always applicable to every location of the country or a specific unpaved rural road.

(ii) ***Financial:*** Excessive investments are being implemented by constructing high standards unpaved roads in terms of geometric designs, and due to low traffic volume, total economic costs resulting from these investments are very high and thus making these projects not economically justified.

(iii) ***Managerial:*** Very wide unpaved roads deteriorate fast and maintenance is very expensive. Centralised road maintenance funding scheme in Rwanda does not allow appropriate responsiveness for maintenance operations whereby lack of regular routine maintenance and timely emergency maintenance accelerate unpaved road deterioration and thus leading to premature periodic maintenance activities or unpaved road rehabilitation.

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It is in this regard that our research question in this work was set as follows: *How cost-effective are the design standards and maintenance practices that are adopted in Rwanda for rural unpaved roads? Could more (or less) roads be built with different standards that are more suited to Rwandan conditions through a complete investment appraisal process?*

1.3 AIM AND OBJECTIVES

1.3.1 Aims

The aims of this project are twofold: to develop alternative techniques, engineering design standards and practices to be used for the construction of and maintenance of unpaved rural roads in Rwanda and; to develop appropriate policies and practices based on decision support tools investments done in the construction and maintenance of unpaved roads in Rwanda.

1.3.2 Objectives

The specific objectives of this research are therefore:

- To review and critically analyze the national policy, engineering standards and practices for rural unpaved roads construction and maintenance in Rwanda
- To identify the gaps and other problematic areas in the design, construction, maintenance and financing structure for rural unpaved roads in Rwanda;
- To evaluate the cost implications resulting from widening unpaved roads with low traffic volume
- To develop alternative engineering construction and maintenance standards and practices for unpaved low volume that are more suitable to Rwandan conditions
- To test cost effectiveness of the proposed alternatives techniques and practices for unpaved rural roads construction and maintenance in Rwanda
- To develop alternative policies, practices and funding schemes for efficient and cost effective investments in the construction and maintenance of unpaved low volume roads in Rwanda.

1.5 SCOPE OF THE RESEARCH

This project will assess how cost effective is the techniques that are being used for constructing and maintaining low volume rural unpaved roads in Rwanda. A diagnosis on availability and clarity of a national policy and standards of construction and maintenance of rural unpaved roads will be conducted as well as an analysis of how the different project planning phases are applied before their execution. This project will look into and propose most suitable construction techniques and practices that would make efficient investments made in low volume unpaved rural roads in Rwanda. This will enable the Government of Rwanda to build many rural unpaved roads with reasonable investments.

This project will not consider high volume nor paved rural roads.

1.6 STRUCTURE OF THE THESIS

The thesis has been divided into six chapters; chapter one is introduction and it discusses the background, problem description, aims and objectives, the scope of the research and a brief summary of thesis. Chapter two gives a brief literature review on investments done in the construction and maintenance of unpaved roads in Rwanda, the new Rwanda Roads law and challenges in its implementation. Literature Review also describes International Best Management Practices and experiences in managing unpaved road assets and gaps were identified with respect to the current practices in Rwanda. The description of methods used to conduct this research including data collection, survey, processing and analysis using HDM-4 model are discussed in chapter three.

Chapter four describes the HDM-4 as data analytical tool for data analysis and some of its default values, data collection that includes construction costs and traffic data on selected case studied roads and finally it reviews all investment options for each case study as well as a set of work standards for each project alternative.

Data analysis was done in Chapter five, cost effectiveness was tested for all project alternatives and alternative cost effective techniques for road design, construction and maintenance of unpaved low volume roads were developed. In this chapter also, appropriate road maintenance policing and funding schemes were proposed for achieving justified investments in this field.

Chapter six summarizes the research findings as a conclusion and provides recommendations to various institutions

CHAPTER 2

LITERATURE REVIEW

A literature review was undertaken, using the resources from KIST Library and online library on: Rwanda road network, current transport policies in Rwanda, investment done on unpaved rural roads in Rwanda, Rwanda Roads Law, international best practice for investing in unpaved rural roads, road services: benefits and attributes, also review was done on current situation on technical, financial, predictive modeling for the condition of unpaved roads and managerial of rural roads maintenance in developing countries.

2.1. OVERVIEW ON THE RWANDAN ROAD NETWORK

The Rwandan road network was estimated by a study done in 2006 to have a length of about 14,000 km and Rwanda Road Classification Act based on that study was published in 2008. The road network is currently classified into two classes, namely the national roads (RN-class) and the district roads (RD-class).

According to the decree relating to the Regulation of the National Road Network (2008), the road classification is made in accordance to the destination and significance of these public roads; and there are other classes of roads that have not been proclaimed, namely rural feeder roads; specific roads and urban road network.

Table 2.1 shows the characteristics of the different road classes in Rwanda.

Table 2.1: Current Road Classification in Rwanda [10]

Class	***Category***	***Characteristics***			
		Road Ownership	**Distinction**	**Minimum Road Width (m)**	**Total Length (km)**
RN	National Road	Ministry of Infrastructure	Connect Rwanda with neighboring state or between urban communities; Access to facilities of national or international importance; Tourism significance	6	2,859

RD	District Road	Districts	Connect headquarters of sectors within the same district	4	1,838
	Rural Feeder	Districts	Connects district roads to centers of rural communities		
Not proclaimed	Specific Roads	Centers for agricultural production, for harnessing of natural resources, or tourist sites	Connect national roads/district roads to centers of agricultural production, tourist sites and natural resources	Not stipulated	Not stipulated
	Urban Roads	Kigali City or District in which urban centre is located	Connects sites within urban centers		
Total					**14,000**

Source: Rwanda Road Classification Act of 2008; Road Inventory dated May 2006.

The same study proposed a length of 4,698 km as a classified Road Network that is maintainable. The Ministry of Infrastructure in its Transport Sub-Sector Plan (2008-2012) has adopted the classification resulting from the study and included also the City of Kigali Road Network with a total length of 1,044 km, thus making a total length of 5,742 km under the management of MININFRA. Roads were classified in the following categories: National Roads (Paved and Unpaved), District Roads (all unpaved) and Kigali urban roads (paved and unpaved).

The following table illustrates the Rwandan Road Network classification with their respective lengths:

Table 2.2: Rwanda Road Network under the Ministry of Infrastructure

S/No	Road classification	Paved roads length (Km)	Unpaved Roads length (Km)	Total length (Km)
1	National Roads	1,074.70	1,784.80	2,859.50
2	District Roads	-	1,838.50	1,838.50
3	Kigali urban roads	153.20	890.80	1,044.00
	TOTAL	**1,227.90**	**4,514.10**	**5,742.00**

Source: MININFRA Transport Sub-Sector Plan (2008-2012)

Based upon the 2005 study Report, MININFRA set up a new transport sub sector Strategic Plan for the period 2009-2012, in which the responsible authorities in charge of maintenance of classified roads were defined. All National Roads (RN) are under the responsibility of MININFRA through its Policy Planning and Capacity Building Unit; management and maintenance of District.

Roads (RD) were assigned to an individual executive committee of 30 Rwandan districts through the coordination of the Directorate of Infrastructure of each district; whereas Kigali City Roads were put under the responsibility of the Kigali City Council, Infrastructure Department [1].

Furthermore, for the purpose of national planning the expenditures and development budgets for road construction, rehabilitation and maintenance, the Strategic Plan determined the aggregate resource envelope for classified roads. Planning and implementation of road construction and maintenance remained the tasks of the road authorities i.e MININFRA, Kigali City and Districts, whereas the Road Maintenance Fund is responsible for financing emergency works, routine maintenance and periodic maintenance works through the recurrent budget.

Road Reconstruction and Rehabilitation works are meant to be financed by the MININFRA through the National Development Budget.

2.2. CURRENT SITUATION ON THE MAINTENANCE POLICY AND INVESTMENTS IN UNPAVED ROADS IN RWANDA

Road prioritization should be reviewed objectively in many Sub-Saharan African countries to better take into account economic potential. Probably more priority should be assigned to maintenance or rehabilitation than to network expansion [8].

Serious efforts have been undertaken to rehabilitate and sometimes expand low-volume road networks. Nowadays, some governments are in a difficult position as far as maintenance is concerned. Incentives should be developed to force governments to allocate funds to maintain the existing road network instead of regularly financing road rehabilitation and network expansion [5].

From the experiences on poor road maintenance policing above, before undertaking new road construction, it is important to have a sound management and maintenance policy of the existing classified network. Basic maintenance i.e emergency works like removal of landslides, routine maintenance and periodic maintenance are key to a successful road network maintenance strategy since it can avoid and/or make possible to postpone to a later stage full rehabilitation works, that are far costly than basic maintenance works

2.2.1 Current Transport Policies in Rwanda

The Rwanda National Transport Sector Policy identifies the important role Transport plays in stimulating economic growth by increasing internal production and facilitating access to domestic and international markets while ensuring favourable conditions for provision and distribution of imported products within the country. The emphasis is placed on the development of transport infrastructure and services, in terms of construction, rehabilitation and maintenance of the transportation networks, aimed at growth and economic development in order to achieve the objectives set by Vision 2020. The Rwanda National Transport Policy identifies the need to reduce constraints to transport in order to promote sustainable economic growth and decrease poverty [11]. Infrastructure should be developed in a sustainable manner to support economic growth of the country, mobility of the population and serve as a “pivot” for exchange of goods and services at national and regional level.

Among the key objectives contained in the policy, the following are relevant in respect of regional integration:

- strengthen the institutional framework and capacity of transport institutions and stakeholders in the planning and management of the sector;
- reduce and control transport costs;
- assure the durability and quality of the rural, urban and international transport network;
- improve safety for goods and passengers in the principle modes of transport;
- increase mobility of the population in order to improve access to essential transport services;
- establish a system to ensure sustainable financing of road maintenance; and
- enhance Rwanda’s integration into the regional economy and to make Rwanda a regional trade and transit centre.

The Policy provides for principle “strategic axes” to guide the actions that will be necessary to give effect to the objectives. Strategic axes of importance to regional integration are:

- private sector to play a more important role in developing infrastructure;
- participation of local communities in maintenance of roads;
- support from decentralized entities that can assume their responsibilities in the management of the sector within the framework of established policies;

- taking into account regional dimensions and processes of integration currently in progress in order to develop a transport sector that will benefit from opportunities offered and which respond to the challenges of the regional context; and
- reinforcement of the human resource capacities to build a viable transport sector.

Clear transport policies exist in Rwanda and objectives are well set. However, the current institutional arrangements for implementing the transport policies are somehow challenging.

There are two broad categories of transport-related functions which need to be assigned to appropriate institutions: governance and delivery. Governance has to do with policy-making and planning, and oversight.

Policy and planning provide the direction (the vision) for the sector.

Oversight entails ensuring that appropriate safety, security and technical standards are in place, the right to provide an infrastructure or service (market access regulation) and the setting of limits on incumbents (economic regulation, e.g. tariff setting).

Delivery entails the provision of transport infrastructure and services. Infrastructure provision entails the physical transport nodes (airports, ports, etc.) and links (road and rail).

Under the 'separation of functions' principle expounded on above, good practice is to house safety and technical regulation in a separate, arm's length government agency. This body would be separate from the institution delivering the infrastructure or service, and also separate from the body that oversees and regulates the market from an economic perspective. However, economies of scale considerations may imply that it is not practical or affordable to set up such safety regulators for every transport or utilities sub-sector [11].

In this regards, the policy and planning function is clearly assigned to MININFRA, although the ministry has non-transport obligations as well. The ministry's transport obligations are supported by the RTDA, which has a dual mandate of sector planning and infrastructure delivery (mainly national roads). The RTDA was established to assist the Ministry with the management and administration of the transport sector. However, the RTDA equally has infrastructure delivery obligations, mostly regarding roads, but also in relation to airports and rail. The RTDA should ideally focus either on strategic transport planning or infrastructure delivery. If infrastructure, it may be considered to establish a separate ministry dedicated to all aspects of transport [11].

2.2.2. Funding scheme and Investments in unpaved roads in Rwanda

Road Law gives to Rwanda Transport Development Agency (RTDA) the responsibilities of managing and maintaining National Roads and related works of maintenance and developments shall be funded by the Government. Districts and the City of Kigali have the responsibilities of carrying out routine maintenance of the parts of the national roads passing over them and their surroundings.

All districts roads are under the supervision of the districts and that of City of Kigali and under her supervision. Management and maintenance of District and City of Kigali Roads – Class one are under the jurisdiction of the Districts or the City of Kigali respectively. Maintenance works related to District and City of Kigali roads shall be funded by the Road Maintenance Fund (RMF) whereas works meant for their development shall be funded by the Government.

Works related to the management, rehabilitation, maintenance and development of Districts and City of Kigali roads-Class 2 as well as the funds thereto allocated are under the jurisdiction of the Districts and the City of Kigali.

Rehabilitation, maintenance and development of specific roads are in the competence of those who are in charge of their management, who can make a special agreement with a special company to carry out road works on them or parts of them.

The new road law provides for a balanced allocation of funds related to the construction and maintenance of the road network, whereby maintenance works on national roads excluding routine maintenance shall be financed by the central government through development budgets. In addition, all reconstruction, rehabilitation and upgrading of all road categories shall be under the responsibilities of the central government.

This financing arrangement is different from the current practice in which the Road Maintenance Fund was in charge of funding all types of road maintenance for the whole network through its limited recurrent budget. Table below illustrates all projects financed by RMF for the last five years in emergency, routine and periodic maintenance.

Table 2.3: Projects financed by RMF for the last five years

Budget or FY	Amount financed to MININFRA/RTDA projects (in RWF)	Amount financed to MVK projects (in RWF)	Amount financed to District projects (in RWF)	Total (in RWF)
2007	8,118,804,000	774,842,000	-	8,893,646,000
2008	1,979,043,000	2,537,856,000	-	4,516,899,000
2009-2010	6,715,814,828	2,953,553,490	77,100,175	9,746,468,493
2010-2011	15,031,913,824	4,383,655,490	-	19,415,569,314
2011-2012	15,915,718,032	4,475,208,956	-	20,390,926,988
TOTAL	**47,761,293,684**	**15,125,115,936**	**77,100,175**	**62,963,509,795**

Source: RMF Annual Reports and FER Work Progress Reports

The majority of the roads financed by RMF during the last five years are national paved and unpaved roads. Under the current road classification, RMF has rarely financed district roads and rural feeder roads.

On the other hand, some works of upgrading national and district roads were financed through RMF recurrent budget. For example, for three financial years, RMF has financed big project of upgrading and paving with asphalt concrete 34.6km unpaved roads in Kigali City, a project that cost 13,748,266,005 Rwf.

2.2.3 Technical and engineering standards for roads construction and maintenance in Rwanda

In 2009 Rwanda drafted a Law entitled the "Draft Law Regulating National Road Network (2009)" which was promulgated in 2011 entitled the Rwanda Road Act, 2011. The said Law states that the Road Network of Rwanda shall be classified as follows:

Table 2.4: Road Classes Identified in the Road Act, 2011 to Regulate the National Road Network

Class	Description	Minimum Road Width (m)	Minimum Road Reserve Width (m)
National Roads	These are: 1. International roads that links Rwanda with a neighbouring state; or 2. Roads that link Districts or a District and the City of Kigali. 3. Roads that link areas of tourist significance and facilities of national or international importance such as ports or airports.	The minimum viable widths of roads, the District and City of Kigali Roads not including the side drains and embankments shall be 7meters.	The road reserve on which run National roads, District and City of Kigali roads category1, is delimited by two parallel lines at twenty
District and City of Kigali Roads – Category 1	These are roads with a local significance linking different headquarters of Sectors within the same District, or within the same Sector.	The minimum viable widths of roads, the District and City of Kigali Roads not including the	

		side drains and embankments shall be 7 meters	two (22) meters on each side of the centre line of the road
District and City of Kigali Roads – Category 2	These are arterial roads that connect District Roads category 1 to community centres.	The minimum width of District and City of Kigali Roads Category 2 of shall be 6 meters .	The public reserve on which run District and City of Kigali Roads -Category 2 shall be of not less than 12 meters on each side from the centre line of the road.
Specific road	These are roads specifically constructed to connect National Roads and District Roads to the centres of agricultural production, natural resources or to tourist sites that ensure linkages within the City of Kigali.	Not specified.	Not specified.

In order to critically analyse the value for the money that is being spent in this area of road construction and specifically road maintenance, it is required to first review what is provided with the Rwanda law related to road network.

In the recent past few years, the GoR has adopted law No 55/2011 of 14/12/2011 governing roads in Rwanda.

The law defines among many others the classification, naming and starting points of Rwandan roads. It also determines the width of all classified roads, and it provides the responsibilities, management, maintenance, financing and development works of the road network.

Furthermore, the law sets different standards of road works as follows:

- ***Routine maintenance***: carrying out works which are required on a continuous basis and involves general cleaning of drainage channels, vegetation control and repairs to landslides on the road;

- ***Recurrent maintenance***: works which are required at intervals throughout the year and involves repair of potholes, grading of earth roads, and patching and sealing of cracks on tarmac roads;
- ***Periodic maintenance***: work which is required at intervals of several years and includes re-gravelling and stabilisation of gravel roads, overlaying or re-surfacing of paved roads;
- ***Road development***: the way a road is upgraded, constructed, widened, reconstructed or adjusted by installing on it other necessary facilities;

The Central roundabout of the City of Kigali located at Latitude South 01^{o} 56' 10", Longitude East 30^{o} 03' 11" and at an Altitude of 1,509.38 m was fixed as the Starting Point for calculating the length of the national roads.

Width of roads

The Law No 55/2011 of 14/12/2011 governing roads in Rwanda provides a minimum viable width of the lane of a roadway as 3.5 m not including the drainage ditches and embankments for national roads, districts and City of Kigali roads and those of other urban areas – class one.
The minimum width of the roadway in Districts and City of Kigali and other urban areas – Class 2, shall be six (6) metres, not including drainage ditches and embankments.
The width of a road may be increased when it is deemed necessary in suburbs and at the entrances of towns, grouped settlements and agglomerations.
The law states that in addition to the above road widths, each road must have a large piece of land for drainage ditches, embankments, dumps and sidewalks on all integral parts of the roads.
According to this law also, National roads which do not conform to the above mentioned requirements for their respective class shall be gradually widened within the existing resources of the country.
It is important to remind here that the Law No 55/2011 of 14/12/2011 governing roads in Rwanda recommends a Ministerial Order that shall establish the national policy related to development, rehabilitation and maintenance of roads as well as a Presidential order establishing the master plan that is to determine national roads. Another Ministerial Order

to define the technical and service standards for roads based on the study and research conducted by experts on the entire road network of Rwanda was established by the Law roads.

The main challenge today is that neither these Ministerial Orders nor the Presidential Order stated above have been put in place and yet, the Road Law that they should complement is being put in place like the Unpaved district road DR 28 (Rwamagana – Karembo: 28.717 km) under periodic maintenance works. According to the Road Network Act ,2008 produced by MININFRA, this road was classified as District Road N° 28 but with the provisions of the new Road Law, it shall be classified as a National Road as it links Rwamagana District to Ngoma District.

The new Road Law shall be complemented by a road reclassification based on the technical studies, including Traffic counts over the whole classified network.

The study has been commissioned by RTDA and a proposal for road reclassification is under the process of approval.

However, based on the articles of the new road law, many district roads as per the current road classification will automatically become national roads or district roads class one, while other previously unclassified roads will become district roads class two.

The expected reclassification will therefore result in high impacts related to the maintenance standards and requirements especially the issue of widening roads in order to comply with the new Road Law articles.

2.2.4 Traffic volumes on National and District Roads in Rwanda

The new road classification is primarily based on road functionality and location and the new road regulation provides design standards to be adopted based on that classification. However, making decisions on investing in road without considering the traffic volume on that specific road would be erroneous.

The results of economic analyses are quite sensitive to traffic data, and most benefits that justify road improvements arise from savings in road user costs. To perform economic analyses in HDM-4, traffic characteristics of roads therefore need to be described and represented at an appropriate level of detail [12].

In 2012, RTDA has commissioned a traffic count survey on all national unpaved and the study has been conducted by ITEC Engineering Ltd.

The analysis of the findings of the report show that many of the national unpaved roads have low to very low traffic volumes.

It is important to define the following terms related to traffic volumes:

ADT*:* Average Daily Traffic in full words which is the total volume passing a particular location or road section in both directions during a 24-hour period. It is commonly obtained during a given time period, in whole days greater than one day and less than one year, divided by the number of days in that time period.

AADT: Average Annual Daily Traffic, which is the average calculated over a year of the number of vehicles passing a point in given counting road section each day (usually expressed in vehicles per day). It simply represents the vehicle flow over a road section (eg highway link) on an average day of the year. AADT is considered as one of the most important raw traffic dataset as it provides essential inputs for traffic modelling and software calibration like for HDM-4 that can be used for the planning of new road construction, existing road maintenance strategy, determination of roadway geometry, congestion management, pavement design and many others.

SF (Seasonal Factor): Traffic is assumed to be not constant in all months of the year. Typically for unpaved rural roads, traffic volume is expected to be less in wet season due to the problems of traffic ability for some road sections, and it is high in dry season as a result of an anticipated unpaved road good condition that allows free movement of people and goods.

Seasonal Factor is commonly estimated using the fuel consumption data over the months of the year; and a SF for each month of the year is thus calculated by dividing the quantity of fuel consumed in that month by the average of that specific year.

The Seasonal Factor may be calculated on the basis of any type of fuel but based on the results of the traffic counts on unpaved roads of Rwanda as illustrated below by ITEC Engineering Report, 2012, motorcycles represent a high percentage of the traffic volume and they exclusively use petrol (PMS: Premium Motor Spirit)., as well as most of cars, minibuses and other light cars, it is preferred to use PMS data for a good representation of traffic volume on rural unpaved roads of Rwanda.

The Seasonal Factor is multiplied by the Average Daily Traffic to get the Average Annual Daily Traffic.

PCU: Passenger Car Unit

Most of time, traffic is mixed with all types of vehicles: motorcycles, cars, pickups, jeeps, minibuses, buses, Lorries, Heavy Good Vehicles and many others. All these types of vehicles do not occupy a same space in a road way nor they cause same stress to the road structure.

Traffic flow or volume can be measured using Vehicles/hour or Passenger Car Unit/Hour. The Passenger Car Unit (PCU) is a way to bring all traffic components to same units.

1 PCU is equivalent to 1 car.

Other traffic components are derived by comparing their headway to that of the car.

Headway (H) is measured from back to back of vehicles during a saturated flow.

For example, PCUBus=HBus / HCar

Below are some typical PCU values

Table 2.5: Typical Values for PCU Factors

Vehicle	**Minimum**	**Maximum**	**Recommended**
Bicycle	0.2	0.4	0.3
Motorcycle	0.2	0.6	0.4
Pedal Rickshaw	0.9	1.4	1.2
Auto Rickshaw	0.5	0.6	0.6
Cars and Vans	1.0	1.0	1.0
Minibus (4 tyres)	1.0	1.3	1.1
Heavy Bus (>4tyres)	1.5	3.6	2.3
Truck (>4tyres)	1.6	2.8	2.1
Horse and Cart	2.6	4.0	3.0
Bullock Cart	4.0	11.2	6.0
Tram	6.0	6.0	6.0

Source: TRL (1993)

Table 2.6: 'Standard' (UK) PCU values

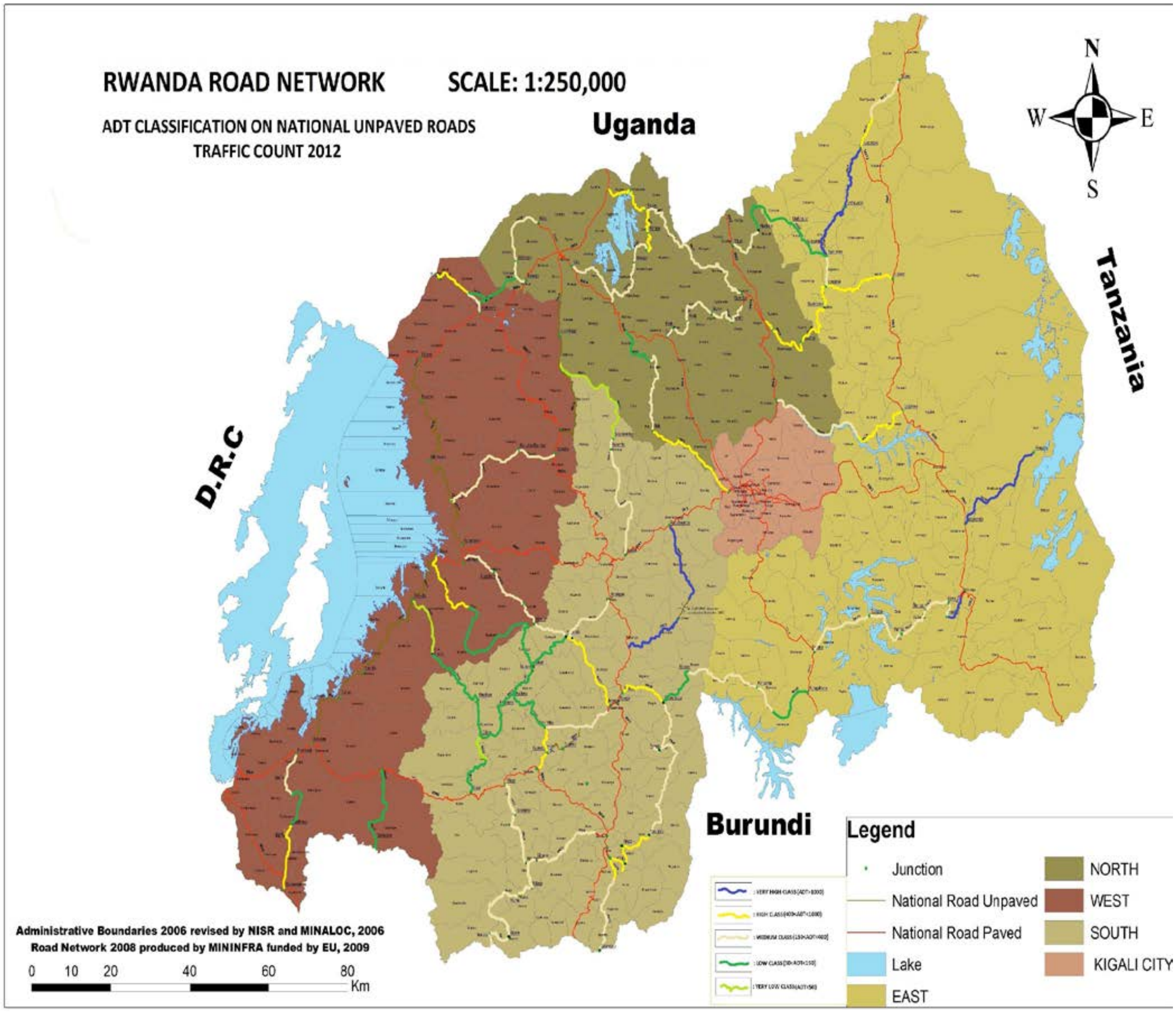
Vehicle type	TP56 (1966)	Branston (1979)	RR67 (1986)
Car/light vehicle	**1.0**	**1.0**	**1.0**
Medium CV	**1.75**	**1.33**	**1.5**
Heavy CV	**1.75**	**1.7**	**2.3**
Bus/coach	**2.25**	**1.7**	**2.0**
m/c, moped	**0.33**	**0.15**	**0.4**
Pedal cycle	0.20	0.10	0.2

Source: ITS

Following the results of the traffic counts surveys; ITEC Engineering has classified National unpaved roads in the following five classes.

- Very high class (ADT>1000)
- High class (400<ADT<1000)
- Medium class (150<ADT<400)
- Low class (50<ADT<150)
- Very low class (ADT<50)

Figure 2.1: Representation of ADTs on Rwanda National Unpaved Roads Network



Source: ITEC Engineering Ltd (2012)

Table 2.6: Estimated ADT on all unpaved National roads

RN 18-43 ALL SECTIONS				Motor-CYCLE	Total		Daily vehicles Without M/C	Ratio	ADT- 24H	Averages /road		Estimated AADT=ADT* SF
Road ID	Road name	Section	Post name	Motor-cycle	L.V	H.V	Estimated ADT*-24H without m/c components	%: (HV/ Estim ADT*24H without m/c components	ADT -24H with m/c * 100	Estimated ADT-24H without m/c /road	Estim ADT-24H with m/c /road	SF=0.88
RN 18	Byumba-Gabiro (61,659km)	Sect-1	Rukoma S	528.00	87.00	40.00	127.00	31.00	655.00	108	592.00	576.40
		sect-2	Gaboro	440.00	61.00	28.00	89.00	31.00	529.00			465.52
RN 19	Butare-Akanyaru,bas (24,186 km)	Sect-1	Rango E	768.00	93.00	28.00	121.00	25.00	889.00	83.00	581.00	782.32
		Sect-2	Nyaruteja E	227.00	35.00	10.00	45.00	22.00	272.00			239.36
RN 20	Byumba-Base (42,098km)	Sect-1	Byuma S	232.00	44.00	24.00	68.00	35.00	300.00	67.00	290.00	264.00
		Sect-2	Base E	215.00	30.00	35.00	65.00	54.00	280.00			246.40
RN 21	Cyakabiri-Nyabikenke-Ndusu (79,31km)	Sect-1	Cyeza	237.00	70.00	20.00	90.00	22.00	327.00	52.00	176.00	287.79
		Sect-2	Ndusu S(Muvumba)	10.00	5.00	9.00	14.00	64.00	24.00			21.12
RN 22	Rugobagoba -Kinazi-Ruhango (44.857km)	Sect-1	Rugobagoba S	755.00	160.00	134.00	294.00	46.00	1,049.00	229.00	1,052.00	923.12
		Sect-2	Ruhango E	891.00	115.00	48.00	163.00	29.00	1,054.00			927.52
RN 23	Nyanza -Kibuye (69.062 km)	Sect-1	Nyanza S	393.00	70.00	37.00	107.00	35.00	500.00	124.00	519.00	440.00
		Sect-2	Buhanda S	612.00	177.00	71.00	248.00	26.00	860.00			756.55
		Sect-3	Nyagasozi/(Ruragwe) E	178.00	12.00	6.00	18.00	33.00	196.00			172.48
RN 24	Butare-Kibeho-Muse (52,753 km)	Sect-1	Matyazo S	300.00	161.00	33.00	194.00	17.00	494.00	138.00	408.00	434.97
		Sect-2	Muse	240.00	56.00	25.00	81.00	31.00	321.00			282.48

RN 25	Kidaho-Kirambo-Kiryi (83,860 km)	Sect-1	Kidaho S	279.00	109.00	24.00	133.00	18.00	412.00	10 0.00	336.00	362.56
		Sect-2	Kiranbo S	116.00	31.00	10.00	41.00	24.00	157.00			138.16
		Sect-3	Kiryi E	312.00	65.00	62.00	127.00	49.00	439.00			386.32
RN 26	Pindura-Bweyeye (31,780 km)	Sect-1	Bweyeye E	44.00	9.00	7.00	16.00	44.00	60.00	16.00	60.00	52.80
RN 27	Nyagasa-Ntoma (64,068km)	Sect-1	Ngarama S	272.00	24.00	7.00	31.00	23.00	303.00	80.00	846.00	266.64
		Sect-2	NyagatareE (Rukoma)	2,057.00	158.00	83.00	241.00	34.00	2,298.00			2,022.24
		Sect-3	Nyagatare-ryabega	382.00	13.00	9.00	22.00	41.00	404.00			355.52
		Sect-4	Ntoma	351.00	14.00	13.00	27.00	48.00	378.00			332.64
RN 28	Kinigi-Busogo-Kora-Kabuhanga (68,460Km)	Sect-2	Kinigi S	131.00	74.00	27.00	101.00	27.00	232.00	54.00	255.00	204.16
		sect-1a	Busogo E	87.00	10.00	9.00	19.00	47.00	106.00			93.28
		Sect-1b	Kabatwa E	353.00	8.00	47.00	55.00	85.00	408.00			359.04
		Sect-1c	Kora S	236.00	22.00	17.00	39.00	44.00	275.00			242.00
RN29	Kibugabuga-Nyamiyaga-Gasoro (68,613)	Sect-1	Kamabuye E	15.00	76.00	16.00	92.00	17.00	107.00	59.00	214.00	94.16
		Sect-2	Ruhuha S	119.00	38.00	26.00	64.00	41.00	183.00			161.04
		Sect-3	Busoro E	90.00	19.00	14.00	33.00	42.00	123.00			108.24
		Sect-4	Nyamiyanga S	395.00	28.00	20.00	48.00	42.00	443.00			389.84
RN 30	Nyaza-Gikongoro (33,951 km)	Sect-1	Nyanza-Rwesero S	113.00	58.00	36.00	94.00	38.00	207.00	61.00	314.00	182.16
		Sect-2	Rukondo-mbazi sector	217.00	18.00	13.00	31.00	42.00	248.00			218.24
		Sect-3	Cyanika S	428.00	40.00	19.00	59.00	32.00	487.00			428.56
RN 31	Kigali-Rushashi-Gakenke (68,062km)	Sect-1	Kigali,after skol factory	312.00	105.00	71.00	176.00	40.00	488.00	99.00	329.00	429.44
		Sect-2	Ruli S at cell office	273.00	68.00	18.00	86.00	21.00	359.00			315.92
		Sect-3	Gakenke E	103.00	22.00	14.00	36.00	39.00	139.00			122.32

RN 32	Byimana-Buhanda Kitabi (99,750)	Sect-1	Byimana S	195.00	163.00	34.00	197.00	17.00	392.00	63.00	163.00	344.96
		Sect-2	Karambi S	107.00	19.00	13.00	32.00	41.00	139.00			122.32
		Sect-3	Kaduha E	75.00	25.00	5.00	30.00	17.00	105.00			92.40
		Sect-4	Gatavu E	37.00	15.00	3.00	18.00	17.00	55.00			48.40
		Sect-5	Kitabi	85.00	15.00	23.00	38.00	61.00	123.00			108.24
RN 33	Ntendezi-Mashuza-Bugarama (37,559km)	Sect-1	NtendeziS	159.00	8.00	11.00	19.00	85.00	178.00	72.00	238.00	156.64
		Sect-2	Mwezi S	76.00	5.00	4.00	9.00	44.00	85.00			74.80
		Sect-3	Bugarama E	264.00	108.00	79.00	187.00	42.00	451.00			396.88
RN 34	Kagasa-Kibungo (56,733km)	Sect-1	Gashora S	70.00	80.00	30.00	110.00	27.00	180.00	173.00	608.00	158.40
		Sect-2	Sake	220.00	100.00	20.00	120.00	17.00	340.00			299.20
		Sect-3	Kibungo S	1,015.00	216.00	73.00	289.00	25.00	1,304.00			1,147.52
RN 35	Rwesero-Gakenke (51,546km)	Sect-1	Rwesero E	180.00	92.00	25.00	117.00	21.00	297.00	77.00	337.00	299.97
		Sect-2	Anglican church(PK18)	121.00	39.00	14.00	53.00	26.00	174.00			153.12
		Sect-3	Kiramuruzi	478.00	39.00	22.00	61.00	36.00	539.00			474.32
RN 36	Ngarama-Mulindi (53,798km)	Sect-1	Ngarama S	103.00	12.00	8.00	20.00	40.00	123.00	60.00	220.00	108.24
		Sect-2	Mulindi at 2km	216.00	54.00	46.00	100.00	46.00	316.00			278.08
RN 37	Byumba-Butaro (51,204km)	Sect-1	Byuma S	298.00	46.00	29.00	75.00	39.00	373.00	51.00	268.00	328,24
		Sect-2	Butaro E	136.00	18.00	9.00	27.00	33.00	163.00			143.44
RN38	Kibuye-Cyanika (105,18km)	Sect-1	Kibuye	337.00	50.00	34.00	84.00	40.00	421.00	34.00	224.00	370.48
		Sect-2	Gahunduguru	65.00	7.00	6.00	13.00	46.00	78.00			68.64
		Sect-3	Masizi S	75.00	5.00	2.00	7.00	29.00	82.00			72.16
		Sect-4	Cyanika	284.00	20.00	12.00	32.00	38.00	316.00			278.08

RN 39	Gishyita-Gatavu (53,798km)	Sect-1	Gasovu E	15.00	7.00	19.00	26.00	73.00	41.00	27.00	70.00	36.08
		Sect-2	Gasovu S	24.00	2.00	26.00	28.00	93.00	52.00			45,76
		Sect-3	Gasavu E	89.00	20.00	8.00	28.00	29.00	117.00			102.96
RN 40	Kabarando-Hotel Akagera (29,120 km)	Sect-1	Kabarondo S	792.00	204.00	109.00	313.00	35.00	1,105.00	313.00	1,105.00	972.27
RN 41	Butare-Nyamiyaga (59,820 km)	Sect-1	Gisagara S	320.00	99.00	16.00	115.00	14.00	435.00	76.00	336.00	382.80
		Sect-2	Nyamiyaga E	200.00	27.00	9.00	36.00	25.00	236.00			207.68
RN 42	Kibeho-Ndago-Bitare (50,586 km)	Sect-1	Ndago E	166.00	143.00	24.00	167.00	14.00	333.00	149.00	269.00	293.04
		Sect-2	Ndago S	73.00	106.00	25.00	131.00	19.00	204.00			294.04
RN 43	Kazabe-Rutsiro (51,757 km)	Sect-1	Kazabe S	242.00	20.00	27.00	47.00	58.00	289.00	57.00	268.00	254.19
		Sect-2	Rutsiro E	180.00	47.00	20.00	67.00	30.00	247.00			217.49
Total				**19,408**	**3,996**	**1,895**	**5,891**		**25,299**			
	Estim Aver For All daily Traffic Estimated ADT 24h components	69	69	281.00	58.00	27.00	85.00		367.00			322.65

Source: ITEC Engineering, Traffic Counts Survey (2012)

The Average calculated AADT is 322 for all vehicle components for the whole 69 sections of National unpaved roads.

According to the above proposed classifications by ITEC Engineering, the AADT is in the Medium Class (150<AADT<400).

The major component of the calculated average AADT for all 69 sections is motorcycles (247) which represent almost 77% of the total AADT.

However, the consultant did not consider the PCU values and the motorcycles being major components of the estimated average AADT, it is obvious that AADT is overestimated.

After applying the PCU values as discussed above, the estimated AADT for all unpaved National Roads are presented in the table below.

Table 2.7: Estimated AADT for all National unpaved Roads (applying PCU values)

RN 18-43 ALL SECTIONS								
Road ID	**Road name**	**Section**	**Post name**	**Motor -cycle**	**Estimated ADT*-24H without m/c components**	**Estimated ADT-24H for m/c applying pcu value of 0.4 for motor cycle**	**Total ADT-24H with m/c**	**Estimated AADT=ADT* SF (SF=0.88)**
RN 18	Byumba-Gabiro (61,659km)	Sect-1	Rukoma S	528.00	127.00	211.2	338.2	298
		sect-2	Gabiro	440.00	89.00	176	265	233
RN 19	Butare-Akanyaru,bas (24,186 km)	Sect-1	Rango E	768.00	121.00	307.2	428.2	377
		Sect-2	Nyaruteja E	227.00	45.00	90.8	135.8	120
RN 20	Byumba-Base (42,098km)	Sect-1	Byumba S	232.00	68.00	92.8	160.8	142
		Sect-2	Base E	215.00	65.00	86	151	133
RN 21	Cyakabiri-Nyabikenke-Ndusu (79,31km)	Sect-1	Cyeza	237.00	90.00	94.8	184.8	163
		Sect-2	Ndusu S(Muvumba)	10.00	14.00	4	18	16
RN 22	Rugobagoba -Kinazi-Ruhango (44.857km)	Sect-1	Rugobagoba S	755.00	294.00	302	596	524
		Sect-2	Ruhango E	891.00	163.00	356.4	519.4	457
RN 23	Nyanza - Kibuye (69.062 km)	Sect-1	Nyanza S	393.00	107.00	157.2	264.2	232
		Sect-2	Buhanda S	612.00	248.00	244.8	492.8	434
		Sect-3	Nyagasozi/(Ru ragwe) E	178.00	18.00	71.2	89.2	78
RN 24	Butare-Kibeho-Muse (52,753 km)	Sect-1	Matyazo S	300.00	194.00	120	314	276
		Sect-2	Muse	240.00	81.00	96	177	156
RN 25	Kidaho-Kirambo-Kiryi (83,860 km)	Sect-1	Kidaho S	279.00	133.00	111.6	244.6	215
		Sect-2	Kiranbo S	116.00	41.00	46.4	87.4	77

RN 26	Pindura-Bweyeye (31,780 km)	Sect-3	Kiryi E	312.00	127.00	124.8	251.8	222
		Sect-1	Bweyeye E	44.00	16.00	17.6	33.6	30
RN 27	Nyagasa-Ntoma (64,068km)	Sect-1	Ngarama S	272.00	31.00	108.8	139.8	123
		Sect-2	NyagatareE (Rukoma)	2,057.00	241.00	822.8	1063.8	936
		Sect-3	Nyagatare-ryabega	382.00	22.00	152.8	174.8	154
		Sect-4	Ntoma	351.00	27.00	140.4	167.4	147
RN 28	Kinigi-Busogo-Kora-Kabuhanga (68,460Km)	Sect-2	Kinigi S	131.00	101.00	52.4	153.4	135
		sect-1a	Busogo E	87.00	19.00	34.8	53.8	47
		Sect-1b	Kabatwa E	353.00	55.00	141.2	196.2	173
		Sect-1c	Kora S	236.00	39.00	94.4	133.4	117
RN29	Kibugabuga-Nyamiyaga-Gasoro (68,613)	Sect-1	Kamabuye E	15.00	92.00	6	98	86
		Sect-2	Ruhuha S	119.00	64.00	47.6	111.6	98
		Sect-3	Busoro E	90.00	33.00	36	69	61
		Sect-4	Nyamiyanga S	395.00	48.00	158	206	181
RN 30	Nyaza-Gikongoro (33,951 km)	Sect-1	Nyanza-Rwesero S	113.00	94.00	45.2	139.2	122
		Sect-2	Rukondo-mbazi sector	217.00	31.00	86.8	117.8	104
		Sect-3	Cyanika S	428.00	59.00	171.2	230.2	203
RN 31	Kigali-Rushashi-Gakenke (68,062km)	Sect-1	Kigali,after skol factory	312.00	176.00	124.8	300.8	265
		Sect-2	Ruli S at cell office	273.00	86.00	109.2	195.2	172
		Sect-3	Gakenke E	103.00	36.00	41.2	77.2	68
RN 32	Byimana-Buhanda Kitabi (99,750)	Sect-1	Byimana S	195.00	197.00	78	275	242
		Sect-2	Karambi S	107.00	32.00	42.8	74.8	66
		Sect-3	Kaduha E	75.00	30.00	30	60	53
		Sect-4	Gatavu E	37.00	18.00	14.8	32.8	29
		Sect-5	Kitabi	85.00	38.00	34	72	63
RN 33	Ntendezi-Mashuza-Bugarama (37,559km)	Sect-1	NtendeziS	159.00	19.00	63.6	82.6	73
		Sect-2	Mwezi S	76.00	9.00	30.4	39.4	35
		Sect-3	Bugarama E	264.00	187.00	105.6	292.6	257
RN 34	Kagasa-Kibungo (56,733km)	Sect-1	Gashora S	70.00	110.00	28	138	121
		Sect-2	Sake	220.00	120.00	88	208	183
		Sect-3	Kibungo S	1,015.00	289.00	406	695	612

RN 35	Rwesero-Gakenke (51,546km)	Sect-1	Rwesero E	180.00	117.00	72	189	166
		Sect-2	Anglican church(PK18)	121.00	53.00	48.4	101.4	89
		Sect-3	Kiramuruzi	478.00	61.00	191.2	252.2	222
RN 36	Ngarama-Mulindi (53,798km)	Sect-1	Ngarama S	103.00	20.00	41.2	61.2	54
		Sect-2	Mulindi at 2km	216.00	100.00	86.4	186.4	164
RN 37	Byumba-Butaro (51,204km)	Sect-1	Byuma S	298.00	75.00	119.2	194.2	171
		Sect-2	Butaro E	136.00	27.00	54.4	81.4	72
RN38	Kibuye-Cyanika (105,180km)	Sect-1	Kibuye	337.00	84.00	134.8	218.8	193
		Sect-2	Gahunduguru	65.00	13.00	26	39	34
		Sect-3	Masizi S	75.00	7.00	30	37	33
		Sect-4	Cyanika	284.00	32.00	113.6	145.6	128
RN 39	Gishyita-Gatavu (53,798km)	Sect-1	Gasovu E	15.00	26.00	6	32	28
		Sect-2	Gasovu S	24.00	28.00	9.6	37.6	33
		Sect-3	Gasavu E	89.00	28.00	35.6	63.6	56
RN 40	Kabarando-Hotel Akagera (29,120 km)	Sect-1	Kabarondo S	792.00	313.00	316.8	629.8	554
RN 41	Butare-Nyamiyaga (59,820 km)	Sect-1	Gisagara S	320.00	115.00	128	243	214
		Sect-2	Nyamiyaga E	200.00	36.00	80	116	102
RN 42	Kibeho-Ndago-Bitare (50,586 km)	Sect-1	Ndago E	166.00	167.00	66.4	233.4	205
		Sect-2	Ndago S	73.00	131.00	29.2	160.2	141
RN 43	Kazabe-Rutsiro (51,757 km)	Sect-1	Kazabe S	242.00	47.00	96.8	143.8	127
		Sect-2	Rutsiro E	180.00	67.00	72	139	122
Total				**19,408**	**5,891**	**7,763**	**13,654**	**12,016**
Estimated Average		69	69	**281**	**85**	**112**	**198**	**174**

38 out of a total of 69 road sections have an AADT below 150.

Estimated Average AADT is 174 and according to the classification, it is in the medium class (150<ADDT<400). However, if we calculate averages for these traffic classes, we get an average AADT of 275 for the medium class and an average of 100 for the low class.

The estimated average AADT is between the two class averages, but closer to the Low class.

We remind here that these data are related to National unpaved Roads, according to the old Network classification and these roads are supposed to have higher traffic volumes than any other classified and unclassified roads of Rwanda.

It is therefore assumed that District Roads and other unclassified roads have lower traffic volumes than those of National unpaved roads.

We can therefore conclude that most of unpaved roads of the Rwandan road network have low volume traffic.

The question is therefore, if these unpaved national and district roads class one are going to be constructed and maintained according to the requirements of the new Road Act before even planning upgrading them to paved roads, how cost effective would it be? We assume that Investment costs related to upgrading (widening) are going to be high and also maintenance is very difficult and costly.

2.3. INTERNATIONAL BEST PRACTICE FOR INVESTING IN UNPAVED RURAL ROADS

Development partners should realize that a 7-meter main road is not required in most rural areas in Sub-Saharan Africa. Some pilots should be supported locally to potentially meet the demand for IMT (although any success may not be replicable in another region or country) [5].

2.3.1. Technical features of road construction and maintenance

A low volume road is considered a road that has relatively low use (an Average Daily Traffic of less than 400 vehicles per day), low design speeds (typically less than 80 kph), and corresponding geometry. Most roads in rural areas are low-volume roads. A well planned, located, designed, constructed, and maintained low-volume road system is essential for community development, flow of goods and services between communities, and resource management activities [14].

Authors of the Best Management Practices also said that poorly planned road systems can have high maintenance and repair costs, contribute to excessive erosion, and fail to meet the needs of the users. The Best Management Practices related to road technical features that have been proposed by these authors include: road planning, road location, road design, road survey, road construction and maintenance.

Road Planning: Road planning and analysis are key to ensuring that a road meets the current needs of the users, that it is not overbuilt, that it minimizes impacts to the environment and to the people along the road, and that it considers future needs of an area. Road Management Objectives (RMOs) help define and document the road purpose standards, and how a road will be used, managed, maintained, and funded, as well as applicable BMPs for the road [14]. The following are therefore some of the BMP's proposed by Gordon Keller & James Sherar, in road planning:

- Do road transportation analysis to determine the optimum road system for an area, user needs, and to evaluate future options;
- Keep minimum road standards consistent with user demands, needs, Road Management Objectives, and public safety.
- Use an Interdisciplinary Team approach to road planning, and coordinate development with local landowners;
- Consider both short-term and long-term access needs of the road users;
- Limit the total area disturbed by minimizing the number, width, and length of roads;
- Use existing roads only if they serve the long-term needs of the area and can be reconstructed to provide adequate drainage and safety; and
- Minimize the number of stream crossings

Road Location: It is much better to have a bad road in a good location than it is to have a good road in a bad location. A bad road can be fixed. A bad location cannot. Most of the investment in the bad road can be recovered, but little, if any, can be recovered from a bad location [14]! In relation to this statement, authors of the BMP's propose the following technical measures:

- Use topographic control points and physical features to control or dictate the ideal location of a road. Use saddles in the terrain, follow ridges, and avoid rock outcrops, steep slopes, stream crossings, etc.
- Locate roads to avoid or minimize adverse affects on water quality and outside of riparian areas and SMZs except at stream crossings. Approach stream crossings at the least gradient possible;
- Locate roads high on the topography to avoid steep inner canyon slopes and provide for more distance between the road and streams;
- Locate roads on well drained soils and slopes where drainage will move away from the road;
- Locate roads to follow the natural terrain by conforming to the ground, rolling the grade, and minimizing cuts and fills;
- Avoid problematic locations such as springs, wet areas, landslides, steep slopes, massive rock outcrops, flood plains, and highly erosive soils;
- Avoid very steep terrain (over 60%) and very flat terrain where drainage is difficult to control.

Road Survey, Design, and Construction:

Road survey, design, and construction are the steps in the process where road user needs are combined with geometric factors and terrain features, and the road is built on the ground. A road or site survey is needed to identify the terrain features, such as drainages, outcrops, and ground slopes, and to add some level of geometric control to a project. A survey may be very simple and accomplished with compass and cloth tape for a rural road or it may be very detailed using instruments and a high level of precision in difficult terrain or for a high standard road.

Elements of design include roadway geometry, design speed, drainage, stream crossing structures, slope stabilization needs, structural sections (materials type, use, and thickness), and road grades**.** Construction involves all aspects of implementation of the design and fitting the project to the ground. A key link between design and construction are the use of *standard plans and drawings* that show how the work should look, and *specifications* that describe how the work is to be done. Another key part of construction is *quality control and inspection* to ensure that the work is done in accordance with the plans and specifications. Some amount of *sampling and testing* is typically specified to ensure that the materials used in construction meet specifications.

Best Practices for road survey, design and construction [14]

General Design

- Use minimum Road Standards needed for safety and traffic use
- Use Standard Plans and Specifications, with Standard Drawings, for most typical construction work. Develop Special Project Specifications and Drawings for unique types of work.
- Construct roads with grades of 12% of less, using short sections of 15% where necessary. On steep roads, drainage is difficult to control.
- Construct the road only wide enough to safely pass the traffic, normally 3.5 to 4.5 meters wide for single lane roads and 5 to 7 meters for double-lane roads. Add turnouts as needed. Minimize the area of clearing.
- Locate roads with a minimum curve radius of 15 meters.

Materials:

- Compact the road embankments, subgrade material, and surfacing materials, particularly in sensitive areas, or allow new roads to “settle” for several weeks before using the road. In wet climates a longer period of time is desirable
- Use road surface stabilization measures, like aggregate or pavements, where needed and as often as possible. Utilize durable materials that will not degrade to fine sediments under traffic

Slopes:

- Typically construct cut slopes on a 3/4:1 or flatter slope. Build fill slopes on a 1½:1 or flatter slope. Revegetate the slopes.
- Typically use balanced cut and- fill construction in gentle terrain. Use full-bench construction on slopes over 65 % and end haul the excavated material to a suitable disposal site.

- In very steep terrain build narrow roads (3-4 meters wide) with turnouts, or use retaining walls as needed. End-haul most excavated material to stable disposal sites. Avoid side-casting

Drainage:

- Outslope road surface 3-5% for road grades less than 10% on stable soils, using rolling dips for cross drainage structures. In slippery soils, either inslope the road or add aggregate surfacing to the road.
- Construct ditches only when necessary. An outsloped road without ditches disturbs less ground and is less expensive to construct.
- Inslope road surface 3-5% with a ditch section for road grades in excess of 10% or in areas with steep natural slopes, erodible or slippery soils, or on sharp turns. Provide cross drainage with culvert pipes or rolling dips.
- Use a crown road section on a wide road with gentle slopes or flat ground to prevent water from standing on the road surface.
- Construct roads with rolling grades to minimize concentration of water
- Provide filter strips or infiltration areas to trap sediment between drain outlets and waterways. Keep roads and streams disconnected
- Use appropriate type an adequately sized drainage structures for natural stream crossings. Design bridges and culverts that are large enough to span the ordinary high water width of flow (bankfull width). Use armoring, headwalls, and trash racks as necessary to protect the structure

Road costs:

Road construction costs are most influenced by the standard of road built particularly road width and type of surfacing, and the steepness of the terrain. Placing a road with cuts and fills on steep cross slopes greatly increases the time of construction, the amount of excavation and earthwork, the areas of clearing and needed revegetation, and adds length to cross-drains and other drainage structures.

Road cost estimates are important in both the planning process and the overall project budgets to ensure that adequate funds are available to properly build the road. Good design and construction techniques require relatively high initial costs but can greatly reduce future maintenance needs and avoid costly failures, repairs, and adverse environmental impacts.

Key cost factors

- Steep side slopes (particularly with wide roads) rapidly increase the quantities of work, including the area involved for clearing and revegetatation, and the amount of excavated material. Thus, steep slopes greatly increase the cost of construction (see *Figure 4.3*and *Table 4.2*)!
- High standard surfacing materials (aggregate, asphalt, etc.) greatly increase road cost -- but also greatly improve user comfort and reduce road surface erosion
- Frequent or large numbers of drainage (stream)crossings greatly increase road costs – but must be used as needed, particularly in dissected terrain
- Steep grades increase long-term maintenance costs of the road

Road maintenance:

Unpaved roads must be maintained during active use, after periodic operations have been completed, and after major storm events, to ensure that the drainage structures are functioning properly. Heavy rainstorms will cause cut slope failures that block ditches, cause water flow on the road surface, and erode the surface and fill slopes. Debris moves down natural channels during heavy rains and blocks drainage structures, causing water to overtop the road and erode the fill. Ruts, washboards, and potholes in the road surface will pond water, weaken the roadway structural section, accelerate surface damage, and make driving difficult, Routine maintenance is needed on any road to keep the road serviceable and its drainage system working properly. A well-maintained road will reduce road user costs, prevent road damage, and minimize sediment production.

How road maintenance will be accomplished should be resolved before the road is built or reconstructed [14].

Best Practices

- Perform maintenance when needed **DO NOT WAIT**! The longer you wait, the more damage will occur and repairs will be more costly
- Keep ditches and culverts free from debris, but maintain an erosion resistant surfacing such as grass or rock in the ditches. Remove debris during inspections. Also keep overflow channels clean.
- Regrade and shape the road surface periodically to maintain proper surface drainage. Keep the road surface moist during grading. Fill in ruts and potholes with gravel or compacted fill as frequently as possible.
- Keep rolling dips shaped and graded. Ideally, compact the final graded road surface
- Apply a surface stabilization material, such as aggregate, cobblestone, or pavement, to the road surface to protect the roadbed from damage and reduce the frequency of maintenance needed
- Avoid widening the road or over-steepening the fill slopes formed by blading surface material off the road
- Close the road during very wet conditions or periods of inactivity
- Inspect the road at regular intervals, especially following periods of heavy rains

2.3.2. Financing Road maintenance

Rural transport networks in most developing countries are underdeveloped and of poor quality. It is estimated that about 900 million rural dwellers in developing countries do not have reliable all season access to main road networks, and about 300 million do not have motorized access at all. At the same time, resources are being spent on upgrading roads to higher than economically justified standards for populations that already have a reasonable level of access. Meanwhile, a more holistic view of rural transport has emerged. Instead of narrowly focusing on roads, it takes into account the provision and affordability of transport services, intermediate means of transport, and the location and quality of services. The sustainable provision of rural transport networks (referred to as rural transport infrastructure, so as to include tracks, paths, and footbridges) crucially depends on appropriate management and financing arrangements, including a sound approach to design and appraisal [13].

Jerry Lebo continues by saying that the design and appraisal of rural transport infrastructure is an urgent task considering evidence that developing countries often adopt excessively high standards of access, particularly when donor financing is involved. Given scarce resources, such an approach raises long-term maintenance costs and denies access to underserved populations. Instead, a basic access approach is recommended, whereby priority is given to the provision of reliable, least-cost, all-season basic access to as many people as possible.

The source of the funds spent on roads may also perpetuate the capital bias we have discerned. The limited evidence available indicates heavy dependence of road investment on official development assistance, ranging from just over 50 percent in Senegal to almost 90 percent in Rwanda. Donors have tended to favor dramatic new construction over mundane maintenance. Moreover, development assistance has proven to be quite volatile, contributing to the erratic pattern of public investment in the sector [16].

A recent review of road funds in Africa suggests that there are several factors which contribute to successful operation [8]. They include:

- *Collecting the revenues*. The road tariff should be collected and deposited directly into the road fund without having to pass through the Ministry of Finance account.
- *Road fund management*. The fund should be managed by a board which includes road user representatives.
- *Setting the tariff level*. There should be a formal mechanism for varying the level of the road tariff.
- *Allocation of funds*. There should be a simple and consistent procedure for allocating funds between the different agencies entitled to draw from the fund.
- *Audit arrangements*. The Fund should be audited by independent auditors, and the works financed through the road fund should be subjected to a full financial and selective technical audit.
-

2.4. CHALLENGES AND GAPS IN ROAD PROJECT PLANNING, INVESTMENT POLICY AND MAINTENANCE STANDARDS

In the previous, we have discussed the current situation in relation to the construction standards, maintenance policies and funding unpaved roads in Rwanda, and if they are compared with International Best Management Practices as presented in the section above, some weaknesses and sometimes malpractices are being noticed:

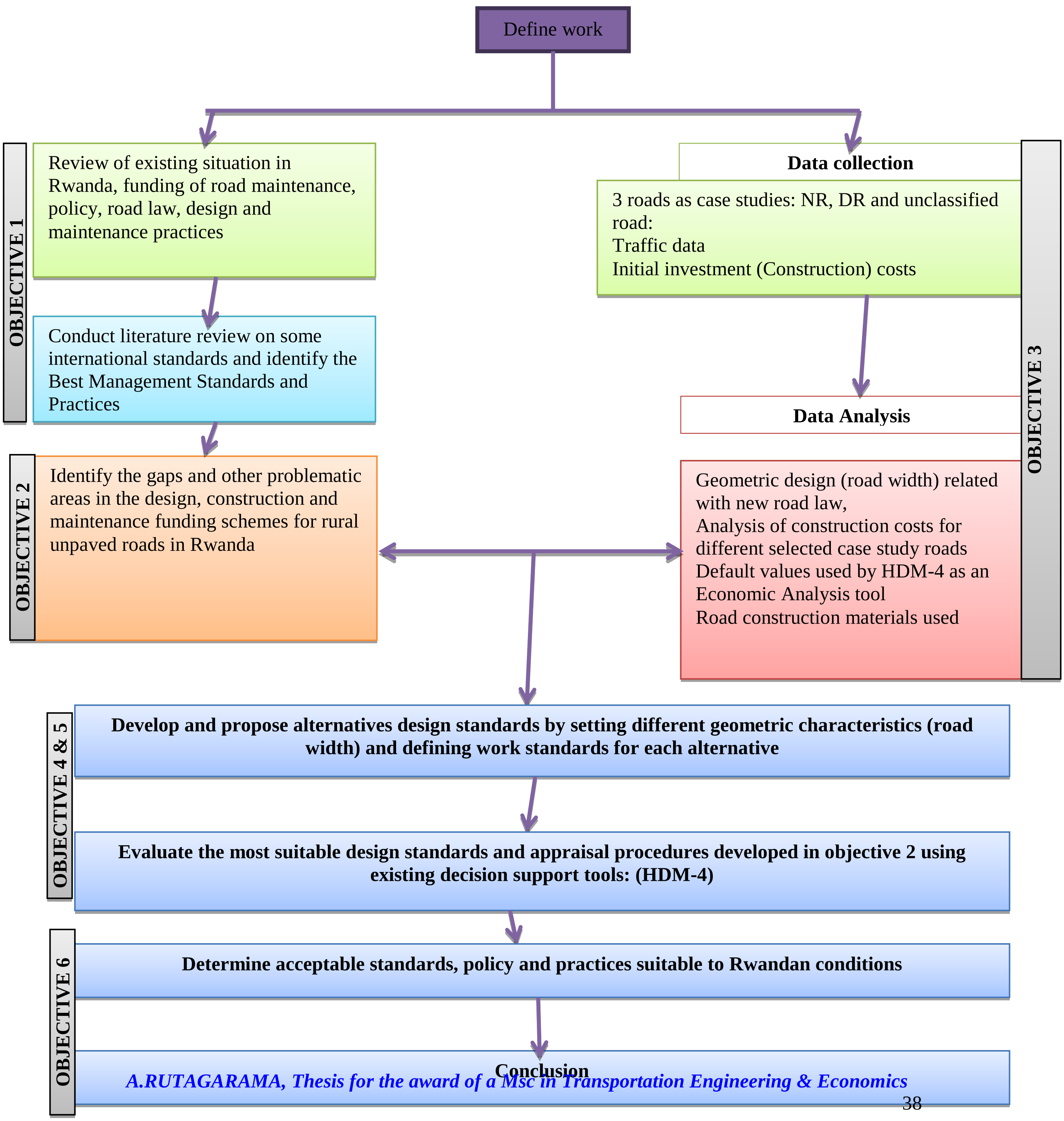
- ***Technical standards:*** provisional classification of the road network under the new Road Law was only based on road functionality and location rather than considering the traffic volume passing through any specific road. For instance, all National roads and District roads shall be constructed with a carriageway width of 7 meters, excluding shoulders, drainage ditches and embankments. The provisions of the new road law will cause widening of many unpaved roads so as to meet the required geometric design and the traffic volume on the majority of these roads was found to be low and even very low. Best Management Practices suggest constructing the road only wide enough to safely pass the traffic, normally 3.5 to 4.5 meters wide for single lane roads and 5 to 7 meters for double-lane roads. It was also noted that the road width together with the type of surfacing, and the steepness of the terrain are the key factors of increasing road construction costs. The problem becomes so complex when the road widening is to be done and the surfacing material is gravel over a road passing through a steep terrain as it is the case for most of roads in Rwanda. Drainage on this type of road is difficult, water will not be quickly evacuated from the road surface and hence, washing away the gravel surfacing material. With this design approach, it is anticipated that not only initial investment cost (road construction cost) will be high, but also maintaining cost will also increase.

- ***Road maintenance funding***: road maintenance funding structure provided in the new roads law in Rwanda is an adequate for reducing shortages in the financing capacity of the Road Maintenance Fund. RMF has been claiming for an increase to her sources of income by reviewing the fuel tax levies, and central government contribution to the fund. However, the main challenges to financing the maintenance of unpaved roads is that the scarce financial resources of RMF are misappropriated and dedicated to new road construction and /or road improvements. This might be a malpractice of revenue collection where road fund pass through the Ministry of Finance before being transferred to RMF account.

CHAPTER 3

RESEARCH METHODOLOGY

Figure 3.1. Research Methodology structure



Definition of works: This Research was about to review and critically analyze the gaps that are being observed in the policies, road laws, engineering standards and practices, appraisal process in the construction, rehabilitation and maintenance of rural unpaved roads in Rwanda, compared to best known international practices.

The main methodological approaches that were used in conducting this Research were of two types:

The first one was the Review of the literature on the existing situation in Rwanda compared to international standards and practices and some gaps that need particular attention were noticed.

The second approach was to collect and analyze data from three different road projects as case studies and this has enabled us to develop other alternatives of design standards and best practices for investing in unpaved rural roads.

Literature Review: The literature Review focuses in its first part on the description of the existing situation in Rwanda related to the funding and expenditures related to rural road construction and maintenance, the provisions of the new road law and many challenges related to its implementation and the discussion on inappropriate practices in rural road design construction and maintenance.

The second part of the Literature Review discusses some known best international practices in rural road engineering that include design, construction and maintenance practices. This part also describes proven efficient methods of appraising rural low volume road investments through a participatory approach.

The last part of the Literature Review captures the gaps and challenges observed in the current situation related to design standards, practices in construction and maintenance of rural unpaved low volume road in Rwanda compared to international techniques and practices developed in the second part of the Literature Review; and thus, this part of the Literature Review has lead us to attain the two first objectives.

Data Collection and Analysis: Data related to traffic, geometric design and recent or planned investments were collected from three different road categories (according to latest road classification of 2008) i.e Byimana – Buhanda – Kaduha (49 km), as a National unpaved rural road, Rwamagana-Zaza (31km), as a District unpaved rural road and Gasiza-Kibisabo-Pinus II (11.305km) in Gishwati Water and Land Management area (132km).

Traffic data helped us to conclude that the case studied roads are of low volume unpaved rural roads; geometric design is somehow dependent to the topographic conditions of the road location (mostly hilly areas) and the implementation of the provisions of the new Road Law especially widening of rural unpaved roads will be cost ineffective in terms of investment and maintenance costs. This will enable us to achieve objective 3 of our research as we will be able to develop and propose alternative design standards that are suitable to Rwandan topographic conditions using the collection and analysis of data from the above mentioned road projects.

Evaluation of the most suitable standards and appraisal procedures:

Using HDM-4 as a decision support tool, we will be able to evaluate or test the cost effectiveness of the developed and proposed design standards, construction and maintenance practices and appraisal procedures. This will help us to determine acceptable standards, policy and practices suitable to rwandan conditions as per our objective no 4 and 5.

This will also help us to test if or not, using the determined acceptable standards, policy and practices can help Rwanda to build and maintain more rural unpaved roads within the same investment limits according objective no 6.

CHAPTER 4

ANALYTICAL TOOL AND DATA REQUIREMENTS

4.1. INTRODUCTION

"Obviously, some significant differences exist in roads needs and design details in varying geographic areas. At times, unique solutions are needed. Mountainous regions typically have steep slopes and cold region conditions; deserts have little moisture to support vegetative erosion control measures but have brief, intense rainfall; jungles often have poor soils and drainage problems; high valley regions have dissected, steep terrain and difficult drainage crossings, and so on"[14]. The authors of the Low Volume Roads Engineering, Best Management Practices (BMP) Field Guide concluded the above statement by saying that the basic road planning, location, design, maintenance concepts and select BMPs apply to any area.

Rwanda is generally considered as a hilly and mountainous country, but this relief is altered and significantly changing from South to North and from East to West.

The western and northern parts of Rwanda are mainly winding and undulating and have more rainfalls with low temperature compared to the Eastern and southern parts of the country, which are relatively bendy and gently undulating with less rainfalls and high temperature variations.

This chapter discusses the main road data that are necessary to conduct economic analysis for selected case studied roads.

4.2. ANALYTICAL TOOL (HDM-4)

Road investment models simulates the relationship between pavement construction standards, maintenance standards and the effects of the environment and traffic loading in order to predict annual trend in road condition. These elements, together with the geometric standards of the road, have a direct effect on vehicle speeds and on the costs of vehicle operation and accident rates on the road.

HDM-4 as the analytical tool

For this research, HDM-4 Version 1.3 was used as the analytical tool.

The HDM-4 analytical framework (HDM-4 Documentation Volume 4, 2000) is based on the concept of pavement life cycle analysis, which is typically 15 to 40 years. This is applied to predict road deterioration, road works effects, road user effects and socio-economic and environmental effects. The analysis considered a pavement life cycle of 15 years, assuming that 15 years after widening of the selected unpaved roads, they will be upgraded from unpaved to paved roads.

After constructing any road, its pavement is subjected to deterioration as a consequence of many factors and they are mostly but not limited to the following: traffic volume and loading, pavement design, types of construction materials, construction quality, environmental weathering and the effect of inadequate drainage systems.

The rate of pavement deterioration has a direct correlation with the standards of maintenance applied to repair defects on the pavement surface or to maintain the structural integrity of the pavement and thus enabling the road to carry traffic in accordance with its design function. It is therefore clear that in addition to the capital costs of road construction, the total costs that are incurred by road agencies/governments will depend on the standards of maintenance and improvements applied.

The impacts of the road condition together with the road design standards on road users are usually measured in terms of Road User Costs (RUC); and other social and environmental effects. RUC include: Vehicle Operation Costs (i.e fuel, tyres, depreciation, etc), the costs of travel time for both passengers and freight due to road condition and traffic congestion and the costs to the economy resulting from road accidents (i.e loss of life, injury to road users, damage to vehicles and roadside objects).

Social and environmental effects comprise: vehicle emissions, energy consumption, traffic noise and other welfare benefits to the population served by the roads.

For economic analysis, total costs incurred by the Road Agency/Government and those incurred by the Road Users, are added together over time in discounted present values. Total economic benefits are therefore calculated by comparing the total cost streams for all maintenance and construction alternatives with a Base case or "Without investment" option scenario.

In this Research, economic benefits were calculated as the difference between the "Without Project" scenario (Maintaining roads with existing road width) and "With Project" option (Widening selected roads to the required width by the new Road Law).

HDM-4 Configuration and Model Calibration

HDM-4 is designed to be used in a wide range and various environments all over the world. It therefore needed to be configured to reflect the Rwanda road characteristics. For all case studied roads under this research, the following data were configured and defined in the customized HDM-4 Workspace.

- Speed-flow type : Two lane standard
- Traffic flow pattern: Inter-urban
- Climate zone: Tropical humid
- Currencies: US Dollars

The process of calibration aims at improving the accuracy of predicted pavement performance and vehicle resource consumption. A fundamental assumption made prior to using HDM-4 is that the pavement performance models will be calibrated to reflect the observed rates of pavement deterioration on the roads where the models are applied.

The calibration exercise was based on desk study. The calibration data used were obtained from the Ministry of Infrastructure, Rwanda (2010) and the HDM-4 default data was considered adequate to achieve the accuracy required. Besides, a detailed sensitivity analysis was conducted to test the robustness of the analysis results.

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

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

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

- Field surveys on the proposed case studied roads
- Rwanda Transport Development Agency
- Ministry of Infrastructure
- Previous studies conducted in various parts of the country
- Internet literature review
- HDM-4 parameter default values

4.3. DATA REQUIREMENTS FOR ECONOMIC APPRAISAL OF ROAD PROJECTS

The required sets of data to describe the roads under study using HDM-4 are the following:

- ***Road class***: road or sections are classified according to a functional hierarchy. HDM-4 provides the following 3 road classes: primary or trunk class, secondary or main class and tertiary or local class.
- **Speed flow characteristics (speed-flow type)**: this reflects the effect of traffic volumes on speeds so that it is possible to determine the economic consequences of road capacity improvements. Though this input data is required for running the programme, it is not an important data since our road sections under project analysis are rural low volume roads.
- ***Hourly traffic distribution (traffic flow pattern):*** This helps to take account of the differing levels of traffic congestions at different hours of the day, and on different days of the week and year.
- ***Intersection type*** as the type and complexity of interchanges along a road has a direct impact on the number and severity of road accidents. This data is typical suited to urban roads where much congestion is expected, especially at junction levels.
- ***Climate zone data:*** The climate in which the road section is situated has a direct impact on the road deterioration and affects to some extent the road user costs. Important climatic factors to be considered for project analysis are temperature, precipitation and winter condition, but the later is not applicable to Rwandan conditions; while the former factors differ from different regions of the country.
- ***Traffic level:*** Traffic volume expressed in terms of mean AADT is a useful data for Project Analysis as it has a direct impact on the pavement deterioration modeling and it is also the basis of calculation of the Road user costs.
- ***Road geometry:*** Road geometry is defined in terms of parameters that reflect the horizontal and vertical curvature: average rise plus fall (m/km), number of rises and falls per kilometer (no/km), average horizontal curvature (deg per km), and super elevation (at bends) which can be calculated as $e = 0.017*C$ for unsealed roads; where:

e = Superelevation at bends (%)

C = Average Horizontal Curvature

Road geometry class is in general an important input data for an economic analysis of a project because the Road works Standards will mainly depend upon the geometric design of the road i.e width, shoulders, horizontal curvatures, embankment slopes etc y and hence have a direct impact on project initial investment cost as well maintenance cost of the road projects. The following data are also defined with the road geometry class: Speed limit (Km/h), Speed limit enforcement factor (the ratio of mean speed to posted speed limit), the speed reduction factors for NMT, MT and road side friction factor.

As stated above, the topography of Rwanda varies much from location to location: for example on section 2 (Buhanda – Kaduha) of one of our case study roads, the road crosses a terrain with an altitude ranging from 1800m to 2700m over a total length of 29km. This implies not only a high average rise plus fall (m/km) but also this kind of topography results into a large number of rises and falls per kilometer (no/km) and the average horizontal curvature (deg per km) is high due to steep slopes that are often avoided for road alignment.

- ***Pavement structure and strength:*** for unsealed roads, structural adequacy and surface condition are represented by the thickness of the surfacing material (gravel) and the quality of the sub grade material. The following data are required for the surface material: maximum particle size (mm), % passing 2.0mm sieve, % passing 0.425mm sieve, % passing 0.075mm sieve and the plasticity index (%); and the same data are also required for defining a subgrade material.

Table 4.1: Default Surface material for unsealed roads used in HDM-4

S/No	**Surface Material**	**Detailed data**				
		Max particle size (mm)	**% passing 2.0 mm sieve**	**% passing 2.0 mm sieve**	**% passing 2.0 mm sieve**	**Plasticity Index in %**
1	Lateritic Gravels	21.9	51.1	41.6	25.5	10.1
2	Quartzic Gravels	23.8	57.5	44.6	24.2	9.1
3	Volcanic Gravels	25	49.3	38.0	23.5	17
4	Coral Gravels angular	21	64.3	49	25	13
5	Earth	4.8	90.5	84.9	70.2	15.8

Source: HDM-4, Volume 2, Part D

Table 4.2: Default Sub grade materials used in HDM-4 (based on Casagrande Soil Classification) for unsealed roads

S/No	Sub grade Material	Detailed data				
		Max particle size (mm)	% passing 2.0 mm sieve	% passing 2.0 mm sieve	% passing 2.0 mm sieve	Plasticity Index in %
1	Well-Graded gravel sands with small clay content, GC	13	60	40	18	15
2	Gravel-Sand mixtures with excess of fines, GF	17	46	34	23	17
3	Sands with excess fines, SF	12	88	68.5	27	8.3
4	Clayey silts (inorganic), CL	10	88	77	54	17.5
5	Clays (inorganic) of medium plasticity, CI	8	83.5	77	59	18.8
6	Clays (inorganic) of high plasticity, CH	4	86.3	81.5	74	34.3

Source: HDM-4, Volume 2, Part D

- ***Road condition:***

Road condition data are usually described by the following:

- *Ride quality* which is an indication of the roughness of the road. It is a parameter that indicates the road condition and maintenance needs, and it is used for predicting vehicle operating costs. It is expressed in terms of roughness IRI (m/km) and it is assigned by road class:

Table 4.3: Default values for ride quality for unsealed roads

Road Class	Ride Quality (m/km IRI)			
	Good	Fair	Poor	Bad
Primary or Trunk	4	6	8	10
Secondary or Main	6	9	12	15
Tertiary or Local	8	12	16	20

Source: HDM-4, Volume 2, Part D

- *Surface condition:* It is a modeling of a number of distress modes. For unpaved roads, surface condition and structural adequacy are both related to the traffic level and are represented by the thickness of the gravel surfacing. Qualitative measures are usually used (new, good, fair, poor, bad etc) to describe the surface condition and for each qualitative measure, and for each of the pre- defined traffic band, a gravel thickness can be defined.

Table 4.4: Default Gravel Thickness (mm) for surface condition of unsealed roads

Traffic band	Surface condition			
	Good	Fair	Poor	Bad
High	200	150	100	50
Medium	150	100	50	25
Low	100	50	25	0

Source: HDM-4, Volume 2, Part D

- ***Surface texture****:* It gives an indication of the texture depth and skid resistance of the surface. At aggregate data level, surface texture can be defined by a qualitative measure (for example: good, fair, slippery etc.*).* For the current version of HDM-4, these parameters are modeled only for bituminous pavements and hence these types of data are not relevant to unpaved rural roads under our case studies.

- ***Pavement history:*** this is expressed by data related to pavement construction quality and for unpaved roads; the default construction method is usually set as ***mechanical***. Other input data related to pavement history like the pavement age and pavement previous condition are most required for paved roads.

- ***Miscellaneous:***

Project economic analysis using HDM-4 miscellaneous data requirements concerns mainly the road shoulders and drainage conditions: number of shoulders, type of shoulders (paved or unpaved) and ESTEP (difference in elevation between the carriageway and the shoulder which is 15mm by default) are the main input data related to road shoulders. Drainage qualitative data are used to describe the Drainage Factor (DF) that is used for modeling the deterioration of the carriageway due to poor conditions of the drainage system.

4.4. SELECTED ROAD PROJECTS

The above mentioned data are if well defined for a project analysis, enough to run an economic analysis using HDM-4 and get all required reports for analysis.

However, since our main aim is to prove the cost effectiveness of some of our construction and maintenance techniques in relation with our standards and/or roads law, it is important to review construction costs related to three roads that were selected to form our case studies.

According to the recent road classification done in 2005, the case studied unpaved road include a National Road (Buhanda-Byimana-Kaduha: 49km) located in Southern Province, a District Road (Rwamagana-Karembo: 28km) located in Eastern Province and an Unclassified road (Gasiza-Kibisabo-Pinus II : 11.303 km) located in Western Province. As explained before in the Literature Review, the new adopted Roads Law will significantly change the classification, where for instance the Unclassified road (Gasiza-Kibisabo-Pinus II : 11.303 km) will become a District Road class one and it should be widened to a carriageway of 7 meters.

It is for this reason therefore, we wanted to highlight the construction costs (investment costs) related to this widening compared to the base scenario of keeping the existing road width.

However, this initial investment alone cannot prove that investments made in widening the roads to the new standards are justified or not before estimating the cost of maintenance works after road widening compared to the base scenario. To achieve our objectives, it is important to have accurate traffic data for the selected road projects because they are used in all 4 sets of HDM-4 models (Road Deterioration, Work Effects, Road User Effects and Social and Environmental Effects).

The required traffic data for an economic analysis using HDM-4 are the following:

- ***Traffic categories including normal, diverted and generated traffic***

The Highway Development and Management Series, Volume 4, Part B defines related traffic terms as follows: *Normal traffic* can be defined as traffic that would pass the project road if no investment took place including normal traffic growth over the considered road section; *Diverted traffic* is defined as traffic that changes from another route or another transport mode to the road section under analysis, but travels between the same origin and destination; whereas *generated traffic* is defined as additional traffic that occurs in response to the road investment. It arises either because the journey becomes more attractive, because of a cost or time reduction or because of the increased development that is brought about by a road investment.

- ***Traffic composition , volumes and growth rates:***

Traffic composition is defined as the proportions of the different vehicle types that use the road. This data is useful as all vehicle types do not cause the same effects to road deterioration, gas emissions etc and specifically traffic composition data can help in any project analysis like but not limited to predicting pavement deterioration, estimation of vehicle operating costs, estimation of travel time, predicting of vehicle exhaust emissions, calculation of energy use, and overall economic project analysis.

Traffic volumes are expressed in terms of Annual Average Daily Traffic delivered from short traffic counts on each section of the road project under analysis.

Traffic growth rates are defined using different growth types i.e annual percentage increase, annual incremental increase and actual AADT followed by another growth period.

Traffic data used for economic analysis of Byimana – Buhanda - Kaduha unpaved road (49km) were directly drawn from the Final Report on Traffic count survey that was produced by ITEC Engineering Ltd and submitted to RTDA in November 2012.

For the project of the Rehabilitation Rwamagana –Zaza unpaved road (31km), we have conducted our own traffic counts and have determined the required traffic data for economic analysis of this particular road project.

The Rehabilitation of Gasiza-Kibisabo-Pinus II unpaved road (11.305km) was taken as a case study in the Gishwati Project Area. Traffic in this project area was evaluated by the consultant to be very low as a T1 class as classified by the Practical Guide to Design in Tropical Countries (CEBTP) 1984). This resulted in general as most of the roads sections were new and no traffic counts were possible on one hand, and on the other hand, the traffic is expected to increase due to diverted and generated traffic as a result of Gishwati road network investment and it is difficult estimate accurately these traffic categories.

The adopted T1 class represents up 50 AADT and this is similar to the very low class of up to 50 ADT as classified by ITEC Engineering Ltd.

We have therefore adopted this value of 50 AADT for this particular project analysis and a traffic composition will be assumed based on similar road sections of same traffic volume and similar socio economic activities.

4.4.1. Rehabilitation of Byimana-Buhanda-Kaduha gravel road (49km)

4.4.1.1. Consistence of road works

The project consisted in the periodic maintenance of Byimana-Buhanda-Kaduha (49km) in the Southern Province of Rwanda and the works started in July 2010. The works consisted in the following main road works:

- Site Mobilization
- Surveying works
- Preliminary works : Bush clearing, Trees cutting , Roots removal, top soil stripping, water and electricity networks relocation
- Earthworks including: Cutting to spoil in soft and rocky ground, bad soil drain off, Removal of landslides, backfilling with borrowed material, Leveling, compaction and finishing of the road sub grade;
- Carriageway: wearing course in lateritic gravel and extra cost for transport of material over 5km
- Drainage works: earth drainage channels(29,720 meters), masonry drainage channels (14,138 meters), RCC Culverts of 80cm dia (764 meters), RCC Culverts of 100cm dia (65 meters), headwalls and various structures in stone masonry, retaining walls in gabions (1287m3), etc.
- Various works in stone masonry and concrete: stone masonry abutments, vehicle crossing slabs in RCC.
- Grass planting and intercepting ditches
- Road vertical signing
- Culverts and bridges: construction of 16 box culverts in RCC, construction of 1 RCC small span bridge and rehabilitation of 8 existing bailey and RCC bridges.
- Improvement and development of a big ravine

4.4.1.2. Cost of road works

Table 4.5 below outlines the final Bill of Quantities related to the periodic maintenance of a National unpaved Road (Byimana – Buhanda – Kaduha: 49 Km) in the Southern Province.

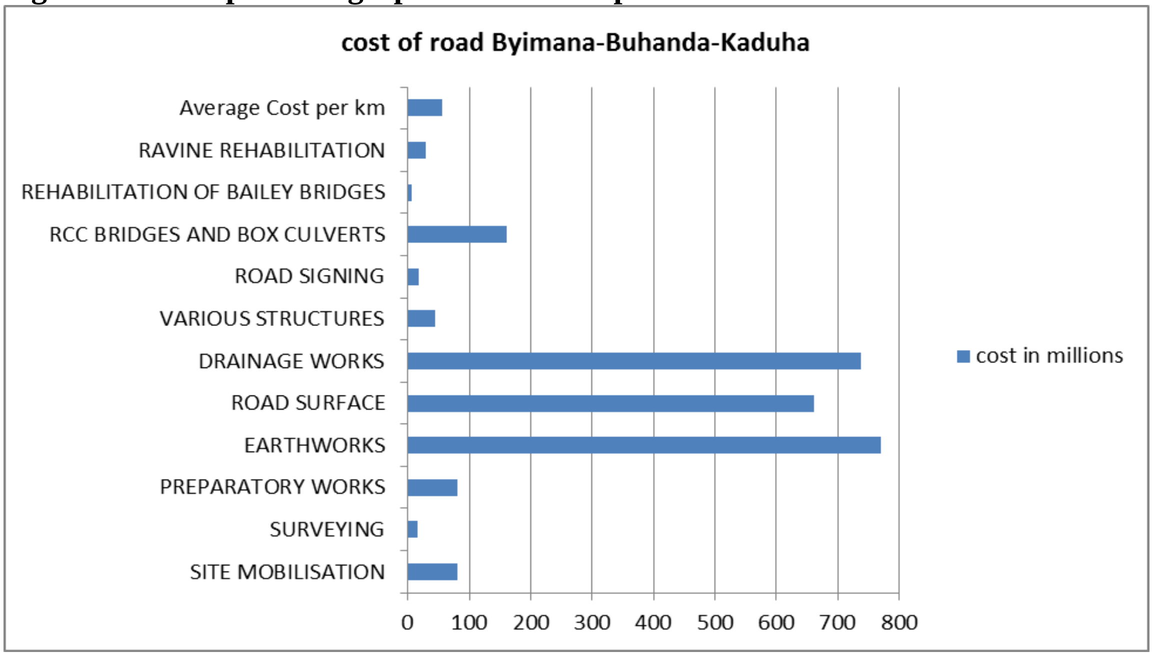
Table 4.5: Summarized cost of works CS1

Price No	Activity	Cost (Rwf)
I	**ROAD WORKS**	
100	SITE MOBILISATION	80, 000,000
200	SURVEYING	15, 000,000
300	PREPARATORY WORKS	80,683,428
400	EARTHWORKS	769,696,500
500	ROAD SURFACE	662,180,000
600	DRAINAGE WORKS	738,345,900
700	VARIOUS STRUCTURES	44,950,000
800	ROAD SIGNING	17,640,000
	SUB TOTAL I	**2,408,495,828**
II	**CIVIL STRUCTURES**	
A	RCC BRIDGES AND BOX CULVERTS	160,877,203
B	REHABILITATION OF BAILEY BRIDGES	6,000,000
	SUB TOTAL II	**166,877,203**
III	**RAVINE REHABILITATION**	
	SUB TOTAL III	**28,584,900**
	GRAND TOTAL FOR THE PROJECT	**2,603,957,931**
	Average Cost per km	**55,403,360 ***

Source: Hycogec (2011)

* Average cost was calculated using a total road length of 47km due to the reason that there was a road section of 2km (from Chainage 18+300 to Chainage 20+300) that was not included in this Project as it was recently constructed in another project.

Figure 4.1: Comparative graph for different post of works CS1



- Average cost of 55,403,360 Rwf (Approximatively 85,250 usd per km) for a periodic maintenance intervention is too much for a gravel road.

- If we refer to Table … above, construction cost for some posts of work seems to be on a higher side if the type of intervention is periodic maintenance:

- Earthworks: some sections of the road needed widening as the required width of 6m was not available and this has brought in considerable volumes of earthworks.
- Drainage works: the whole project had only earth drainage channels; it was then necessary to upgrade those earth channels to stone masonry ditches where road geometrical characteristics (longitudinal slope, superelevation…) were so demanding. Many new pipe culverts were also supplied and installed.
- Civil structures including new RC bridges construction, construction of new box culverts in RC and rehabilitation of many RC bridges and bailey bridges

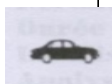
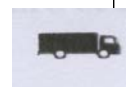
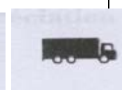
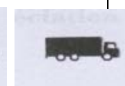
Considering the average cost per kilometre and the nature of the works done, the project can neither be taken as a periodic maintenance nor Regravelling, but it is simply a Reconstruction phase of the road, which includes road widening where the width of 6m does not exist.

For data analysis, we will therefore consider for the Base Scenario, the reconstruction of Byimana-Buhanda- Kaduha (49km) with a minimum width of 6m.

4.4.1.3. Traffic Data

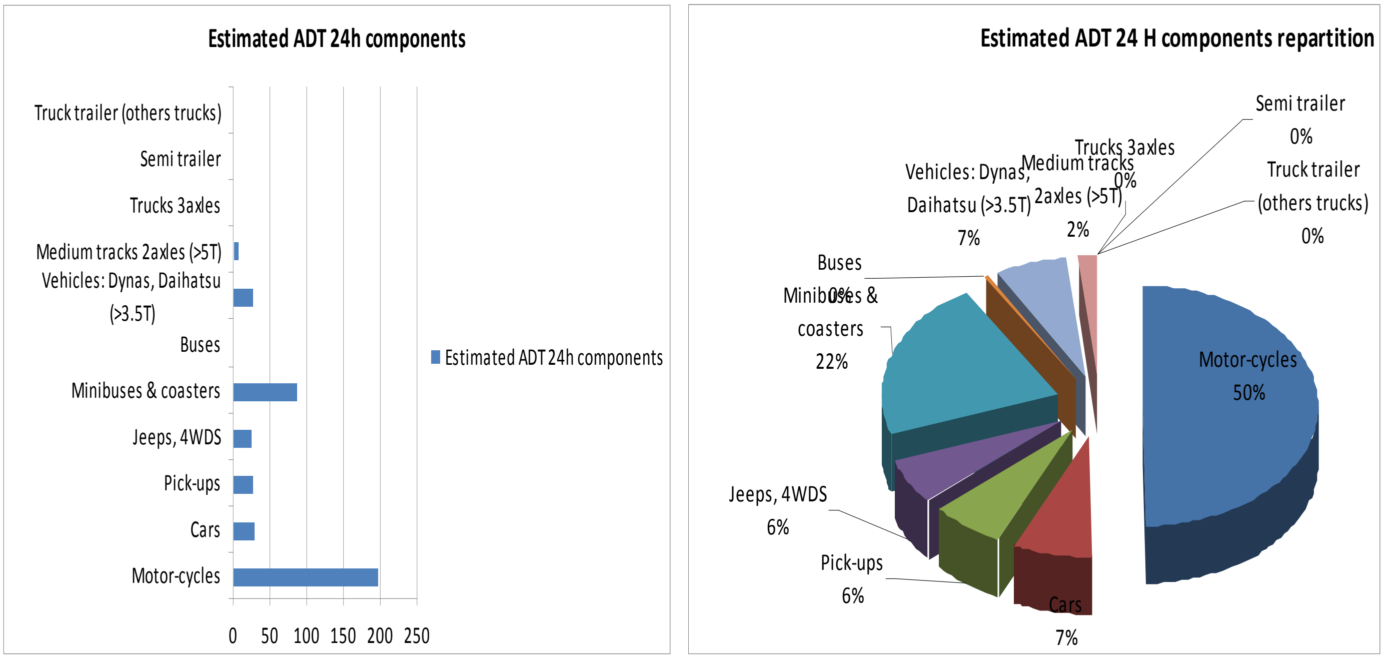
This project is composed of two sections of NR 32 due to traffic volume differences on those sections.

Figure 4.2: Traffic data on RN 32 Byimana – Karambi (both directions)

Times (days)	**Motor-cycles**	**Cars**	**Pick-ups**	**Jeeps, 4WDS**	**Minibuses & coasters**	**Buses**	**Vehicles: Dynas, Daihatsu (>3.5T)**	**Medium tracks 2axles (>5T)**	**Trucks 3axles**	**Semi trailer**	**Truck trailer (others trucks)**	**TOT without motorcycles**	**TOT(All vehicles included)**
													
Monday	152	11	10	9	76	3	23	2	0	0	0	134	286
Tuesday	121	10	29	35	85	0	29	4	0	0	0	192	313
Wednesday	121	11	22	19	75	0	13	11	0	0	0	151	272
Thursday	115	7	23	18	66	0	19	8	0	0	0	141	256
Friday	171	19	21	19	68	2	14	0	0	0	0	143	314
Saturday	199	55	22	26	74	0	7	0	0	0	0	184	383
Sunday	164	46	14	29	105	0	13	3	0	0	0	210	374
Total	1043	159	141	155	549	5	118	28	0	0	0	1155	2198
Average	149	23	20	22	78	1	17	4	0	0	0	165	314
Wednesday Night	46	6	5	2	7	0	10	2	0	0	0	32	78
WEDNESDAY 24H	167	17	27	21	82	0	23	13	0	0	0	183	350
Estimated ADT 24h components	**195**	**29**	**25**	**24**	**85**	**1**	**27**	**6**	**0**	**0**	**0**	**197**	**392**
ADT 24h with PMS August Seasonal Factor (0.88)	**172**	**26**	**22**	**22**	**75**	**1**	**24**	**6**	**0**	**0**	**0**	**170**	**342**
AADT (Applying PCU values)	**69**	**26**	**22**	**22**	**82**	**2**	**36**	**9**	**0**	**0**	**0**	**190**	**259**

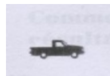
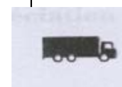
The consultant opted for using a Seasonal Factor (SF) based on the Premium Motor Spirit (PMS) consumption data due to the reasons that motorcycles components are high and they exclusively use PMS on one hand, and on the other hand, major part of Automotive Gasoil (AGO) consumption in Rwanda is used in generators (EWSA) for energy production and not in road transport sector.

Figure 4.3: Traffic composition on RN 32 Byimana – Karambi (both directions)



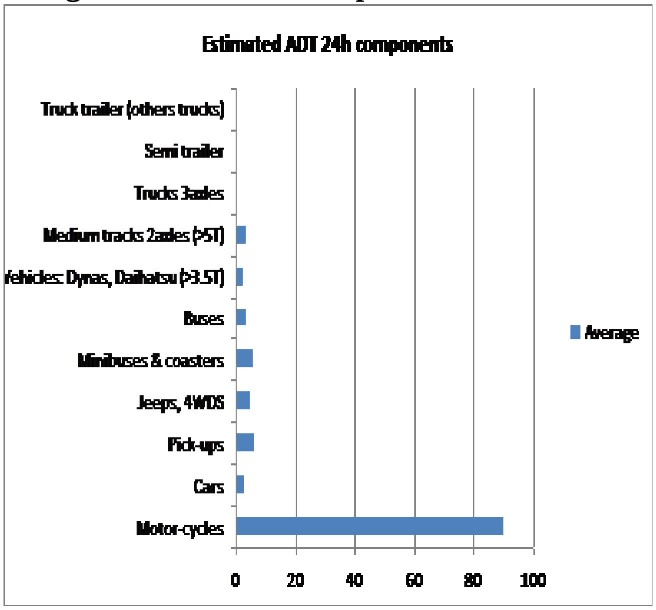
Source: ITEC Engineering (2012)

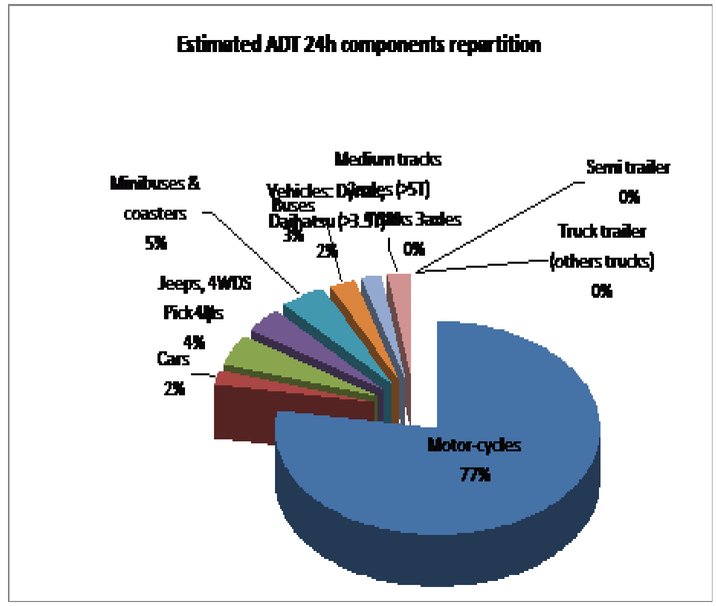
Figure 4.4: Traffic data on RN 32: Karambi-Kaduha (both directions)

	Motor-cycles	Cars	Pick-ups	Jeeps, 4WDS	Minibuses & coasters	Buses	Vehicles: Dynas, Daihatsu (>3.5T)	Medium tracks 2axles (>5T)	Trucks 3axles	Semi trailer	Truck trailer (others trucks)	TOT without motorcycles	TOT(All vehicles included)
Times (days)													
Monday	94	2	8	2	8	1	0	0	0	0	0	21	115
Tuesday	82	2	11	8	8	5	4	4	0	0	0	42	124
Wednesday	86	0	7	3	6	3	5	0	0	0	0	24	110
Thursday	95	0	5	2	0	3	2	4	0	0	0	16	111
Friday	89	1	4	7	5	2	2	7	0	0	0	28	117
Saturday	88	7	4	3	2	4	0	0	0	0	0	20	108
Sunday	93	5	0	4	8	3	1	6	0	0	0	27	120
Total	**627**	**17**	**39**	**29**	**37**	**21**	**14**	**21**	**0**	**0**	**0**	**178**	**805**
Average	90	2	6	4	5	3	2	3	0	0	0	25	115
Wednesday Night	17	0	0	0	2	1	2	2	0	0	0	7	24
WEDNESDAY 24H	103	0	7	3	8	4	7	2	0	0	0	31	134
Estimated ADT 24H component	**107**	**2**	**6**	**4**	**7**	**4**	**4**	**5**	**0**	**0**	**0**	**32**	**139**
ADT 24h with PMS August Seasonal Factor (0.88)	**94**	**2**	**5**	**4**	**6**	**3.5**	**3.5**	**4.4**	**0**	**0**	**0**	**28**	**122**
AADT (Applying PCU values)	**38**	**2**	**5**	**4**	**6**	**7**	**5**	**7**	**0**	**0**	**0**	**36**	**74**

Source: ITEC Engineering (2012)

Figure 4.5: Traffic composition on RN 32 Karambi - Kaduha (both directions)





Source: ITEC Engineering (2012)

4.4.2. Rehabilitation of Rwamagana-Zaza gravel road (31km)

The project consists in the Rehabilitation of Rwamagana-Zaza (31km) located in Eastern Province. Before undertaking construction works, the Road Agency produced approximate Bill of Quantities based on rough estimates resulting from field road surveys which means that no detailed technical studies were conducted before works.

After contracting the works, the client (Road Agency) hired a consultant firm and its first mission was to conduct quick studies, update and approve the Bill of Quantities before the Contractor could proceed with the execution of works.The estimated quantities produced by the client and contained in the Tender Documents were produced in consideration of a 6m road width; but after signing the contract, the new road law was published. The Road Agency has therefore instructed the Consultant to review the project by implementing the provisions of the new law No. 55/2011 of 14/12/2011 related to the standards of road construction in Rwanda; thus the road width was to be of 7m of carriageway, 1m of shoulder on each side of the roads plus other road side works including drainage channels as per cross sectional profile.

4.4.2.1. Consistence of road works

- Site Mobilization
- Surveying works before, during and after completion of works
- Preliminary works : trees cutting without removing roots, removing roots of trees, clearing of undergrowth-cleaning of road surface, top soil stripping, Relocation of water pipes, electrical cables and fiber optic, demolition of existing masonry and concrete structures
- Earthworks including: excavation and haulage, cuts and fills, rocky excavation, scarification, compaction and completion of the sub grade etc.
- Roadway: wearing course in lateritic gravel and extra cost for transport of material over 5km
- Drainage and crossing works: Supply and installation of concrete culverts of 80cm and 100cm diameters, earth drainage channels, stone masonry drainage channels, headwalls and various structures in stone masonry, retaining walls in gabions, intercepting ditches etc.
- Various works in stone masonry and concrete: stone masonry abutments, vehicle crossing slabs in RCC and repairs on existing bridges.

- Grass planting and Rising the heights of Cyaruhogo and Gisaya dykes

4.4.2.2. Cost of road works

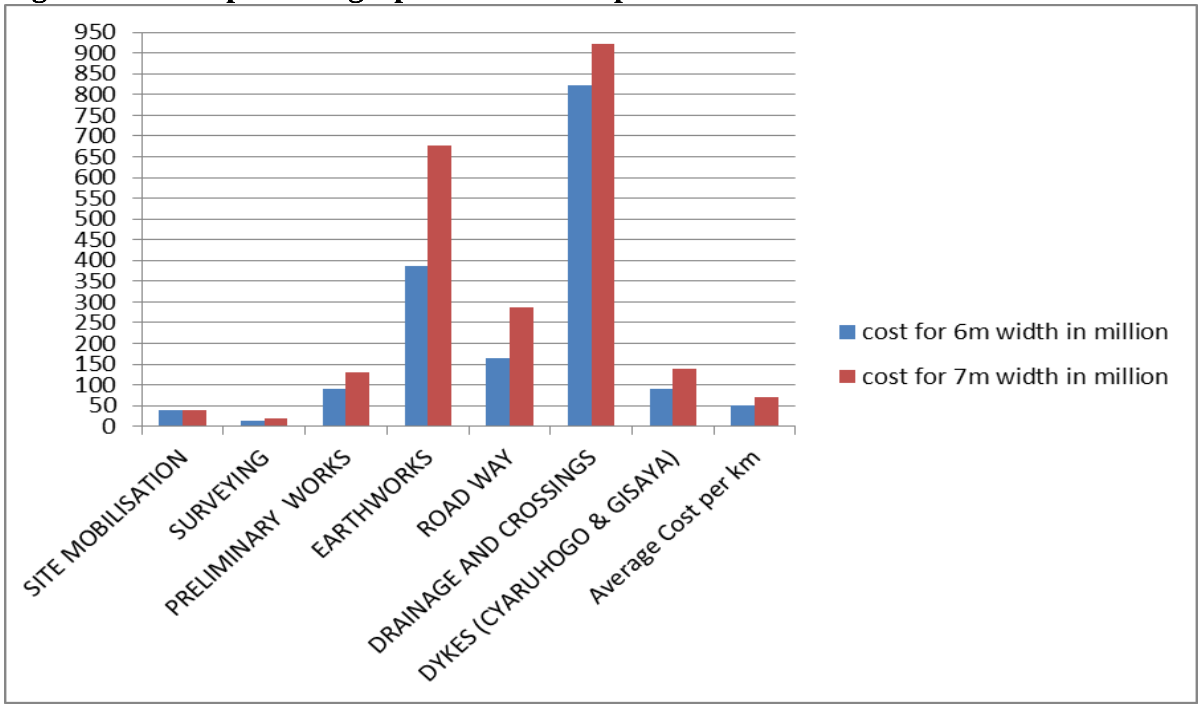
Table 4.6 below outlines the final Bill of Quantities related to the periodic maintenance of a District unpaved Road (Rwamagana - Zaza: 31 Km) under the old road classification in the Eastern Province.

Table 4.6: Summarized cost of works CS2

Price No	Activity	Cost in Rwf (for 6m width)	Cost in Rwf (for 7m width)
100	SITE MOBILISATION	40, 000,000	40, 000,000
200	SURVEYING	15, 000,000	18,600,000
300	PRELIMINARY WORKS	91,469,200	129,170,600
400	EARTHWORKS	388,044,500	677,543,700
500	ROAD WAY	165,036,000	287,622,000
600	DRAINAGE AND CROSSINGS	822,482,200	923,242,000
700	DYKES (CYARUHOGO & GISAYA)	91, 469,200	138,760,000
	GRAND TOTAL FOR THE PROJECT	**1,613,501,100**	**2,214,938,300**
	Average Cost per km	**52,048,423**	**71,449,623**

Source: Hycogec consultant (2012)

Figure 4.6: Comparative graph for different post of works CS2



Source: Author's calculations

- Average construction cost per km is 52,048,423 Rwf if it was to maintain the existing road width of 6m; while the average construction cost per km is 71,449,623 Rwf after widening the road by 3m; giving an increase of around 37.28% in the initial investment cost.
- Considering the nature of works done as described above and the calculated average cost per kilometre, the project was not a periodic maintenance but rather, it is full rehabilitation or reconstruction of Rwamagana – Zaza road (31 km).
- The Base scenario for our data analysis will be therefore reconstruction of Rwamagana – Zaza road (31 km) by maintaining a width of 6m
- Though it is clear that widening the road has direct financial impacts (increase of 37.27%) in total initial investment cost, it is necessary to test the Net Present Value so that other economic benefits for different road stakeholders can be analysed.
- Investment efficiency should not be looked at only initial investment cost because regular and basic maintenance of feeder roads is required; otherwise reconstruction works are to be expected at shorter intervals. The question is therefore, how cost effective is to maintain a rural unpaved road of an overall width of 9m like as it is the case for Rwamagana – Zaza gravel road (31Km)

4.4.2.3. Traffic Data

Figure 4.7: Traffic data on *DR 28* Rwamagana - Karembo Station:Kabilizi Total Summary for both directions

days	Motor-cycles	Cars	Pick-ups	Jeeps, 4WDS	Minibuses& coasters	Buses	Light Goods vehicles: Dynas, Daihatsu (<5T)	Medium tracks 2axles (>5T)	Trucks 3axles	Semi trailer	Truck trailer (others trucks)	TOT without motorcycles	TOT(All vehicles included)
Manday	126	3	27	6	4	0	19	0	6	2	0	67	193
Tuesday	102	5	21	8	1	0	6	0	4	0	0	45	147
Wednesday	95	3	13	10	0	0	9	3	5	1	0	44	139
Thursday	104	6	28	14	1	0	20	1	6	1	0	77	181
Friday	98	0	17	8	2	0	5	0	5	1	0	38	136
Saturday	147	13	21	7	7	0	11	0	4	1	0	64	211
Sunday	131	7	19	12	8	0	9	0	3	1	0	59	190
Total	803	37	146	65	23	0	79	4	33	7	0	394	1197
Average	115	5	21	9	3	0	11	1	5	1	0	56	171
Thursday night	43	6	20	7	6	0	13	1	5	3	0	61	104
Thursday 24H	147	12	48	21	7	0	33	2	11	4	0	138	285
Estimat ADT (24H)COMPO	158	11	41	16	9	0	24	2	10	4	0	117	275
ADT 24h with PMS June Seasonal Factor (1.01)	159	11	41	16	9	0	25	2	10	4	0	118	278
AADT (Applying PCU values)	64	11	41	16	14	0	37	2	20	8	0	150	214

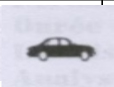
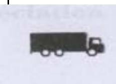
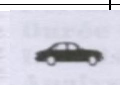
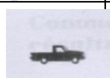
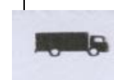
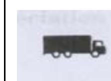
	Motor-cycles	Cars	Pick-ups	Jeeps, 4WDS	Minibuses & coasters	Buses	Light Goods vehicles: Dynas, Daihatsu (<5T)	Medium tracks 2axles (>5T)	Trucks 3axles	Semi trailer	Truck trailer (others trucks)	TOT without motorcycles	TOT(All vehicles included)
Days													
Manday	320	4	13	8	3	0	8	0	2	1	0	39	359
Tuesday	404	4	7	4	8	0	8	2	0	0	0	33	437
Wednesday	337	3	7	5	18	2	11	1	1	1	0	49	386
Thursday	372	6	12	11	0	0	11	3	2	1	0	46	418
Friday	397	2	17	13	10	0	10	2	2	1	0	57	454
Saturday	316	8	6	1	21	0	6	1	0	0	0	43	359
Sunday	274	6	15	14	8	0	3	0	0	1	0	47	321
Total	2420	33	77	56	68	2	57	9	7	5	0	370	2790
Average	346	5	11	8	10	0	8	1	1	1	0	53	399
Wednesday night	63	2	0	0	4	0	1	0	0	0	0	7	70
Wednesday24H	400	5	7	5	22	2	12	1	1	1	0	56	456
Estimated ADT (24H)COMPONENTS	409	7	11	8	14	0	9	1	1	1	0	60	469
ADT 24h with PMS June Seasonal Factor (1.01)	413	7	11	8	14	0	9	1	1	1	0	60	473
AADT (Applying PCU values)	165	7	11	8	14	0	14	2	2	1	0	60	225

Figure 4.7: Traffic data on DR 28 Rwamagana - Karembo Station:Sovu Total Summary for both directions

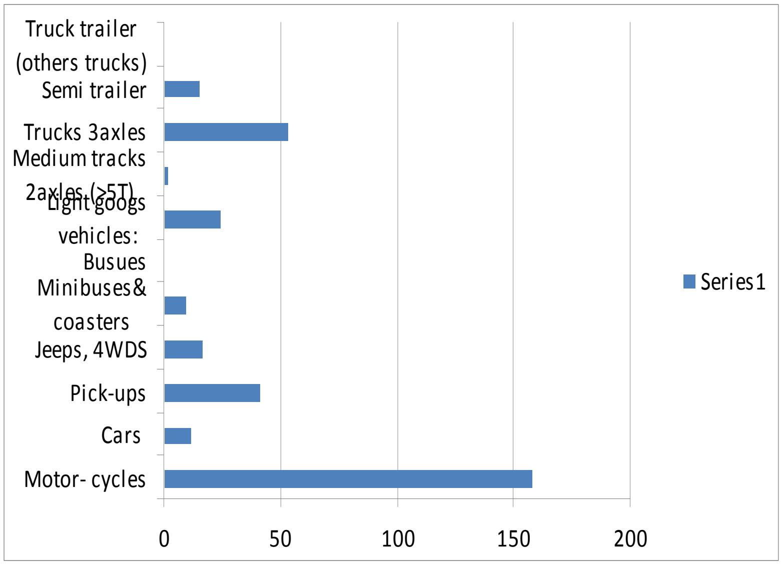
Based on the results from the traffic counts on the two stations as illustrated above and since the road passes through a similar topographic region, the road can be considered as a unique section for analysis and hence the AADT to be used in economic analysis is calculated as an average of the estimated AADT from the two stations.

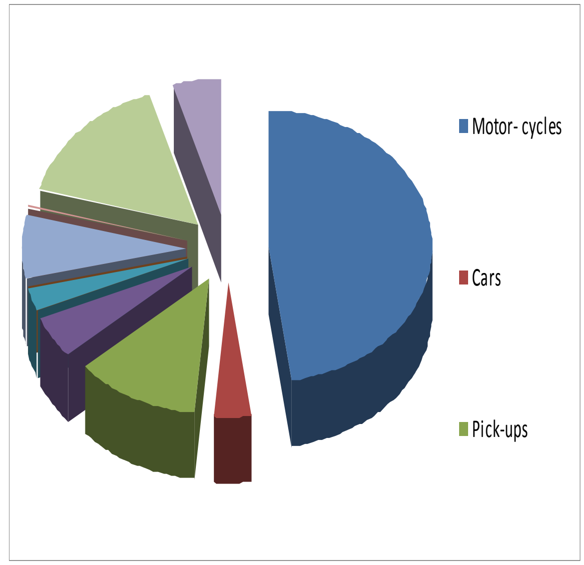
Figure 4.8: Traffic data on DR 28 Rwamagana - Karembo Station:Sovu&Kabilizi Total Summary for both directions

	Motor-cycles	Cars	Pick-ups	Jeeps, 4WDS	Minibuses & coasters	Buses	Light Goods vehicles: Dynas, Daihatsu (<5T)	Medium tracks 2axles (>5T)	Trucks 3axles	Semi trailer	Truck trailer (others trucks)	TOT without motorcycles	TOT(All vehicles included)
Days													
AADT (Applying PCU values) , Sovu Station	165	7	11	8	14	0	14	2	2	1	0	60	225
AADT (Applying PCU values) , Kabilizi Station	64	11	41	16	14	0	37	2	20	8	0	150	214
AADT (Total for the 2 stations)	229	18	52	24	28	0	51	4	22	9	0	210	439
AADT (Average for the 2 stations)	*115*	*9*	*26*	*12*	*14*	*0*	*26*	*2*	*11*	*5*	*0*	*105*	*220*

Source: Author's traffic counts

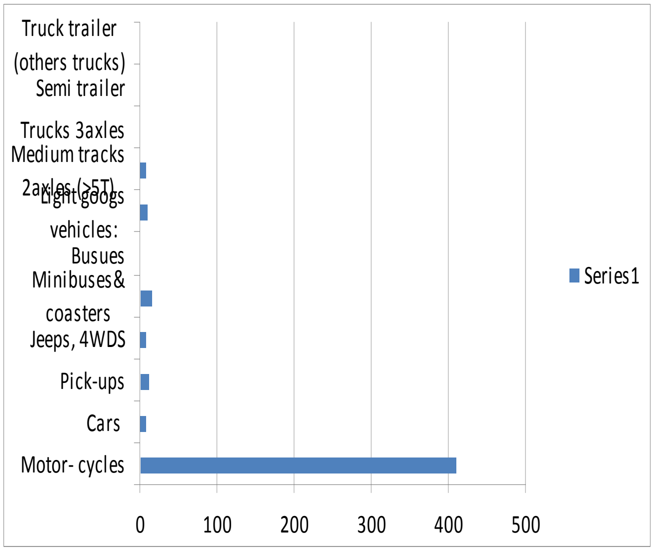
Figure 4.9: Traffic composition on DR 28 Rwamagana – Karembo Station: Kabilizi (both directions

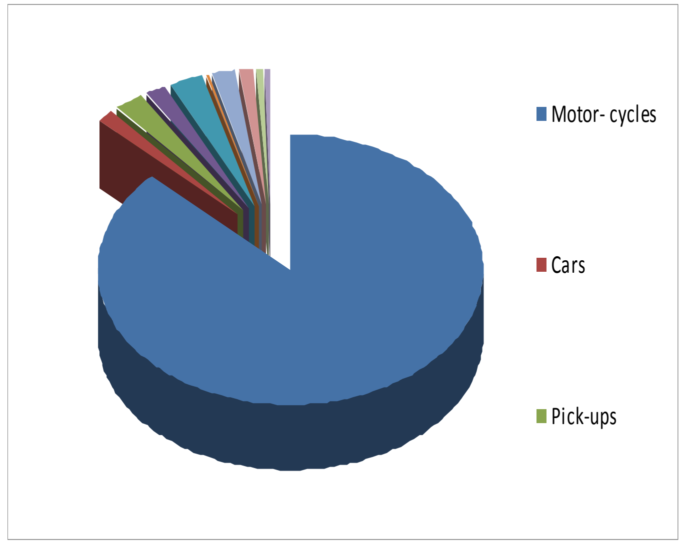




Source: Author's traffic counts

Figure 4.10: Traffic composition on DR 28 Rwamagana – Karembo Station: Sovu (both directions)





4.4.3. Rehabilitation of Gasiza-Kibisabo-Pinus II (11.305km) around Gishwati Project Area

Gishwati Water and Land Management (GWLM) Project is being developed by Ministry of Agriculture and Animal Resources through the Task Force for Irrigation and Mechanization. The total project area is about 6,600 ha, divided into twenty (20) land sensitivity units in consideration of slope, soil, depth, soil types and regimes.

The total 20 land-sensitivity categories are grouped into three land-use types: land for crop farming, land for range development (husbandry) and land for forest regeneration [17]

By initiating this project, the Government of Rwanda aims at modernizing Agriculture and livestock so as to achieve food security. The transformation of agriculture form an activity of subsistence to a productive high value, market oriented farming is pillar to this government vision.

Among many other development programs undertaken, the Task Force Irrigation and Mechanization intends to carry out works related to the rehabilitation of the natural drainage system and additional waterways construction, water and land management (WLM) technologies development, construction and rehabilitation of roads and bridges.

It is in that last intention of construction and rehabilitation of roads and bridges within the earmarked area of Gishwati that MININAGRI through the Task Force Irrigation and Mechanization Unit has commissioned to HYCOGEC Consultant the study to carry out a detailed design and elaboration of tender documents for construction works of access roads network in Gishwati project area (contract 017/S2011-AOIO/TFI&M/BO/MINAGRI).

The main objective of this study was to provide access to different project areas and to increase mobility and commercialization of agricultural and livestock products that are expected to increase.

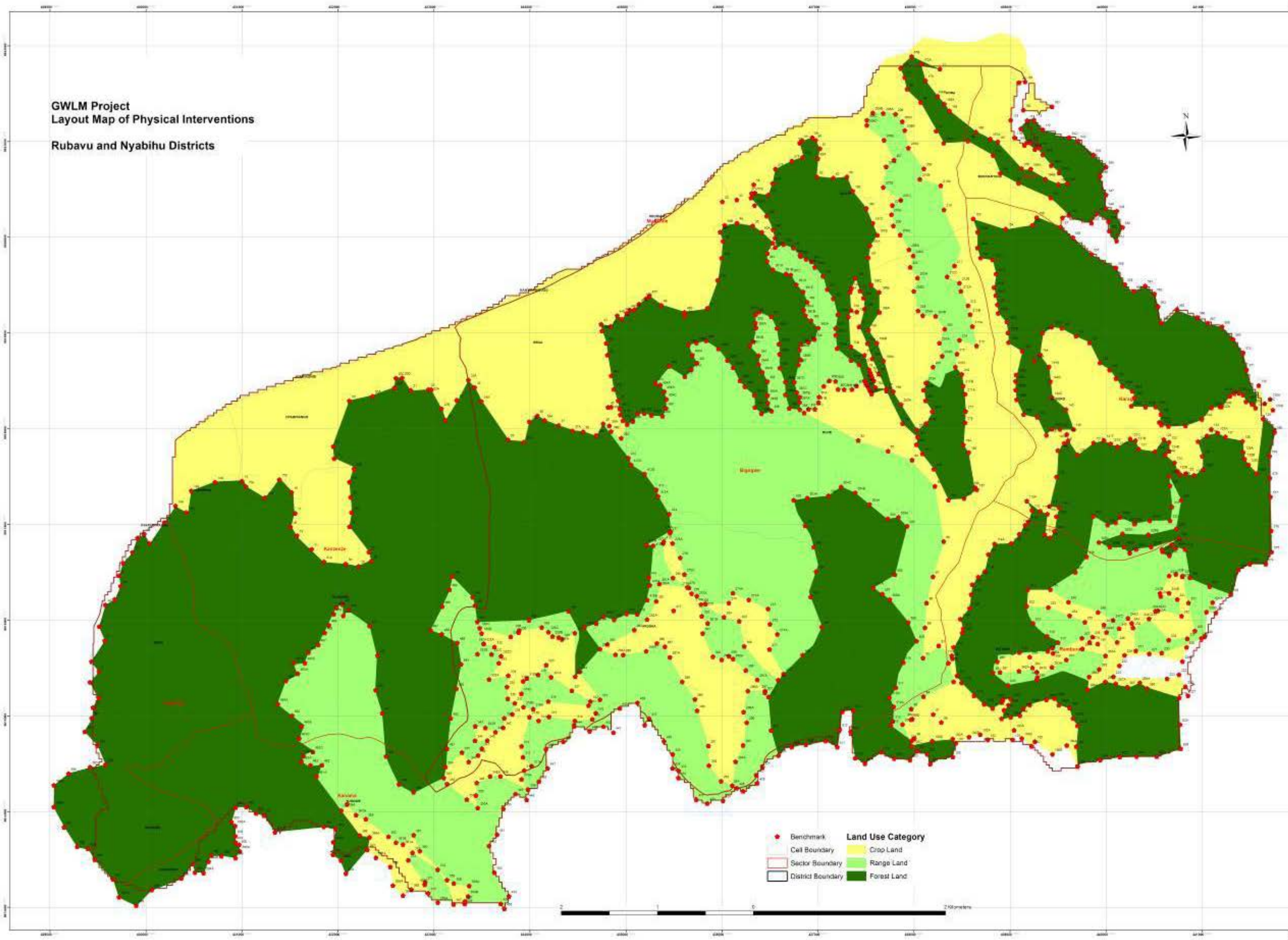
Previous studies have allocated the project area in the following way as shown on the map below:

-1476 ha will be additionally directed to agricultural development (land unit 1 to 4)

- 522 ha will be jointly directed in the range development of livestock (land unit 5) and

- 2971.8 ha will be dedicated to the regeneration and restoration of natural forest of Gishwati

Figure 4.11: Sitemap development of Gishwati



Source MINAGRI

It is in this context that the study has focused on the identification of a reliable network within the project, hence ensuring a spatial and balanced distribution of the network on prospective users [17]. The consultant proposed a network of 132km within the project area, of which 68 .4 km were existing roads that needed rehabilitation and upgrading to some extent whereas 61. 6 km were new proposed access roads so as improve the road network and provide accessibility to all project areas.

The consultant arrived at this final network length based on a design approach of Basic Access. Basic access can be defined as the minimum level of Rural Transport Infrastructure (RTI) network service required to sustain socioeconomic activity. According to Hycogec

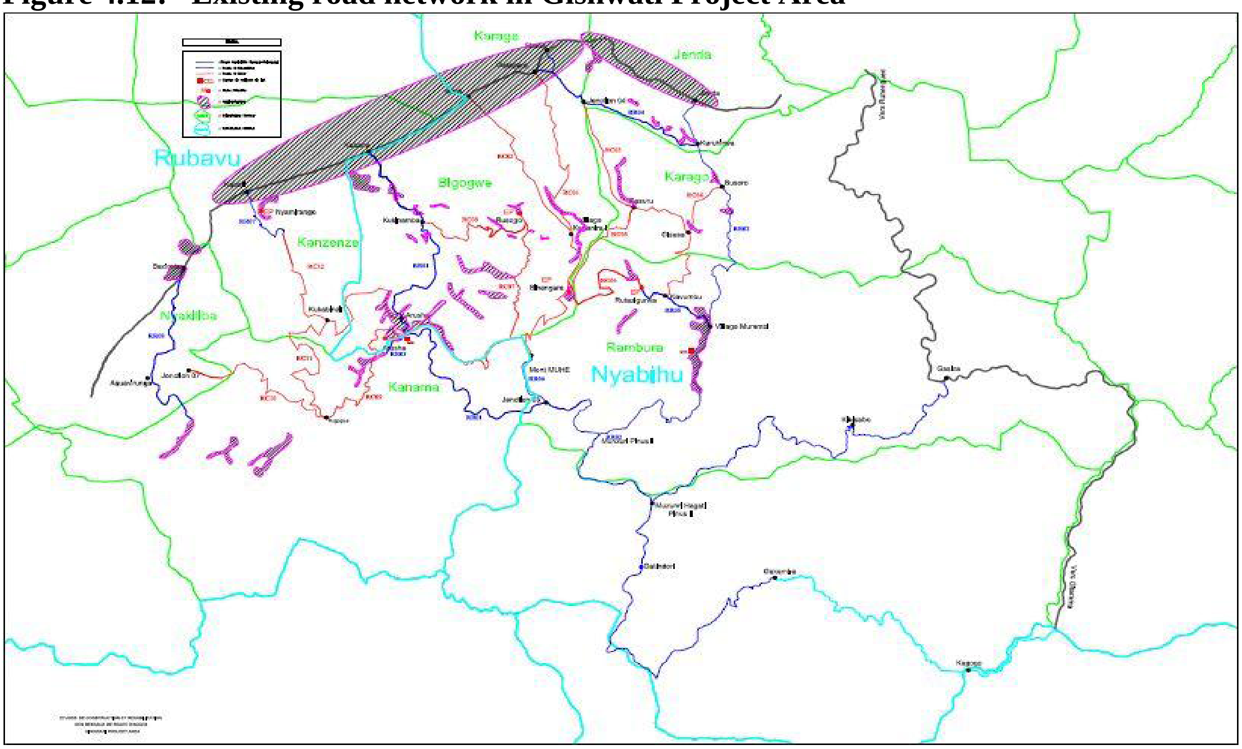
Consultant [17], the provision of basic access is often viewed as a basic human right, similar to the provision of basic health and basic education.

A basic access intervention, in this context, can be defined as the least-cost (in terms of total lifecycle cost) intervention for ensuring reliable, all weather traffic for the locally prevailing means of transport.

Most rural access roads have very low initial traffic volumes, and expected benefits of improvement come primarily through increased socio-economic opportunities, which increase traffic, but are difficult to forecast and quantify in monetary terms. This means that the approach of basic access considers the number of people larger and costly road geometry for rural roads with limited traffic volumes.

However, the design also provided an acceptable geometry design, convenient to all users and complying with laws governing roads (a minimum of 6m width for classified roads).

Figure 4.12: Existing road network in Gishwati Project Area



Gasiza-Kibisabo-Pinus II (11.303 km) is one of the 10 existing roads that need to be rehabilitated. The consultant designed this road to a 6m wide road like all other existing roads to be rehabilitated as well as new roads to be created in Gishwati Project area. This was based on estimated low traffic volume on one hand, but on the other hand, the geometric design was based on the above explained concept of ensuring basic access i.e increasing accessibility and mobility to as many as possible remote rural areas with limited resources.

When the consultant presented his provisional design report, he explained to the client and all invited panel members the concept of basic access and all other conditions that led him to decide a maximum road width of 6m, the concept was approved and the consultant was given an a green light to proceed with the final report.

During the validation session, a representative from the road agency (RTDA) told the participants that the new Roads Law is clear: the rehabilitation of any classified road should respect the design standards especially the road width. This observation has brought in hot discussions after which the participants have disclosed that some roads to be rehabilitated including Gasiza-Kibisabo-Pinus II (11.303 km) would be classified as District roads class 1 as they connect two or more different sectors, and hence, their minimum width should be 7m of driveway.

The discussions were challenging to the extent that some representatives of the financing institutions were of the view that investment in those kinds of rural roads would not be justified. Many of the arguments against immediate implementation of the new road law were based on the general topography of Gishwati Project Area, which would necessitate a lot of cuts and protection works for widening existing unpaved roads with very low traffic volumes.

We have analyzed the Bill of Quantities produced later by the consultant and a tremendous increase in the cost of works is evident, but it is still needed to test the efficiency or inefficiency of such investments considering not only the Road Agency Costs, but also other costs and benefits like: Road Deterioration, Work Effects, Road User Effects and Social and Environmental Effects. Therefore, the road Gasiza-Kibisabo-Pinus II (11.303 km will be taken as a sample from Gishwati Project Area and an economic analysis will be carried out to test the efficiency and effectiveness of widening it to meet the provisions of the new roads law.

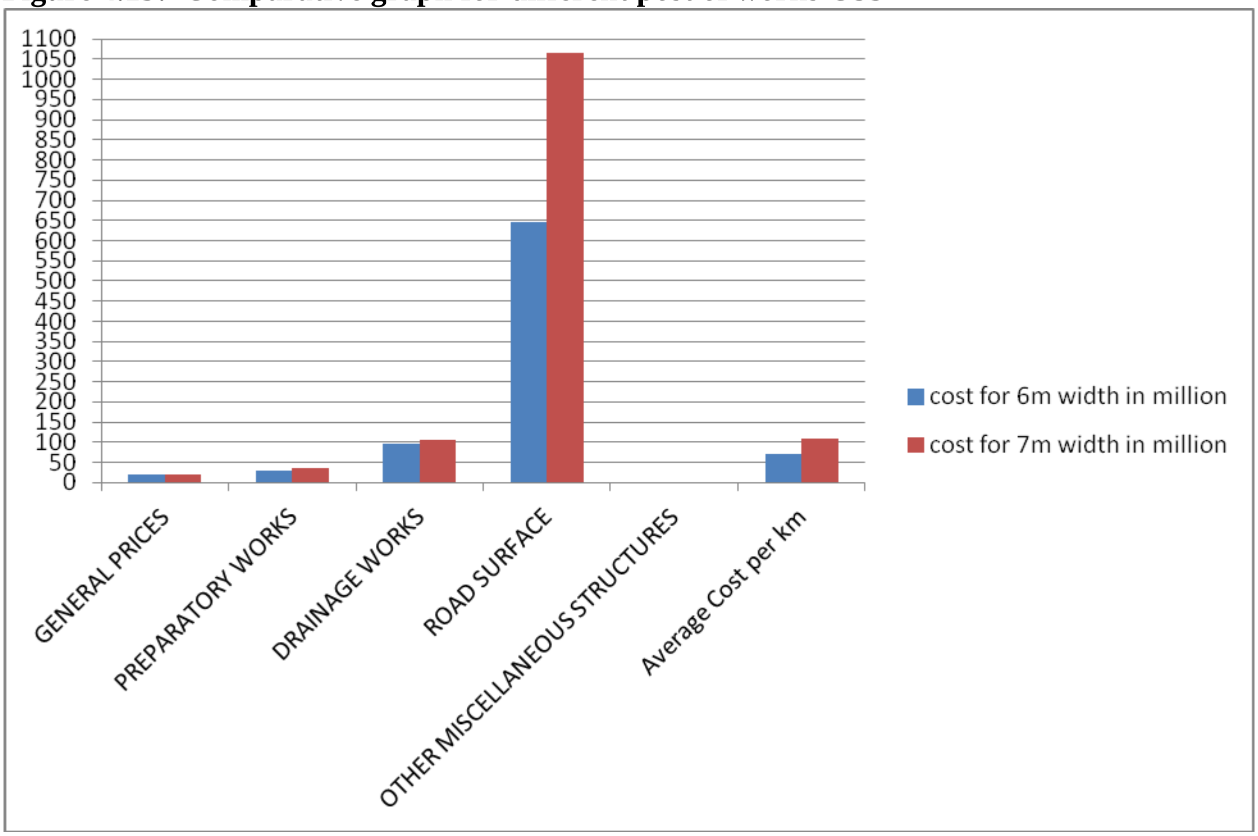
Table 4.7 below illustrates a summary of the final Bill of Quantities related to the Rehabilitation works of unclassified unpaved Road (Gasiza – Kibisabo – Pinus II: 11.3 Km) under the old road classification in the Western Province.

Table 4.7: Summarized cost of works CS3

Price No	Activity	Cost in Rwf (for 6m width)	Cost in Rwf (for 7m width)
Serial 01	GENERAL PRICES	19,381,489.00	19,381,489.00
Serial 02	PREPARATORY WORKS	29,569,050.20	36,126,722.00
Serial 03	DRAINAGE WORKS	97,692,073.00	106,123,273.00
Serial 04	ROAD SURFACE	644,594,651.00	1,063,915,387.00
Serial 05	OTHER MISCELLANEOUS STRUCTURES	0	0
	TOTAL	**791,237,263.2**	**1,225,546,871.00**
	Average Cost per km	**69,984,579.99**	**108,399,069.42**

Source: Hycogec Consultant (2012)

Figure 4.13: Comparative graph for different post of works CS3



Source: Author's calculations

- Considering a road width of 6m option, the average cost per kilometer is estimated at 69,984,580 Rwf which is quite high compared to other cases studied above. This can be explained by the nature of the area in general where the road passes through steep grade terrain that increase the volume of cuts but also, some sections of the existing road do not have a sufficient width of 6m, which means that works included road widening for those narrow sections.

- The cost of works for serial 4 (Road Surface) that include earthworks increases from Rwf 644,594,651 to Rwf 1,063,915,387 for road width of 6m and 7m respectively, thus justifying how the effect of widening the road is very high in terms of investment cost due mainly to huge volume of cuts and fills resulting from the topography of Gishwati Project Area. A high increase in the average cost of works per kilometer that is seen as a result of widening the road is generally due to the hilly topography of the area that involve large volumes of earthworks.
- From the above figures, it is clear that the cost of works shall considerably increase if the road is to be widened. But then, can it be assumed that there could be other benefits resulting from this widening so that they can compensate this cost of works and make the NPV at a higher level? It is needed to be proven using HDM-4 and all maintenance works that are required after rehabilitation should be considered.

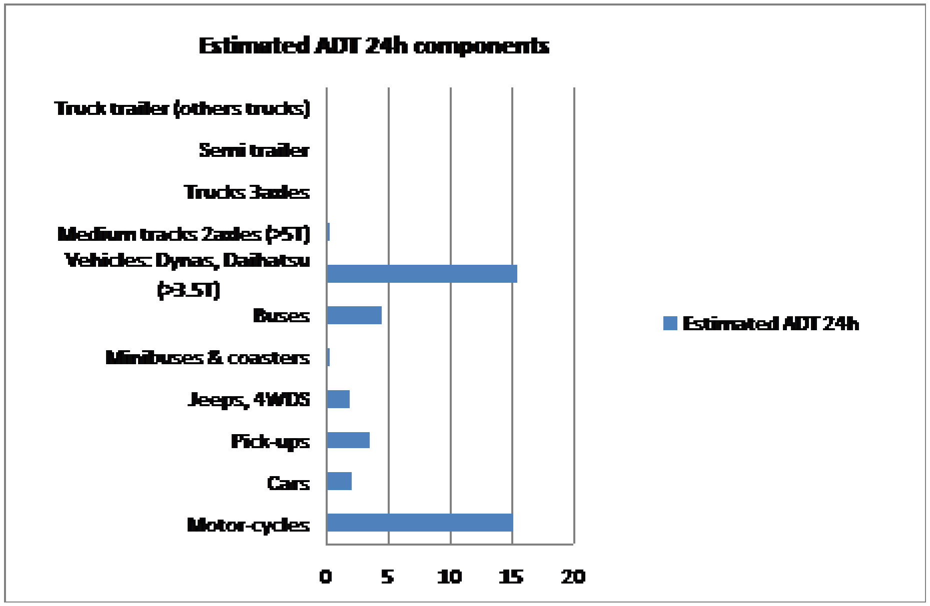
Traffic data

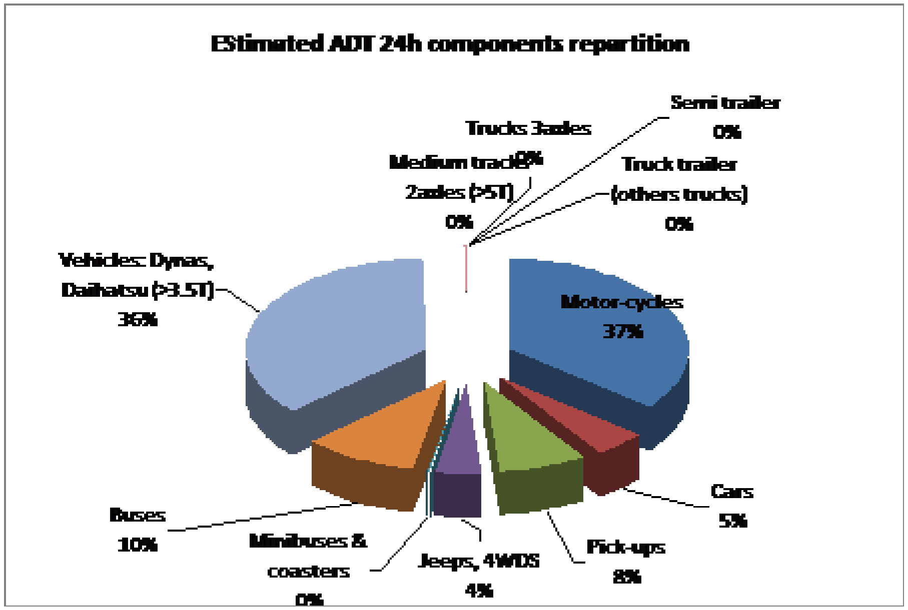
We have not conducted traffic counts on this particular road and we have adopted a very low class (50 AADT) due to the reasons explained in the previous paragraphs. Based on the land use of the area and intended agricultural developments, we have tried to simulate the traffic composition on this road to that of one Section of National Unpaved Road 39, Section Gishyita-Gisovu that mainly lead to Gisovu Tea Factory.

Figure 4.14: Traffic data on NR39 Gishyita-Gisovu Station:Gishyita Total Summary for both directions

Times (days)	Motor-cycles	Cars	Pick-ups	Jeeps, 4WDS	Minibuses & coasters	Buses	Vehicles: Dynas, Daihatsu (>3.5T)	Medium tracks 2axles (>5T)	Trucks 3axles	Semi trailer	Truck trailer (others trucks)	TOT without motorcycles	TOT(All vehicles included)
Monday	8	2	0	2	0	0	20	0	0	0	0	24	32
Tuesday	6	1	5	3	0	0	13	0	0	0	0	22	28
Wednesday	12	3	8	2	1	0	13	1	0	0	0	28	40
Thursday	5	0	1	3	0	0	12	0	0	0	0	16	21
Friday	3	0	2	0	0	1	15	0	0	0	0	18	21
Saturday	10	1	1	2	0	1	3	0	0	0	0	8	18
Sunday	5	0	0	0	0	0	10	0	0	0	0	10	15
Total	**49**	**7**	**17**	**12**	**1**	**2**	86	**1**	**0**	**0**	**0**	**126**	**175**
Average	7	1	2	2	0	0	12	0	0	0	0	18	25
Tuesday night	8	1	1	0	0	4	3	0	0	0	0	9	17
TUESDAY 24H	**14**	**2**	**6**	**3**	**0**	**4**	**16**	**0**	**0**	**0**	**0**	**31**	**45**
Estimated ADT 24h components	**15**	**2**	**3**	**2**	**0**	**4**	**15**	**0**	**0**	**0**	**0**	**27**	**42**
ADT 24h with PMS August Seasonal Factor (0.88)	**13**	**2**	**3**	**2**	**0**	**3.52**	**13.2**	**0**	**0**	**0**	**0**	**24**	**37**
AADT (Applying PCU values)	**5**	**2**	**3**	**2**	**0**	**7**	**20**	**0**	**0**	**0**	**0**	**32**	**39**

Source: ITEC Engineering (2012)





Source: ITEC Engineering (2012)

Table 4.8: Unit Costs of Road Maintenance Operations for unpaved rural roads

Operation	Unit cost in US Dollars	
	Economic	**Financial**
Grading (per km)	400	470
Spot regravelling (m^3)	42	50
Gravel resurfacing/Regravelling (m^3)	40	47

Source: HDM-4 Documentation

Table 4.9: Traffic Composition for case studied roads

Vehicle Type	Composition (%)			
	Byimana - Buhanda: Section 1	Buhanda – Kaduha: Section 2	Rwamagana – Zaza	Gasiza – Kibisabo- Pinus I (Gishwati)
Motorcycles	26	51	52	13
Cars	10	3	4	5
Pickups	8	7	12	8
Jeeps, 4WDs	8	6	5	5
Minibuses & Coasters	31	8	6	0
Buses	1	9	0	18
Dynas, Daihatsu & Medium trucks	16	16	14	51
Trucks (3 axles & semi trailers	0	0	7	0
Trucks with trailers	0	0	0	0

Source: ITEC Engineering (2012) & Author's traffic counts (2013)

Table 4.10: Case study roads data

Name of Road	**Length (km)**	**Width (m)**	**AADT**	**Gravel Thick (mm)**	**Roughnes s (IRI)**	**Economic Unit cost (US $/km)**
Byimana – Buhanda : Section 1	20	6	259	200 (in 2011 after regravelling)	6	93,350
Buhanda – Kaduha: Section 2	27	6	74	200 (in 2011 after regravelling)	6	93,350
Rwamagana - Zaza	31	6	220	200 (in 2008 after regravelling)	6	87,938
Gasiza – Kibisabo- Pinus I (Gishwati)	11.3	6	39	200 (in 2008 after regravelling)	6	133,415

Source: Hycogec Consultant (2011-2012)

Table 4.11: Summary of Roads attributes

Definition	**Road/Section Name**			
Section name				
Section ID	**Section 1:** Byimana - Buhanda	**Section 2:** Buhanda - Kaduha	Rwamagana - Zaza	Gasiza – Kibisabo- Pinus I (Gishwati)
Length (km)	18	29	31	
Carriageway width (m)	6	6	6	6
Shoulder width (m)	0.25	0.25	0	0
Speed flow type	Two lane road	Two lane road	Two lane road	Two lane road
Traffic low pattern	Free flow	Free flow	Free flow	Free flow
Accident class	Two lane road	Two lane road	Two lane road	Two lane road
Calibration set	National RD Calibration	National RD Calibration	National RD Calibration	National RD Calibration
Calibration item	*US 1*	*US 2*	*US 3*	*US 4*
Flow direction	2-way	2-way	2-way	2-way
Geometry (before upgrading)				
Rise plus Fall (m/km)	55	65	57	49
No rises and falls (no/km)	2	3	3.15	2.39
Av horiz curv (deg/km)	100	50	100	50
Superelevation %	5.0	4.0	5.0	3.0
□dral	0.1	0.1	0.1	0.1
Speed limit (kph)	60	50	80	60
Speed limit enforcement	1.4	1.3	1.3	1.2
Altitude (m)	1400	1500	1400	1600
Pavement (before upgrading)				
Surface material	Quartzic Gravels	Quartzic Gravels	Lateritic Gravels	Volcanic Gravels
Subgrade material	Well-graded gravel-sands with small clay content, GC	Well-graded gravel-sands with small clay content, GC	Clays (inorganic) of medium plasticity, CI	Gravel-sand mixtures with excess of fines, GF
Compaction method	Mechanical	Mechanical	Mechanical	Mechanical
Last regravel year	2011	2011	2008	2008
Condition 2011				
Gravel Thickness (mm); Condition at end of last regravel	200	200	200	150
Roughness (IRI, m/km) Condition at end of last regravel	6	6	6	8
Motorised Traffic 2011				
AADT (2012)	259	74	220	39

Source: Hycogec Consultant (2011-2012)

4.5. PROJECT ALTERNATIVES

Under this Research and based on available data from three unpaved roads as presented in the previous paragraphs, we propose to test the cost effectiveness of the design standards, policies and techniques of constructing and maintaining unpaved roads according the provisions of the new Roads Law in Rwanda especially widening roads so as to meet the required width by the new Law.

It is in this context that we use HDM-4 for the three case studies to assess the economic benefits resulting from the investments to be done by widening those unpaved rural roads. The cost effectiveness or the economic benefits of every project among the three case studied roads is assessed by comparing a Project Alternative against a base – line alternative.

Case Study 1: Byimana-Buhanda-Kaduha unpaved road (NR 32)

Without Project: Maintain existing gravel road of 6m width of the road since 2011 as Base Year (which is the year of last regravelling).

With Project: Maintain existing gravel road before widening the carriageway to 7m + 1m of shoulder at each side of road in 2016 (approximate year of new resurfacing) and maintain after widening (2017).

Case Study 2: Rwamagana - Zaza unpaved road (DR 28)

Without Project: Regravelling existing gravel road of 6m width followed by Maintenance since 2013 as Base Year (which is the year for new regravelling).

With Project: Widening the carriageway to 7m + 1m of shoulder at each side of road followed by Maintenance works since 2013 (as the Law proposes upgrading the roads at every stage of Rehabilitation).

Case Study 3: Gasiza – Kibisabo - Pinus unpaved road (Unclassified)

Without Project: Regravelling existing gravel road of 6m width followed by Maintenance since 2013 as Base Year (which is the year for new regravelling).

With Project: Widening the carriageway to 7m + 1m of shoulder at each side of road followed by Maintenance works since 2013 (as the Law proposes upgrading the roads at every stage of rehabilitation)

The Without Project Alternative consists for all case studies in grading every six months, spot regravelling to replace 30% of material loss each year (or if the gravel thickness falls below 50mm for Case studies 1 and 2, and below 25mm for case studied unpaved road 3); and all these operations are scheduled every year except when gravel resurfacing is triggered for.

The With Project Alternative includes for Case Study 1, maintaining the gravel road with 6m width by grading every six months and spot regravelling to replace 30% of material loss each year (if the gravel thickness falls below 50mm) from 2011 to 2016, followed by widening the road to a carriage width of 7m plus 1m of shoulder at each side of the road. The duration of works is estimated at 12 months for the two sections of the roads.

After widening the road, maintenance works of unpaved roads will be performed i.e grading every six months and spot regravelling to replace 30% of material loss each year (if the gravel thickness falls below 50mm) from 2011 to the last year of Analysis period.

The With Project Alternative for Case Studies 1 & 2 is about to widen the carriageway to 7m+1m of shoulder at each side of the road by the year 2013, operation estimated to be done in 12 months for Case Study 2 and 6 months for Case Study 3; and the operation will be followed by maintenance practices as above described for unpaved roads. We propose an analysis period of 15 years, in assumption of another major upgrading that could include Upgrading of these roads to Bituminous Pavements in coming fifteen years.

Table 4.12: Details of Road works standards for each project alternative

Case Study Road	Section ID		Road works Standards	Effective from year	Maintenance works/Improvement type
Byimana-Buhanda –Kaduha unpaved road (49km)					
Without Project: Maintain existing Gravel road	CS 1-1	M	Maintenance of CS 1	2011	Grading CS11 and CS12 (Grd 1)
					Spot Regravelling CS11 and CS12 (SR 1)
					Gravel Resurfacing CS11 and CS12 (GR 1)
	CS 1-2	M	Maintenance of CS 1	2011	Grading CS11 and CS12 (Grd 1)
					Spot Regravelling CS11 and CS12 (SR 1)
					Gravel Resurfacing CS11 and CS12 (GR 1)
With Project: Widening by 3m Gravel Road CS1	CS 1-1	M	Maintenance of CS 1 before widening	2011	Grading before widening CS11 and CS12 (GBW)
					Spot Regraveling before widening CS11 and CS12 (SRBW)
		I	Widening by 3m CS 11	2016	Widening
		M	Maintenance of CS 1 after widening	2017	Grading after widening CS11 and CS12 (GAWID)
					Spot Regravelling after widening CS11 and CS12 (SRAWID)
					Gravel Resurfacing after widening CS11 and CS12 (GRAWID)
	CS 1-2	M	Maintenance of CS 1 before widening	2011	Grading before widening CS11 and CS12 (GBW)
					Spot Regraveling before widening CS11 and CS12 (SRBW)
		I	Widening by 3m CS 12	2016	Widening
		M	Maintenance of CS 1 after widening	2017	Grading after widening CS11 and CS12 (GAWID)
					Spot Regravelling after widening CS11 and CS12 (SRAWID)
					Gravel Resurfacing after widening CS11 and CS12 (GRAWID)
Rwamagana – Zaza unpaved road (31km)					
Without Project: Maintain existing Gravel road CS 2	CS 2	M	Maintenance of CS 2	2013	Grading CS2 (Grd 2)
					Spot Regravelling CS2 (SR 2)
					Gravel Resurfacing CS2 (GR 2)
With Project: Widening by 3m Gravel Road CS1	CS 2	I	Widening by 3m CS 2	2013	Widening
		M	Maintenance of CS 2 after widening	2014	Grading after widening CS2 (GAWID)
					Spot Regravelling after widening CS2 (SRAWID)
					Gravel Resurfacing after widening CS2 (GRAWID)
Gasiza – Kibisabo – Pinuss II unpaved road (11.3km)					

Without Project: Maintain existing Gravel road CS 3	CS 3	M	Maintenance of CS 2	2013	Grading CS3 (Grd 3)
					Spot Regravelling CS3 (SR 3)
					Gravel Resurfacing CS3 (GR 3)
With Project: Widening by 3m Gravel Road CS 3	CS 3	I	Widening by 3m CS 3	2013	Widening
		M	Maintenance of CS 3 after widening	2014	Grading after widening CS3 (GAWID)
					Spot Regravelling after widening CS3 (SRAWID)
					Gravel Resurfacing after widening CS3 (GRAWID)

4.6. SUMMARY

Under this Chapter, HDM-4 was selected and described as an appropriate tool for conducting economic analysis. The required data for running HDM-4 were identified from HDM-4 documentation and other sources of information within road construction sectors in Rwanda. Three unpaved roads with current different classification (National unpaved road, District unpaved road and unclassified unpaved road) were selected for economic analysis. It was revealed that the classification of Rwanda road network is to be changed and adapted to the new Roads Law including widening some of them despite their relatively low to very low traffic volumes. It was found that construction costs related to widening of unpaved roads have significantly increased compared to maintaining the existing road widths. However, investments made in widening these roads might result into other benefits and it is not possible to conclude on their cost effectiveness and efficiency. It is necessary to conduct an economic analysis by comparing investment alternatives with do minimum option. Road work standards have been defined for every project alternative and at this stage, analysis was run using HDM-4 software and important results are presented in appendices for being analysed and commented on in the following chapter.

CHAPTER 5

DEVELOPMENT OF APPROPRIATE CONSTRUCTION AND MAINTENANCE STANDARDS, POLICIES AND ALTERNATIVE TECHNIQUES

5.1. INTRODUCTION

Road deterioration is broadly a function of the original design, material types, construction quality, traffic volume, axle loading characteristics, road geometry, environmental conditions, age of pavement, and the maintenance policy pursued [18].

In the previous chapter, we have discussed and presented construction costs related to widening of three unpaved rural roads under our case studies. After analysing construction costs related to widening of two roads out of the three under our case studies to a minimum carriageway width of 7m, construction costs were found to increase by 37.27% for Rwamagana – Zaza unpaved District Road, and by 54.89% for Gisiza-Kibisabo-Pinus II unpaved unclassified road. All these financial implications related to road widening cannot alone prove that road geometric designs suggested by the new Rwandan road Law are not cost effective as there exists other components of the overall economic analysis that need to be assessed so that economic viability of different alternatives is determined. It is for this reason that we propose to conduct project analysis for the three roads under our case studies using HDM-4.

The Guide to Calibration and Adaptation, Volume 5 of HDM-4 Series describes HDM-4 as designed to make comparative cost estimates and economic evaluations of different construction and maintenance options, including different time-staging alternatives, ... It estimates the total costs for a large number of alternative project designs and maintenance year by year, discounting the future costs if desired at a different postulated discount rates so that the user can search for the alternative with the lowest discounted total cost.

The following are but not limited to important areas of project analysis using HDM-4:

Vehicle Operating Costs (VOC) are the costs of vehicle operation. They are comprised of fuel, tyres, maintenance, labour, depreciation, interest, lubricants, crew, cargo and travel time.

Road User Effects (RUE) are the VOC along with safety, vehicle emissions, noise and energy balance.

Road Deterioration and Works Effects (RDWE) encompass pavement deterioration and the effects of works improvements that include maintenance as well as improvements such as widening.

5.2. DATA ANALYSIS USING HDM-4

After running HDM-4, the program has conducted an economic analysis and generated many reports that
include the following report categories:

- Deterioration/Work Effects
- Road User Effects
- Environmental Effects
- Cost Streams

Based on the objectives of our Research, we have tested the cost effectiveness for different project alternatives from the following HDM-4 reports:

- **Deterioration/Work Effects** which is analysed with the results related to Average Roughness by Project Alternative, Gravel Thickness and Timing of works
- **Road User Effects** comprising Annual Average Vehicle Operating Cost per veh-km, Annual Average Travel Time Cost per veh-km and Annual Average Road User Cost per veh-km.
- **Cost Streams** which include an Economic Analysis Summary (Net Economic Benefits: NPV, and Economic Internal Rate of Return: EIRR) as well as Road Agency and User Costs that makes the Total Transport Costs.

For all roads studied, Non Motorized Traffic was estimated to be low and hence not analysed and Social, Accident and Environmental Costs and Benefits were not calculated due to lack of related and appropriate data for unpaved roads.

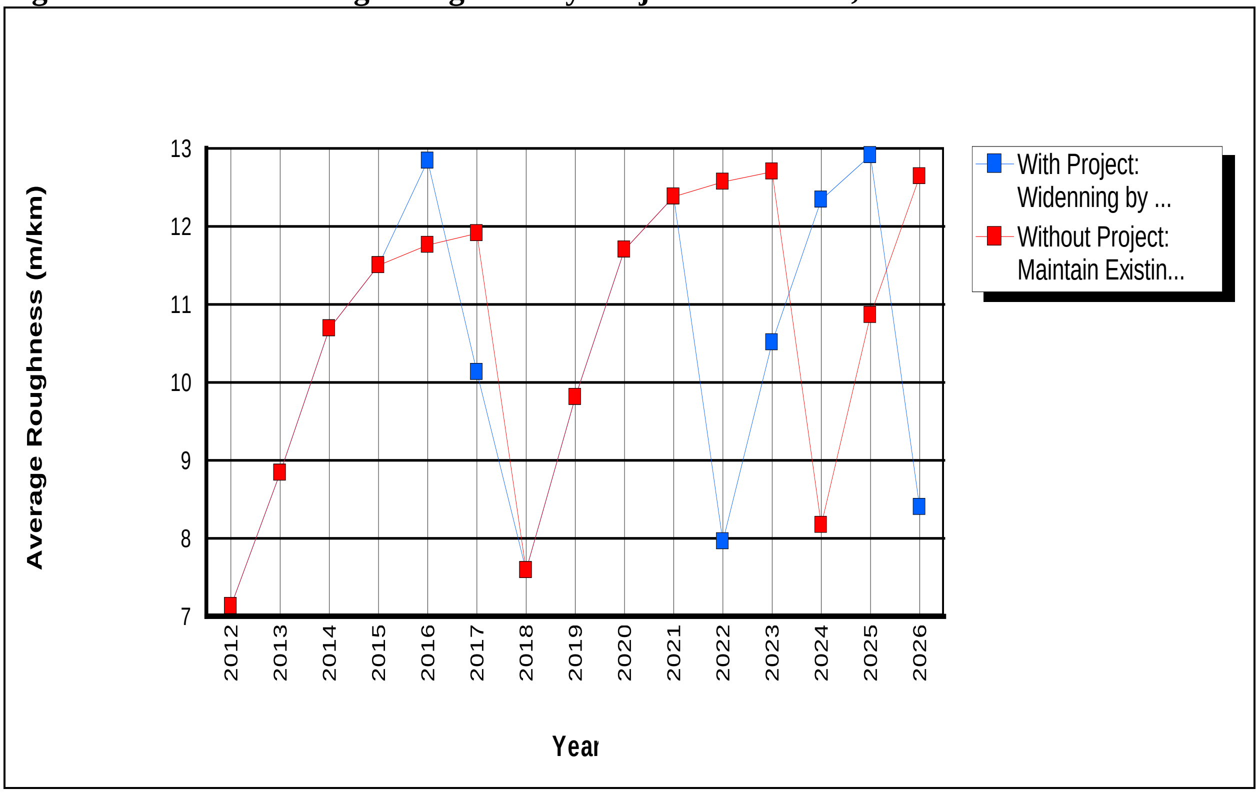
5.2. 1. Deterioration/Work Effects

5.2.1.1. Annual Average Roughness by Project Alternative

Case Study 1: Byimana – Buhanda-Kaduha unpaved road

Section CS 1-1 (Byimana – Buhanda):

Figure 5.1: Annual Average Roughness by Project Alternative, CS1-1



Source: HDM-4 results

Without Project alternative, from 2012 to 2017, the IRI will gradually increase from 7.13 to 11.90 and will reduce to 7.58 in 2018 after carrying out Grading and Gravel Resurfacing operations triggered for in 2017.

From 2018 to 2023, roughness will be subjected to slight increase with time (from 7.58 in 2018 to 12.70 in 2023) until it reduces to again to 8.17 in 2024 due to Grading and Gravel Resurfacing to be done in 2023.

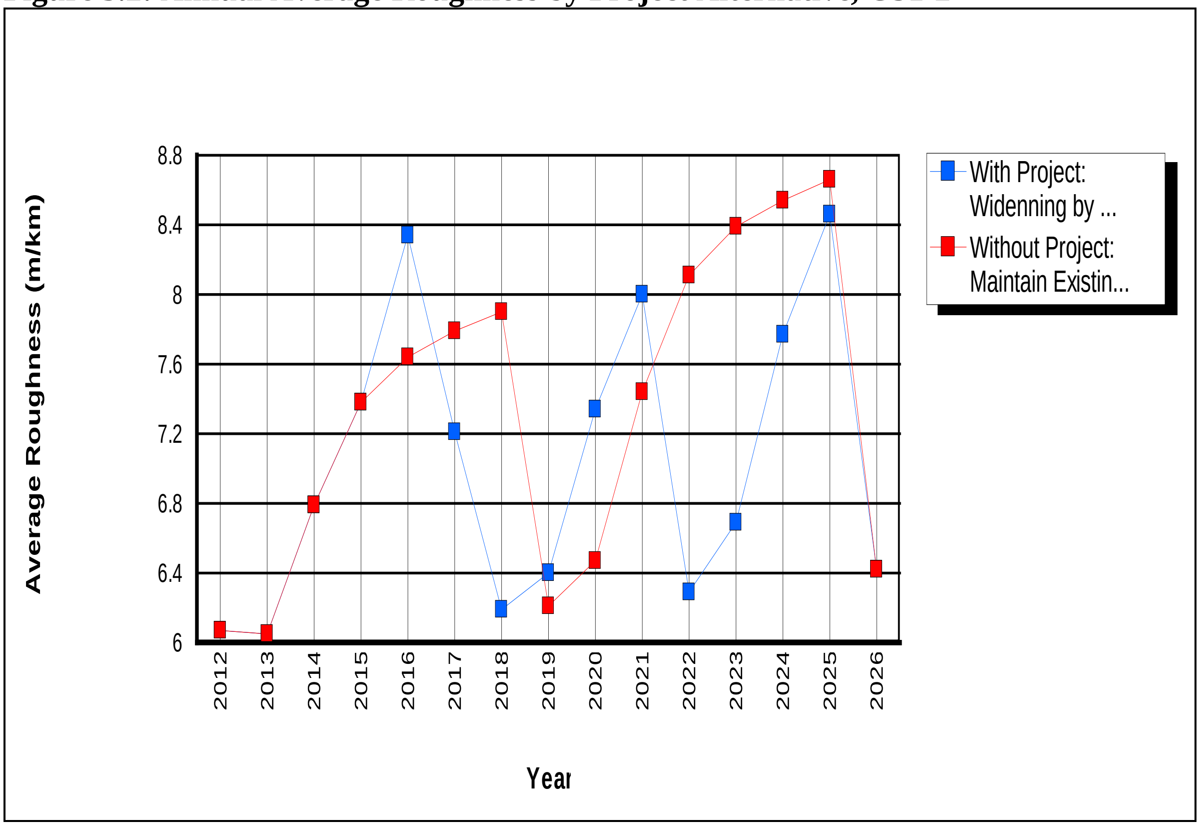
With Project alternative, roughness increases from 7.13 to 10.13 for the period between 2012 and 2017 and reduces to 7.58 in 2018 due to Grading and Gravel Resurfacing to be done in 2017 like for the without project alternative.

Road section deterioration measures follow the same trend of increase with respect to time and intermediate roughness decreases are observed during the years following Gravel Resurfacing.

Roughness varies between 7and 12.90 for both project alternatives of Section CS 1-1: Maximum IRI is 12.70 for the Without Project Alternative, while max IRI is 12.90 for With Project Alternative.

Section CS 1-2 (Buhanda - Kaduha):

Figure 5.2: Annual Average Roughness by Project Alternative, CS1-2



Source: HDM-4 results

Without Project alternative: Roughness will be subjected to slight increase (from 6.07 to 7.89 IRI) for the period ranging from 2012 to 2018**,** the year in which the road section will be graded and resurfaced with gravel, thus reducing the roughness to 6.21. Same rate of deterioration expressed by increase in IRI measure will be observed till 2026, where the roughness will again drop to 6.41 IRI as a result of the same activities of Grading and Gravel Resurfacing to be done in 2025.

With Project alternative:

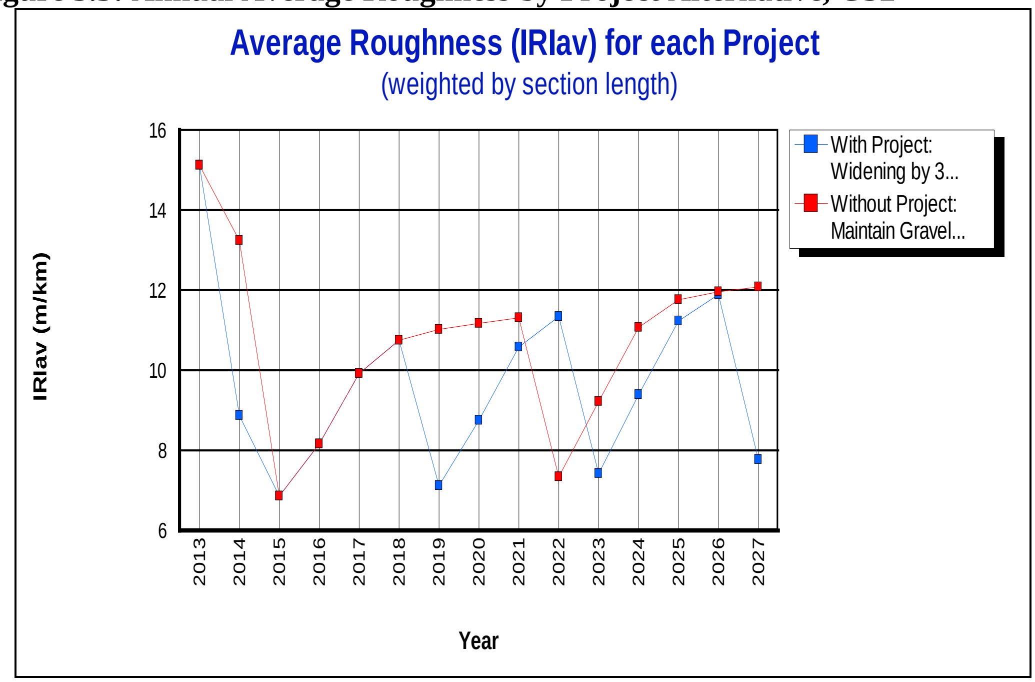
The roughness is to increase at a small rate between 2012 and 2016 (from 6.07 to 8.33) due to regular maintenance works before widening the road to 7m, and it drops to 6.39 IRI in 2019 as a result of widening the road section in 2016, accompanied by Gravel Resurfacing and Grading in the following two years.

The deterioration process continues in the same way, where it is expected to reach 8.56 IRI in 2026, the last year of the project life analysis.

Roughness varies between 6 and 9 for both project alternatives of Section CS 1-2: Maximum IRI is 8.64 for the Without Project Alternative, while max IRI is 8.56 for With Project Alternative.

Case Study 2: Rwamagana – Zaza unpaved road

Figure 5.3: Annual Average Roughness by Project Alternative, CS2



Source: HDM-4 results

Without Project alternative: Road condition in 2013 is poor as the roughness is 15.12 IRI. Spot regravelling and Resurfacing works in 2014 will improve the road condition with a roughness of 6.86 IRI in 2015, after which time, road condition will progressively deteriorate and reach a roughness of 11.31 IRI in 2021.

Gravel Resurfacing scheduled to take place in 2021 will improve the roughness (7.34 IRI in 2022) and the process of road deterioration due to traffic loading will follow and reach a final value of 12.08 IRI in 2027, the last year of the Project analysis.

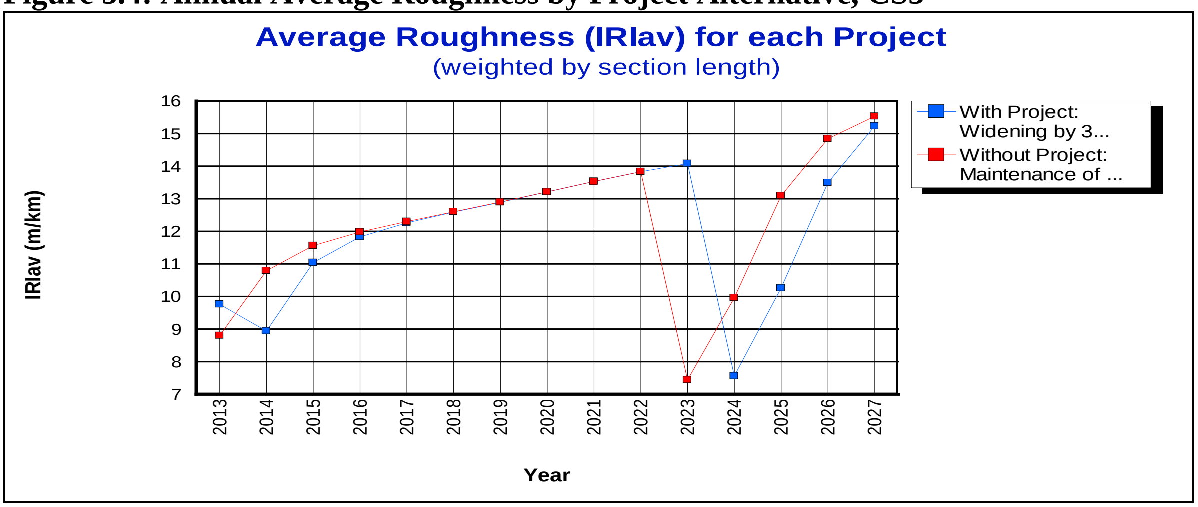
With Project alternative: Widening activities in 2013 followed by Gravel resurfacing in 2014 will reduce the roughness from an initial value of 15.12 to 6.86 IRI in 2015, and thereafter road deteriorates very fast as the roughness reaches 10.75 in 2018, and from then to 2026 two Gravel Resurfacing (2022 and 2026) will be required to maintain the roughness in the range between 7.12 and 11.89 IRI.

Except high initial roughness of 15.12 in the start year, roughness varies between 6 and 12 for both project alternatives of CS 2: Maximum IRI is 12.08 for the Without Project Alternative, while maximum IRI is 11.89 for With Project Alternative

In addition to the heavy cost of widening the road, three operations of Gravel resurfacing are triggered for the With Project Alternative, while only two gravel resurfacing would be enough for achieving an approximate same level of service in terms of road condition (roughness) when the Without Project is considered.

Case Study 3: Gasiza – Kibisabo – Pinus II unpaved road

Figure 5.4: Annual Average Roughness by Project Alternative, CS3



Source: HDM-4 results

Without Project alternative: Though small works of Grading are to be done from 2013 to 2022 , the road will be subjected to minor deterioration as the roughness will vary between 7.63 and 10.63 IRI; the latter will drop again to 6.60 IRI as a result of the only Gravel resurfacing triggered for in 2022 for the whole project life cycle.

With Project alternative: Heavy works of widening the road in 2013 will impact small changes in road condition (8.43 IRI in 2013 and 7.70 IRI in 2014, but roughness deterioration will follow a slow pattern till 2022 where the roughness will reach 10.68 IRI despite light works related to grading to be done in that period. Gravel resurfacing to be only applied in 2022 will bring back the roughness at 6.60 IRI in 2023 and road deterioration will continue to give a final roughness of 12.00 IRI in 2027, the last year of the project analysis.

Roughness varies between 6 and 12 for both project alternatives of CS 3: Maximum IRI is 12.00 for both Without and With Project Alternatives,

Road condition expressed in terms of average roughness is same for the two investment options while the With Project Alternative implies a heavy investment cost for widening the road by 3 meters.

Summary and general findings for all roads

Generally, the roughness varies between 6 and 13 for both alternatives (With and Without Project) and for all road sections of our case studies. Based on the figures given in Table xxx for Default values for ride quality for unsealed roads, CS 1 (Byimana – Buhanda – Kaduha) and CS 2 (Rwamagana – Zaza) roads will have a ride quality ranging from good, fair and rarely poor for the whole project analysis; while the ride quality for CS 3 (Gasiza – Kibisabo – Pinus II) will vary from good to fair.

For each case study, all project alternatives have similar maximum roughness throughout the project analysis period (small differences)

Heavy investments done in widening the case studied roads do not contribute much in improving the quality of riding.

5.2.1.2. Gravel Thickness

Following the results of traffic analysis conducted by RTDA in 2012, it was proved that mean AADT for all unpaved roads in Rwanda is between medium and low and also traffic counts that were made on one of the case studied unpaved road (Rwamagana – Zaza) confirmed this traffic band classification. Referring to Table 4.4 in the previous chapter, a Gravel Thickness ranging from 150 to 100mm gives a good to fair surface condition for medium traffic band, while the surface condition is considered to be poor when the gravel thickness falls below 50mm for medium traffic band.

Gravel thickness of 100 to 50mm provides a good to fair surface condition for low traffic volume roads like for the case studied Gasiza – Kibisabo – Pinus II unpaved road and the road condition is poor when the gravel thickness reduces up to 25mm and below.

Case Study 1: Byimana – Buhanda-Kaduha unpaved road

Without Project alternative: It is observed that, from the pavement condition summary from HDM-4 results in appendices 5.1.A and 5.1.B, for both sections, the Gravel thickness reduces as the road section is subjected to traffic loading and environmental effects throughout the project life. Gravel resurfacing is always undertaken to achieve a total thickness of 200mm whenever the Gravel thickness falls below 50mm and thus, improving the road surface condition as the roughness also decreases. However, beyond a gravel thickness of 150mm, it is noticed that the road condition is not in a direct correlation with gravel thickness. For example, on Section CS 1-2, in 2013, the Gravel thickness is 151.38mm with a ride quality of 6.05 IRI while in 2019, Gravel thickness of 175.08mm will give a 6.21IRI surface condition; and on Section CS1-1, roughness achieved with a gravel thickness of 145.44mm in 2013 (8.84 IRI) is very close the one corresponding to a gravel thickness of 170.59mm in 2018 (7.58 IRI).

With Project alternative: The same trend of material loss as for without project option is observed, but for any gravel thickness greater than 145mm, a ride quality less than 9 IRI (between good and fair surface condition) can be achieved for Section CS1-1; while for road section CS1-2, gravel thickness above 150mm will sorely keep the road surface condition in a good condition (very close to 6 IRI) and any gravel thickness close to 50mm and above would be enough to maintain a good to fair road pavement condition (6-9 IRI).

Case Study 2: Rwamagana – Zaza unpaved road

Without Project alternative: Gravel thickness close to 150mm (147.12mm in 2016) can result into a good to fair ride quality (8.16 IRI) whereas much thicker gravel does not significantly improve the roughness compared to the former in 2016 (200mm gravel thickness with a roughness of 7.34 IRI in 2021).

It is also noted that a gravel thickness close to 50mm can still provide a ride quality less than 12 IRI, which is the starting point of the poor pavement condition.

With Project alternative, it is also possible to maintain a good to fair riding quality of the road when a gravel thickness of 150mm is applied: for example, 144.80mm gravel thickness vs 8.75 IRI roughness in 2019 and 141.91mm GT vs 9.39 IRI roughness. For this project investment option, it is required to have always a gravel thickness close to 100mm so that a maximum fair roughness can be maintained.

Case Study 3: Gasiza – Kibisabo – Pinus II unpaved road

Without Project alternative: The lowest Gravel Thickness achieved throughout the whole project life is 22mm in 2022 with a corresponding ride quality of 10.68 IRI which is below the maximum range for providing a fair riding quality for a tertiary road class as per Table xxx defining the default values for ride quality for unsealed roads.

With Project alternative: From the start year (2013) to 2022, the year of Gravel resurfacing, Gravel thicknesses less than 100mm entails a roughness ranging between 9.76 and 10.68 IRI which is good enough for this category of road.

Resurfacing this road in 2022 with a gravel thickness of 200mm will increase the ride quality to more than enough (6.60 IRI) and road will deteriorate very fast, thus being an unnecessary cost because a gravel thickness of 100mm would provide the required surface condition for a tertiary road like this one.

Summary and general findings for all roads

- *From the BOQs related to the construction works of all the 3 case studied roads, a gravel thickness of 200mm has been applied;*
- *Gravel thickness to be applied mainly depend upon the traffic loading*
- *There is a limit at which additional gravel thickness applied in road construction does not much contribute to pavement ride quality:*
- *Gravel thickness of 150mm would be enough for CS1-1 and CS-2, while only a 100mm gravel thick layer is required so that a good to fair pavement ride quality can be maintained all the time.*

5.2.1.3. Timing of Works

Case Study 1: Byimana – Buhanda-Kaduha unpaved road

Without investment option, regular maintenance works that include grading and spot regravelling will be carried out to provide to required level of service. Gravel resurfacing works will be performed twice in 15 years, with an interval of five years for section CS1-1 (2017 and 2023) and seven years for section CS1-2 (2018 and 2025) and this difference comes from the fact that Section CS 1-1 has much traffic than Section CS 1-2.

With investment option, regular maintenance works (grading and spot regravelling) will be performed from 2012 to 2015 before widening the two road sections in 2016. After widening, Gravel resurfacing will be done in the following year (2017) for all road sections and will be repeated every four years for Section CS 1-1 (2017, 2021 and 2025) while the interval for gravel resurfacing will be five years for Section CS 1-2 (2017 and 2022).

Total financial cost of works for the Without project option is 5,612,903 Usd, when it is estimated to be 12,356,559 Usd for With investment option; thus being an increase of 120% in investment cost.

Case Study 2: Rwamagana – Zaza unpaved road

Without Project alternative: The main maintenance operation of Gravel resurfacing will be done every seven years (2014 and 2021) while other routine maintenance works will be regularly executed every year to achieve a reasonable surface condition.

With Project alternative: After widening the road in 2013, a gravel resurfacing activity is to follow in 2014, 2018, 2022 and 2026, thus an interval of four years. Grading activities are triggered for every year of the project analysis period.

Without Project alternative has a financial cost of 4,158,896 Usd while the cost of the With Project option is 10,363,172 Usd, which represents an increase of 149% when we compare without and with project options.

Case Study 3: Gasiza – Kibisabo – Pinus II unpaved road

Without investment option, only grading activities will be performed for the first seven years of the project lifecycle, and grading works will be complemented by spot regravelling in 2020 and 2021. The single Gravel resurfacing activity is scheduled in 2022, after which regular grading works will be done until 2027, the last year of the project analysis.

With investment option, after widening the road in 2013, grading activities will be enough to maintain the road until a Gravel Resurfacing that is to take place in 2022, followed by grading works till the end of the project analysis period.

Financial cost related to without investment alternative is 764,361 Usd, and for with investment option, it is 2,966,451Usd, representing a 288% increase in investment cost when with investment option is considered.

Summary and general findings for all roads

- *Gravel resurfacing is a heavy and costly maintenance operation for a wide road of 9 meters: it is difficult to perform it every four years as it would require so close tendering process and costing of works to be done.*
- *For all studied projects, there is a high increase in investment cost (120%, 149% and 288%) when we opt for the with project alternatives.*

5.2.2. Road User Effects

Vehicle Operating Costs and Travel time costs are the main components of the Road User Costs. Variations in the costs incurred by Road Users for without and With Project options can be analysed by the following results illustrated in the MT RUC Summary per veh-km:

- Annual Average Vehicle Operating Cost per veh-km
- Annual Average Travel Time Cost per veh-km
- Annual Average Road User Cost per veh-km

Note that all mentioned costs here are total costs including all vehicle types as defined in the Vehicle Fleet Folder.

- *For all road sections, Annual Average Vehicle Operating Cots per veh-km and Annual Average Travel Time Cost per veh-km increase in a progressive manner throughout the project lifecycle except small reductions resulting from the Gravel Resurfacing works that improve the road condition (roughness and gravel thickness)*
- *When comparing With and Without Project options, Annual Average Road User Cost per veh-km is almost same since investment done does not contribute much in the road surface condition.*

5.2.3. Cost Streams

5.2.3.1. Economic Analysis Summary

The tables below show total economic benefits for case studied roads. Economic analysis is done by comparing the Base Alternative (Without Project) to Alternative (With Project).
Non Motorized Traffic was estimated to be low and hence not analyzed, Social, Accident and Environmental Costs and Benefits were not calculated as no data were available.
All costs and benefits are discounted with 10% and the currency is the United States Dollar (USD).

Case Study 1: Byimana – Buhanda - Kaduha unpaved road

Table 5.1: Economic Analysis Summary for CS1

	Increase in Road Agency Costs			Savings in MT VOC	Savings in MT Travel Time Costs	Savings in NMT Travel & Operating Costs	Reduction in Accident Costs	Net Social / Exogenous Benefits	Net Economic Benefits (NPV)
	Capital	Recurrent	Special						
Undiscounted	4.81	-0.23	0.00	0.32	0.24	0.00	0.00	0.00	- 4.03
Discounted	3.41	-0.14	0.00	0.12	0.09	0.00	0.00	0.00	-3.06

Economic Internal Rate of Return (EIRR) = - 15.4%

Source: HDM-4 Results

From the figures in the above table, the following are the Costs and Benefits of Widening by 3m CS1 road in 2016 (With Project Alternative) when compared to Maintaining the existing CS1 road (Without Project Alternative):

- Capital (investment cost) will increase by 3.41 million USD while the cost of Recurrent works would reduce by 0.14 million USD; thus being additional cost on the side of the Road Agency by summing up the increase in capital cost and the reduction in recurrent maintenance works.
- There will be a saving of 0.12 million USD in Motorized Vehicle Operating costs and a saving of 0.09 million USD in Motorized Travel Time costs: these savings are benefits of implementing the With Project Alternative.

The Net Economic Benefits (NPV) is -3.06 million USD if With Project Alternative is adopted, whereas the Economic Internal Rate of Return (EIRR) is -15.4%, meaning that project is not viable since the Costs are higher than Benefits.

Case Study 2: Rwamagana – Zaza unpaved road

Table 5.2: Economic Analysis Summary for CS2

	Increase in Road Agency Costs			Savings in MT VOC	Savings in MT Travel Time Costs	Savings in NMT Travel & Operating Costs	Reduction in Accident Costs	Net Social / Exogenous Benefits	Net Economic Benefits (NPV)
	Capital	Recurrent	Special						
Undiscounted	4.90	-0.33	0.00	1.88	0.28	0.00	0.00	0.00	- 2.40
Discounted	3.84	-0.16	0.00	0.93	0.14	0.00	0.00	0.00	-2.60

Economic Internal Rate of Return (EIRR) = - 12.8%

Source: HDM-4 Results

The above table illustrates the Costs and Benefits related to Widening by 3m CS2 road when the investment option (With Project Alternative) is compared to Do Minimum Option (Without Project*):*

- There will be an increase in the Road Agency Costs since the investment alternative would imply additional 3.84 million USD for Capital cost and only a reduction of 0.16 million USD in the costs related to recurrent maintenance works.
- Investment alternative will bring in some Benefits to the Road User side resulting from the savings of 0.93 million USD in Motorised Transport Vehicle Operating Costs and 0.14 million USD in MT Travel Time costs.

After summing up all Costs and Benefits, The Net Economic Benefits (NPV) is -2.60 million USD and the Economic Internal Rate of Return (EIRR) is -12.8%.

Since the NPV is negative and the IRR is much low than the Discount Rate (10%), the project of widening by 3 meters Rwamagana – Zaza unpaved road is not economically viable.

Case Study 3: Gasiza – Kibisabo – Pinus II unpaved road

Table 5.3: Economic Analysis Summary for CS3

	Increase in Road Agency Costs			**Savings in MT VOC**	**Savings in MT Travel Time Costs**	**Savings in NMT Travel & Operating Costs**	**Reduction in Accident Costs**	**Net Social / Exogenous Benefits**	**Net Economic Benefits (NPV)**
	Capital	**Recurrent**	**Special**						
Undiscounted	1.44	0.03	0.00	0.00	0.00	0.00	0.00	0.00	- 1.47
Discounted	1.53	0.01	0.00	0.00	0.0	0.00	0.00	0.00	-1.54

Economic Internal Rate of Return (EIRR) = - 14.3%

Source: HDM-4 Results

- The results from the above table shows that there will be an increase in the Road Agency costs as capital cost will increase by 1.53 million USD and the Recurrent maintenance works will also slightly increase by 0.01 million USD when the investment option is compared to the Do minimum scenario.
- Investment option will result into no benefits for the Road User since savings in MT Vehicle Operating Costs as well as savings in MT Travel Time costs are nil.

The result of adding up the above Costs and Benefits is – 1.54 million USD Net Present Value and an Economic Internal Rate of Return equivalent to -14.3%.

Investment in this project is therefore not economically justified since the NPV is negative and IRR is negative and largely below the Discounting Rate of 10% used for the project analysis.

Summary and general findings for all roads

- *For all case studied roads, there is high increase in Road Agency costs that result from heavy capital or initial investment cost while there is a small reduction in the costs of recurrent maintenance works for CS 1 and CS 2, while the cost of recurrent works has also increased when the With Project option is compared to Without Project alternative for CS 3.*
- *Investment option brings in small savings for the Road Users, resulting from few savings in MT VOC and MT Travel Time costs for CS1 and CS2, but those savings are nil for CS3.*
- *Higher increased costs and lower benefits for all roads result into negative NPV and IRR, and hence making economically unjustified proposed investments of widening by 3m the three studied gravel roads.*

5.2.3.2. Road Agency and User Costs

The objective of investing in road construction is to reduce costs and increase benefits as a result of a reduction in user costs and improvement in socio-economic services. The economic appraisal of road projects is therefore essentially a comparison of transport cost components calculated for at least two alternatives for road construction, usually referred to as the "Do Nothing" alternative and one or more "Do Something" or project alternatives (HDM-4 Training Course, 2009) .

Case Study 1: Byimana – Buhanda - Kaduha unpaved road

Table 5.4: Summary of Project costs CS1 (in US Dollars millions) discounted at 10%

Alternative	Total Road Agency Costs	Total Road User Costs	Total Transport Cost
With Project	5.505	19.951	**25.456**
Without Project	2.236	20.155	**22.391**

Source: HDM-4 Results

Total Transport costs for the With Project option are higher than Total Transport Costs for the Without Project option (13.69% increase). This is due to the fact that Total Road Agency Costs have significant increase (120%) while Total Road User Costs decrease sightly with investment option (10%).

Case Study 2: Rwamagana – Zaza unpaved road

Table 5.5: Summary of Project costs CS2 (in US Dollars millions) discounted at 10%

Alternative	**Total Road Agency Costs**	**Total Road User Costs**	**Total Transport Cost**
With Project	6.016	21.856	**27.872**
Without Project	2.337	22.931	**25.238**

Source: HDM-4 Results

Total Transport Costs increase by 10.44% when we compare Without Project option with the With Project option. Increase in the Total Transport Costs is a result of highly increased costs in the Total Road Agency Costs (157%) due to mainly high capital costs related to the activities of widening the road by 3m, while the benefits of widening the to the road User are negligible as the Total road User Costs are only reduced by 4.69%.

Case Study 3: Gasiza – Kibisabo – Pinus II unpaved road

Table 5.6: Summary of Project costs CS3 (in US Dollars millions) discounted at 10%

Alternative	**Total Road Agency Costs**	**Total Road User Costs**	**Total Transport Cost**
With Project	1.837	2.117	**3.954**
Without Project	0.296	2.120	**2.416**

TRAC will be increased by 520%, TRUC only reduces by 0.14% thus causing a high increase of more than 63.65% in the TTC when we compare the investment option to Do minimum alternative.

Summary and general findings for all roads

- *With Project option, Total Road Agency Costs highly increase due to heavy capital costs related to the works of widening by 3m the three case studied roads (more than 100% increase in cost)*
- *More increase in Total Road Agency Costs result into small benefits to Road User Costs (10 to 0.14% decrease in costs)*
- *For all three case studied road projects, Total Transport Costs increase in the range between 63.65% and 10.44% and since the objective of investing in road construction is to reduce the Total Transport Costs, widening the three roads by 3m is not economically justified*.

5.3. SENSITIVITY ANALYSIS

All road projects involve some degree of uncertainty in the outcome of the project. The decision to proceed with a project therefore includes some element of risk taken by road authorities. Many road projects will have a significant element of risk attached to them. These will in general be due to several factors amongst which the following are the main causes (HDM-4 Documentation):

- Unforeseen events beyond the control of the engineer; for example, improved technology, political changes.
- National economic changes; for example, future economic growth, traffic growth rates.
- Unpredictability of pavement performance due to environment, traffic, construction.
- Impact on socio-economic factors that cannot be evaluated.

It is therefore necessary to assess the impact of uncertainty on the viability of road projects for the following reasons:

- Road investments often take up a large proportion of national income, therefore any failure will be expensive,
- Alterations during implementation can be very expensive and prohibitive and should therefore be avoided by selecting the most suitable alternative at the outset,
- To determine impact of possible changes (for example, to the environment, socioeconomic) on the overall viability of road projects and plan for these accordingly.

We have conducted a Sensitivity Analysis to test errors magnitude by changing key parameters i.e Traffic Growth Rates, Construction Costs and Initial AADT.

In conducting sensitivity analysis, only one parameter was changed at a time.

Table 5.7: NPV values as result of Changes in Parameter Values

Case Study	**Base**	**Traffic Growth Rate**		**Construction Costs**			**AADT**		**Worst Case Scenario**
	(0%)	(-10%)	(+10%)	(-20%)	(-40%)	(-60%)	(+20%)	(+40%)	CC (-80%) and AADT (+150%)
CS 1	-3.06	-3.08	-3.24	-2.54	-1.97	-1.42	-3.09	-3.09	-1.04
CS 2	-2.60	-2.63	-2.58	-2.11	-1.59	-1.08	-2.47	-2.40	0.32
CS 3	-1.54	-1.54	-1.54	-1.25	-0.97	-0.68	-1.54	-1.54	-0.35

For all reasonable changes to parameter values, construction costs is the most sensitive parameter (a decrease of 60% in CC results into a 53.6% increase in NPV, but it is still negative.

A worst case scenario considers what would happen if Construction Cost decreased by 80% and at the same time, AADT was increased to a maximum of 150% (by considering Diverted and Generated Traffic resulting from Widening of unpaved roads).

Analysis results from the above table revealed that the NPV for CS2 increased by 112.3% and changed from negative to positive value. This shows that economic analysis results for CS 2 are robust. In contrast, NPV increased by 66% for CS1 and by 77.2% for CS3 but they remained negative.

5.4. ROAD DESIGN AND CONSTRUCTION STANDARDS

Following the results of road deterioration as described in the paragraph 5.2. 1 and road construction costs as per attached Bill of Quantities for the three case studied roads, it is clear that road construction costs in Rwanda are high compared to the limited improvements in the road surface condition (Level of service).

Deterioration trends that follow a road construction or rehabilitation show that despite relatively very low to medium traffic loading on rural roads in Rwanda, there is a fast and accelerated reduction of the Gravel Thickness, thus increasing road roughness and therefore increasing the Vehicle Operating Costs and Travel Time Costs which implies an increase in the Total Transport Costs. Since the traffic volume is generally low for these rural roads, the weather causes more damage than does the traffic.

The main reason for this quick reduction in the Gravel Thickness is erosion that is being caused by a poor road drainage system. For instance, only 14,500 meters out of the total road length of 49,000 meters for CS; 17,068 meters out of 31,000 meters for CS2 were provided with lined drainage channels while only earth (non lined) channels are provided for the whole length of CS3.

Longitudinal profiles of the majority of rural road in Rwanda pass through steep slopes that need adequate drainage and sometimes drainage channels are required on both sides of the road.

Three of the most important aspects of road design are **drainage, drainage, and drainage** [14]!

Appropriate drainage is necessary for controlling surface water and adequately passing water under roads in natural channels.

When surface water stagnates in potholes, ruts and sags or when kept on the road surface for long distances, it accelerates erosion as well as washes off the surface material, thus accelerating road deterioration process. The roadway surface needs therefore, to be shaped to evacuate or disperse water and move it off the road quickly and as frequently as possible.

Roadway surface water should be controlled with positive drainage measures using **outsloped, insloped**, or **crown** sections of road[14].

Outsloped roads are best to disperse water by minimising concentration of water on the roadway and minimise the road width since they reduce need for an inside crossing ditch and thus reducing considerably road construction costs. The advantages of outsloped roads are sometimes the need for rock stabilization of the roadway surface and fill slope on clayey soils and slippery road surface materials and can sometimes provide limited used during rainy periods to assure traffic safety. On road grades over 10 to 12% and on steep hill slope areas, they are difficult to drain surface water and road users can feel unsafe.

Insloped roads are good to control the road surface water but they require a system of ditches and cross-drains because they concentrate water on one side of the roadway, and therefore a need for extra road width for the ditch. The ditch requires most of the time to be lined depending upon the nature of soil of the subgrade and cut slope and the road grade so that erosion resulting from the intensity of the surface water can be controlled. Armored or lined drainage ditches and cross-drains using either rolling dips or culvert pipes that are frequently spaced enough to remove all surface water before erosion occurs can be a source of increased construction costs for this type of road section.

Crown section roads are appropriate for higher standard, two lane roads on gentle grades. They also require a system of inside ditches and cross drains thus increasing road construction costs. It is difficult to create and maintain a crown section on a narrow road while Outsloped and Insloped sections are generally applied on narrow rural roads.
These three types of road drainage measures are the most commonly used in any road project in Rwanda including the three case studied roads.
For a roadway of 9 meters (7 meters for the carriageway and 1.5 meters of shoulder at each side), insloped and outsloped sections are not possible since the evacuation of roadway surface water to one side of the road would delay and cause erosion and washing out the road surface material.

Only crown section would be suitable for quickly dispersing surface water out of the roadway.It is possible to adopt crown section and provide no drainage ditches for roads with gentle grades but most of rural road in Rwanda are located on steep terrain like the CS 3, where 46% of the total road length has a grade >7% up the maximum of 16.3% at Chainage 2+513, which means that if the road profile was mixed (cut and fill) at least one side of the roadway (cut side) would be provided with a lined drainage ditch where grade is greater than 7%. However for this particular road and like many others, the roadway passes through hills meaning cut profiles which implies a need for lined drainage ditches on both sides of the roadway.

Considering the longitudinal profile and topographic area where CS3 passes, widening this road by 3 meters would necessitate an approximate length 7,000 meters of lined drainage ditches out of the total length of 11,300 meters (62%) for effective preservation of the road at reduced maintenance cost.

However, current practices are that road designers and road agency try to minimise investment cost related to the provision of adequate drainage ditches by neglecting them where they are required, and thus increasing Road Users Costs due to poor road surface condition and Road Agency Costs that result from many Gravel Resurfacing activities that increase maintenance costs.

5.5. ROAD MAINTENANCE POLICIES AND PRACTICES

From the paragraph above, widening low traffic volume unpaved rural roads involves heavy capital budgets as well as many maintenance works for keeping the roads in good condition and thus reducing RUC.

Before even considering the widening works, maintenance level of existing roads is sometimes inadequate for the major part of the Rwandan road network due to the general expenditures related to these works. This can be illustrated by situations whereby an unpaved road might be in the need for rehabilitation in five years after being constructed, which by definition is caused by a lack of maintenance. Earth and gravel roads are much vulnerable to weather elements and will often not survive a single season without proper maintenance.

A road or path is no better than its weakest link, and one failed drainage structure or section can be sufficient to disrupt access. The principle roots of maintenance neglect are institutional and financial [13].

Maintaining unpaved earth or gravel roads is costly; as a rule of thumb, undiscounted maintenance costs over the typical life of RTI will equal the initial construction costs. For example, a typical $5,000/km basic access road may cost an average of $250 a year per km to maintain over its assumed twenty-year life, continues Jery Lebo. However, neglecting unpaved roads maintenance due to these financial implications like it happens sometimes in Rwanda can increase the Total Transport Costs as it can be proved by the following statement from Heggie; Maintaining a gravel road for ten years costs between $10,000 and $20,000 per km, depending on climate and traffic volumes. On the other hand, leaving it without maintenance for ten years will require rehabilitation costing about $40,000 per km. Rehabilitating gravel roads every ten years is thus twice as expensive, in cash terms, as regular routine and periodic maintenance, and between 14 and 128 percent more expensive in terms of NPVs discounted at 12 percent per year.

Engineers and Road Agency officials have always important tradeoffs between various road maintenance interventions, i.e routine, recurrent and periodic maintenance by comparing them with new investments.

Usually, it was observed that enhanced routine maintenance that can always maintain a proper roadway camber together with the protection of drainage structures can reduce the need for periodic maintenance and rehabilitation. This was proved by the results obtained by running HDM-4, when comparing the costs of regular and frequent grading and Gravel Resurfacing, the former is much more economical and the resulting road conditions are almost same for relatively low traffic volume unpaved roads.

The new Rwandan Roads Law provides as discussed in the Literature Review, that financing the maintenance and developments of all National roads shall be the responsibility of the Government, District and City of Kigali City roads Class one shall be financed by the Road Maintenance Fund, while District and City of Kigali roads Class two are to be financed by the respective districts and the City of Kigali.

The financing plan established by this Law could be a remedy to the shortcomings observed in the funding of road construction and maintenance since the normal practises are that RMF is responsible for all emergency, routine and periodic maintenance works for whole classified road network (paved and unpaved roads).

However, the provisions of the new road law related to road construction and maintenance funding are not adhered to because RMF's limited incomes are not only allocated to maintenance of national paved and unpaved roads, but also they are used for new road construction and rehabilitation.

RMF incomes are limited and yet are used to fund the maintenance of the whole classified road network since the main sources of incomes are mainly Road User Charge levied on gas, oil & petrol (representing 68.92%) and Road Toll levied on foreign registered Vehicles Taxes (representing 25.81%) for the Financial Year 2011-2012 (RMF Annual Report 2011-2012).

Budgets and funding problems for rural unpaved roads are combined with administrative processes (mainly tendering process) at the level of the Road Agency whereby local communities would have to report the need for road maintenance and this can take a long process for the Road Agency to visit and evaluate the required maintenance works for a specific road. This is an institutional problem in connection with sometimes the lack of sufficient number of staff to manage the whole network as well as the long tendering process required for a centralised road agency like RTDA. For instance, it might be required to execute emergency works of removing landslides that have blocked the drainage ditch on an unpaved road in a rainy season and this process could take two months or more to get the works started, after which the maintenance works would have increased (repairing the drainage ditches, regravelling a part of the road section) due to damages caused by blocked and over flooded drainage ditches and thus washing away the gravel surface material.

These changes in the scope of maintenance works result sometimes into conflicts in the contract management, whereby contractors end up with complaints that the required works to reinstate the road to a desired level of service are different from what they have tendered for.

Disputes related to project budgets due to additional works as well as claims for additional time resulting from the change in the scope of works end up most of the time in the application of delay penalties on the side of the contractor, and worse cases can lead to contract termination because sometimes the Road Agency has no room for negotiating additional budget for it might increase to high percentages that are beyond the maximum allowed for addendum (20%).

Changes in the framework for maintenance management of unpaved rural roads are required to overcome the above technical and institutional problems. The role of the centralised Road Agency (RTDA) with oversight over all classified road network should be limited to planed periodic maintenance works and other road developments. Emergency, routine and recurrent maintenance works should be done using decentralised models that provide a framework for local governments (districts) to manage unpaved under their respective area of responsibilities. This can be achieved by either signing fixed time based agreements between districts and local contractors or organising micro – enterprises from local communities who can get training on road maintenance operations or by establishing Joint Service Committees in which adjoining local authorities may come together and establish a joint committee to coordinate road maintenance activities.

The former maintenance model could be associated with equipping each district with minimum road construction equipment such as a motor grader, a roller compactor and few tippers.

This maintenance framework should be supported by technical assistance in training district engineers, technicians and local communities in charge of road maintenance works as well as by providing a budget support to districts from RTDA and RMF.

5.6. ALTERNATIVE TECHNIQUES, POLICIES AND PRACTICES FOR ROAD CONSTRUCTION AND MAINTENANCE

A Strategic Transport Master Plan for Rwanda has been prepared by Aurecon South Africa Ltd and was adopted by RTDA in 2012. The report indicated a lack of national standards for the management of road network in Rwanda and recommended urgent required actions to be taken that include the development of the following standards:

- Geometric Design Standards for National and District Roads
- Geometric Design Standards for unclassified roads and local streets
- Standards for culvert and bridge design per road classification
- Pavement Design standards
- Construction best practice including labour

Rwanda Roads Law no N°55/2011 of 14/12/2011 classifying roads and determining road widths is a good step and a starting point for the development of some road design and construction standards.

However, the present study showed that implementing that law especially widening roads before establishing other technical standards are not only cost effective but also does not provide a surplus to Road users' benefits.

Road design and construction standards to be developed should be based on different type of subgrade soils, topographic conditions and environmental including weather conditions.

Before the development of such standards, the following alternative and best practices related to road construction and maintenance are suggested but not limited to:

Alternative techniques

Gordon Keller & James Sherar developed the following typical design standards for low volume roads.

Table 5.8: Typical low volume roads design standards

Design Element	**Rural Access Road**	**Collector Road**
Design Speed	25-35 kph	45-60 kph
Road Width	3.5-4.5 m	4-5.5 m
Road Grade	15% max	12% max.
Curve Radius	15 m min.	25 m min.
Crown/Shape	Outslope /inslope (5%)	In/outslope or crown (5%)
Surfacing Type	native or gravel	Gravel, cobble- stone or pavement

Rural Access Road are suggested to be designed with a width between 3.5 and 4.5 meters, while Collector Roads should be kept to minimum widths of 4 meters up to a maximum of 5.5 meters. Our research findings proved that excessive road width for low to medium volume roads is the main reason for highly increased construction costs as well as maintenance costs. The best alternative construction technique would be to adopt a maximum width of 5.5 meter for a medium volume unpaved road and a minimum width of 3.5 meters for low volume unpaved road. The adoption of limited road widths can facilitate the provision for suitable and less costly recommended in/outsloped cross section for low volume roads that can enhance good road condition with limited maintenance operations.

It is much better to have a bad road in a good location than it is to have a good road in a bad location. A bad road can be fixed. A bad location cannot. Most of the investment in the bad road can be recovered, but little, if any, can be recovered from a bad location [14].

This is much related with the standard design road grade proposed by the same authors, where a 15% maximum road grade is recommended for rural access roads and a maximum road grade of 12% is suitable for collector roads. It was found in this research that some sections of unpaved roads in Rwanda have grades greater than 16% and it makes very difficult to manage the drainage system over these steep grades and thus causing erosion that washes away the surfacing material, implying fast road deterioration process and hence increasing road maintenance costs.

Some unpaved road sections in Rwanda also cross swampy areas that make necessary frequent repairs due to flooding like for the CS1 (Byimana-Buhanda-Kaduha) where some sections need to get heavy rehabilitation works after every rain season. The photographs below illustrate a road section at chainage 12+000 taken during site visit prior to the project final handover, one year after the road reconstruction.

Figure 5.5: CH 12+000 – Damaged road section on CS1-1 , source : Hycogec Consultant

The best alternative is therefore to carefully select a good road location. Longer routes that can increase initial road construction costs may be needed to avoid such bad road locations like steep terrains and swampy areas, but it would largely reduce maintenance costs, provide all season traffic and reduce Total Transport Costs on a long term basis.

Many areas in Rwanda have gravel or lateritic subgrade soils. However, most designs for the construction of unpaved roads tend to adopt gravel surfacing irrespective of the traffic volume and the type of the subgrade soil condition. Table xxx above shows that for rural access roads, the surfacing material can be kept to native soils. This can also be applied to other unpaved roads with low to medium traffic and good type of subgrade material. The possibility of keeping earth roads can also be demonstrated when analysing HDM-4 results for CS3 (Gasiza – Kibisabo – Pinus II) where the gravel thickness can reach zero without much affecting the road condition (roughness). Some maintenance works like gravel resurfacing are just triggered for because of the set interval intervention criteria not as a result of poor road condition.

In relation to this approach, typical standards related to subgrade soil conditions that do not need gravel resurfacing according to traffic level on a road section should be developed and implemented by all road design and construction stakeholders.

On those particular road sections, where it is possible to keep native earth subgrade, much emphasis can be put on road drainage works to avoid unnecessary gravel resurfacing incurring additional costs to road agency and preserve the environment by limiting the extraction of the surfacing materials (gravel) that are being depleted every day.

Alternative practices

Financing arrangements are crucially important. Without an adequate and stable flow of funds, road maintenance policies will not be sustainable. That is an important part of the problem in Africa. Road maintenance expenditures in virtually all countries are well below the levels needed to keep the road network in stable long-term condition. In most countries, they are less than half the estimated requirements and, in some, less than a third [8]. Ian G. Heggie continues to say that the flow of funds for financing road maintenance is erratic as budget allocations are often cut at short notice in response to difficult fiscal conditions, funds are rarely released on time, and actual expenditures are often well below agreed budget allocations.

Countries continue to upgrade existing roads and build new ones even when there are no funds to maintain them. One of the reasons for preferring construction over maintenance is that maintenance is financed under the recurrent budget, while investment is financed under the development budget. Since donors are willing to support the development budget, development funds are less constrained than recurrent funds, which are mainly financed from domestic revenue sources. However, a more important reason for favoring new construction is that contracts tend to be larger (hence offering greater opportunities for gratification payments) and are politically more visible and glamorous.

This situation happens in Rwanda and this is mostly due to inadequate funding practice whereby maintenance of the whole road network is being financed through the recurrent budget from RMF, resulting into continuous roads deterioration and, rural unpaved roads regularly become impassable during the rainy season, and the large backlog of road rehabilitation continues to increase.

Road prioritization should be reviewed objectively in many Sub-Saharan African countries to better take into account economic potential. Probably more priority should be assigned to maintenance or rehabilitation than to network expansion [5].

It is therefore necessary to allocate some of development budget for road maintenance operations as provided by the new Road Law, instead of allocating the whole of the development budgets in new road construction.

The main reason why road maintenance is underfunded is that road users pay very little for the use of the road network. They pay the usual import duties, excise taxes and sales taxes, but so does everyone else. Road user charges in the form of vehicle license fees, a specific surcharge added to the price of fuel (the fuel levy), and international transit fees rarely cover more than 50 percent of expenditures on maintenance and, in some countries, barely cover 25 percent . Most road expenditures are still financed from general tax revenues and donor-financed loans and grants. This is not necessary. Roads can be commercialized, put on a fee-for-service basis, and treated like any other public enterprise [8].

In Rwanda, many road charges like over weights (weighbridges) are not paid. It is therefore necessary to review road charge policing so that revenue collection can be maximised for the benefit of RMF to be able to meet road maintenance requirements.

Lack of enough budgets for unpaved road maintenance frequently leads to late responsiveness to required maintenance works, and most of time maintenance works are carried out as emergency works resulting to complete road failure. Many mistakes always happen in estimating the required actions for road maintenance.

The alternative best practice is to enhance road surveys and conduct thorough field investigations especially during the rains to observe the movement of water before designing and estimating the volume of works to be done and contractors should carefully conduct study reviews before sta

5.7. SUMMARY

In this chapter, after analysing HDM-4 results, it was proved that widening the case studied unpaved roads results into increased Total Road Agency Costs and insignificantly decreased Total Road User Costs and, thus making higher Total Transport Costs compared to the base scenario of maintaining the existing unpaved road widths and finally leading to negative NPV and IRR. Negative values of these economic indicators show that all proposed projects of widening the three unpaved roads are not cost effective and not viable.

By conducting sensitivity analysis, the main reason for cost ineffectiveness was found to be high initial investment costs related the works of widening of roads together with high maintenance costs of such wide roads.

The research has identified some weaknesses of road design and construction standards especially poor road drainage system and cross sectional profiles that contribute to quick road deterioration and proposed the best design and construction standards to be adopted.

Malpractices and poor policing in unpaved road construction and maintenance like inadequate funding schemes were discussed and the best management practices and policies were developed for different road network stakeholders.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6. 1.CONCLUSION

1. Based on the analysis of the data collected on the case studied unpaved road, construction and maintenance costs are very high due to adopted road geometric design standards especially excessive road width as proposed by the new Rwanda Road Law no N°55/2011 of 14/12/2011.

2. High construction and maintenance costs together with low traffic volume on unpaved roads are the main causes of increased Total Transport Costs for all studied roads and yet, widening those unpaved roads according to the provisions of the above law do not contribute much to improve the average road condition. This causes negative NPVs and IRR and therefore leading to conclude that investments done in widening low volume unpaved roads are not economically justified.

3. The Research proved that road design and construction standards in practice today in Rwanda related to road width, road grade, road location drainage system and surfacing materials are sometimes not suited to Rwandan condition and therefore not cost effective.
4. Road construction and maintenance policies and practices in Rwanda were found to have inadequate institutional and financing arrangements where road maintenance is neglected leading to pre mature full rehabilitation and/or reconstruction of unpaved roads.
5. Alternative road construction and maintenance techniques that can reduce Total Transport Costs like minimizing road width, avoiding steep road grade by selecting good location, providing adequate drainage system and surfacing unpaved road with gravel where it is necessary were found to be the best options for assuring good road condition, minimizing Road Agency costs and thus making investments economically viable.

6. The following but not limited to, alternative practices and policies were found to be key elements for appropriate maintenance management of unpaved roads:

- Improved road surveys before designing: inspection during the rains to observe the movement of water
- Study reviews before starting the works
- Decentralisation of unpaved road funding schemes
- Objective prioritization of road works by optimizing maintenance activities instead of constructing new roads.
- Increasing road maintenance financing by creating additional sources of funds like road use charging where possible and complementing recurrent budget by development budgets.

6.2. RECOMMENDATIONS

1. Data Analysis and testing was done using HDM-4 for all case studied roads with low to medium traffic volume. Further research using Roads Economic Evaluation Model (RED) is required since it might be the most appropriate analysis tool for very low volume unpaved roads.
2. Article 11 of Rwanda Road Law no N°55/2011 of 14/12/2011 says that a Ministerial order shall define the technical and service standards for roads based on the study and research conducted by experts on the entire road network of Rwanda in general. Since this order is not yet established,

   Rwanda Transport Development Agency should postpone implementation of some articles of this law, especially widening of unpaved roads, because it was found to be not cost effective.
3. Road development and maintenance funding policy should be implemented as provided by the road Law: all road development works as well as all types of maintenance of all national roads shall be funded through government development budgets, while the RMF should only fund maintenance of other classified road network. Additional funds should also be mobilized from other sources of incomes like

road user charging for increasing the funding capacity of RMF. The decentralization of road funding schemes at the local government levels together with capacity building for local technical staff in charge of road maintenance works should be initiated.

4. Before the publication of other orders and standards that are needed to complement Rwanda roads Law, the following alternative techniques and best management practices can improve the quality of road construction and maintenance, but can also increase economic benefits of investments done in unpaved roads in Rwanda:

   a. Minimizing the width of unpaved low to medium volume roads
   b. Improving the drainage system of unpaved roads
   c. Adoption of in/outsloped road sections wherever possible
   d. Avoiding steep grades and swampy areas by selecting most suitable routes for unpaved roads
   e. Gravel surfacing should be used after thoroughly studying the subgrade soil and traffic level on any unpaved road; native or earth surfacing should be adopted where conditions are favorable
   f. Enough site visits before determining the required maintenance works and study reviews prior to commencement of works are recommended for effective road maintenance management.

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APPENDICES:

Appendix 4.1: Final updated BoQ for the Periodic Maintenance of Byimana-Buhanda-Kaduha (49km)

PRICE No	ROAD WORKS DESCRIPTION	U	U.P (RWF)	QUANTITY	AMOUNT
I. ROAD WORKS					
100	**SITE MOBILISATION**				
101	General site mobilisation and demobilisation	Ls	80,000,000	1.00	80,000,000.00
	Sub Total 100				**80,000,000.00**
200	**SURVEYING**				
201	Surveying (before, during and after works)	Ls	15,000,000	1.00	15,000,000.00
	Sub Total 200				**15,000,000.00**
300	**PREPARATORY WORKS**				
301	Bushes removal, top soil removal	m2	180	185,574.60	33,403,428.00
302.a	Cutting of trees with derooting	pce	20,000	293.00	5,860,000.00
302.b	Cutting of trees without derooting	pce	20,000	185.00	3,700,000.00
303	Removal of roots in road way	m2	2,000	650.00	1,300,000.00
304	Top soil stripping	m2	300	117,500.00	35,250,000.00
305	Relocation of electriacl pawls and cables	lm	3,000	250.00	750,000.00
306	Relocation of water taps and pipes	lm	2,000	210.00	420,000.00
	Sub Total 300				**80,683,428.00**
400	**EARTHWORKS**				
401	Top soil removal off site including haulage	m3	2,000	211,460.00	422,920,000.00
402	Cutting in rocky ground				
402.a	Cutting in rocky ground using machnine rippers	m3	12,000	2,786.00	33,432,000.00
402.b	Cutting in rocky ground using explosives	m3	14,000	2,150.00	30,100,000.00
403	Bad soil drain off	m3	2,500	10,985.00	27,462,500.00
404	Removal of landslides	m3	2,200	4,500.00	9,900,000.00
405	BackFilling with borrowed materials	m3	4,000	17,408.00	69,632,000.00
406	Levelling, compaction and finishing the sub grade	m2	500	352,500.00	176,250,000.00
	Sub Total 400				**769,696,500.00**
500	**CARRIAGEWAY**				
501	Wearing course in lateritic gravel	m3	7,800	65,100.00	507,780,000.00
502	Extra cost for material transport over 5 km	m3/km	400	386,000.00	154,400,000.00
	Sub Total 500				**662,180,000.00**
600	**DRAINAGE WORKS**				
601.a	Earth drainage channel in soft terrain	lm	500	29,720.00	14,860,000.00
601.b	Earth drainage channel in rocky terrain	lm	800	5,380.00	4,304,000.00
602	Stone masonry channels	lm			
	Type I	lm	23,000	150.00	3,450,000.00
	Type II	lm	27,000	14,250.00	384,750,000.00
603	Supply and install pipe culverts in RCC	lm			
603.a	Culvert □60cm	lm	70,000		
603.b	Culvert □□ 0cm	lm	90,000	754.00	67,860,000.00
603.c	Culvert □□□ 0cm	lm	120,000	55.00	6,600,000.00

604	Stone masonry for culvert headwalls, etc …	m3	62,000	1,280.00	79,360,000.00
605	Stone rip raps of 30 to 50 kg	m3	35,000	248.30	8,690,500.00
606	Protective Gabions	m3	72,000	1,666.20	119,966,400.00
607	Retaining walls in stone masonry	m3	65,000	469.00	30,485,000.00
608	Downstream exit channelsl	lm	25,000	441.40	11,035,000.00
609	Clearing of Existing culverts	lm	2,000	30.00	60,000.00
610	Under ground drainage	lm	25,000	220.00	5,500,000.00
611	Extra cost for material transport over 5 km	m3	500	150.00	75,000.00
612	Demolition of existing structures	m3	15,000	90.00	1,350,000.00
	Sub Total 600				**738,345,900.00**
700	**VARIOUS STRUCTURES**				
701	Pedestrian crossing facilities				
701.a	Abutments in stone masonry	m3	65,000	60.00	3,900,000.00
701.b	RC slabs, thick 15cm	m3	270,000	16.29	4,398,300.00
702	Vehicle crossing facilities				
702.a	Abutments in stone masonry	m3	65,000	131.96	8,577,400.00
702.b	RC support walls	m3	270,000	37.71	10,181,700.00
702.c	RC slabs, thick 20cm	m3	280,000	25.92	7,257,600.00
703	Grass planting	m2	3,500	2,400.00	8,400,000.00
704	Intercepting ditches	lm	1,500	1,490.00	2,235,000.00
	Sub Total 700				**44,950,000.00**
800	**ROAD SIGNING**				
801	Vertical signs installation	Pce	180,000	98.00	17,640,000.00
	Sub Total 800				**17,640,000.00**
	TOTAL I : ROAD WORKS				**2,408,495,828.00**
II. CIVIL STRUCTURES					
Construction of RCC Box Culvert at CH1+875					
	Total Box Culvert at CH 1+875				7,098,925.00
Construction of RCC Box Culvert at CH3+480					
	Total Box Culvert at CH 3+480				7,850,550.00
Rehabilitation of a RC Bridge at CH 5+025					
	Total Bridge at CH 5+025				438,000.00
Construction of RCC Box Culvert at CH 6+125					
	Total Box Culvert at CH 6+125				8,657,550.00
Construction of RCC Box Culvert at CH 7+468					
	Total Box Culvert at CH 7+468				6,344,800.00
Rehabilitation of a RC Bridge at CH 8+367					
	Total Bridge at CH 8+367				380,000.00
Construction of RCC Box Culvert at CH 9+225					
	Total Box Culvert at CH 9+225				7,873,750.00
Construction of RCC Box Culvert at CH 9+380					
	Total Box Culvert at CH 9+380				11,657,500.00
Construction of RC Bridge at CH 11+425					
	Total RC Bridge at CH 11+425				21,549,500.00
Construction of RCC Box Culvert (0.7 x 0.7) at CH 11+580					

	Total Box Culvert at CH 11+580				4,051,989.10
Construction of RCC Box Culvert (0.7 x 0.7) at CH 11+715					
	Total Box Culvert at CH 11+715				4,051,989.10
Construction of RCC Box Culvert at CH 12+825					
	Total Box Culvert at CH 12+825				9,422,050.00
Construction of RCC Box Culvert at CH 20+925					
	Total Box Culvert at CH 20+925				15,321,800.00
Construction of RCC Box Culvert at CH 24+275					
	Total Box Culvert at CH 24+275				4,382,500.00
Construction of RCC Box Culvert at CH 24+825					
	Total Box Culvert at CH 24+825				18,991,500.00
Rehabilitation of an Arch Bridge at CH 28+280					
	Total Arch Bridge at CH 28+280				918,500.00
Construction of RCC Box Culvert at CH 32+375					
	Total Box Culvert at CH 32+375				7,747,500.00
Rehabilitation of an Arch Bridge at CH 33+855					
	Total Arch Bridge at CH 33+855				110,000.00
Construction of RCC Twin Box Culvert (1.00 x 0.7) at CH 35+888					
	Total Twin Box Culverts at CH 35+888				9,171,500.00
Rehabilitation of an Arch Bridge at CH 36+705					
	Total Arch Bridge at CH 36+705				253,000.00
Construction of RCC Box Culvert at CH 38+078					
	Total Box Culvert at CH 38+078				7,820,050.00
Construction of RCC Box Culvert at CH 44+964					
	Total Box Culvert at CH 44+964				6,784,250.00
	Total for Concrete Structures				**160,877,203.20**
REHABILITATION OF OTHER BAILEY BRIDGES					
	Rehabilitation of a bailey bridge at CH 11+950	Ls	2,000,000	**1.00**	2,000,000
	Verification and replacement of defectives bolts and nuts				
	Welding and fixing of old steel elements				
	Replacement of old wooden deck, painting etc...				
	Rehabilitation of a bailey bridge at CH 30+775	Ls	2,000,000	**1.00**	2,000,000
	Verification and replacement of defectives bolts and nuts				
	Welding and fixing of old steel elements				
	Replacement of old wooden deck, painting etc...				
	Rehabilitation of a bailey bridge at CH 38+900	Ls	2,000,000	**1.00**	2,000,000
	Rehabilitation of stone masonry elements				
	River banks protection, realignment of the river bed				
	Total for Rehabilitation of Bailey bridges				**6,000,000.00**
	TOTAL II : CONCRETE STRUCTURES & BAILEY BRIDGES				**166,877,203.20**
III. REHABILITATION OF A RAVINE FROM CH 1+575 TO CH 1+825					
302.a	Cutting of trees with derooting	Pce	20,000	13.00	260,000.00

401	Top soil removal off site including haulage	m3	2,000	1,830.65	3,661,300.00
405	BackFilling with borrowed materials	m3	4,000	992.00	3,968,000.00
406	Levelling, compaction and finishing the sub grade	m2	500	2,170.00	1,085,000.00
704	Intercepting ditches	ml	1,500	116.67	175,000.50
602	Stone masonry channels, Type 1	ml	23,000	250.00	5,750,000.00
606	Protective Gabions	m3	72,000	135.00	9,720,000.00
1006	Stone masonry for culvert head walls	m3	62,000	10.33	640,600.12
703	Grass planting	m2	3,500	950.00	3,325,000.00
	Total for the Rehabilitation of the Ravin				**28,584,900.62**
	TOTAL COST OF THE PROJET				**2,603,957,931.82**

Source : Hycogec Consultant, Project Update, March 2011.

Appendix 4.2: Final updated BoQ for the Periodic Maintenance of Rwamagana - Zaza (31km)

S/No	Designation of work	Unit	QTY (6 m)	QTY (7 m)	Unit price	Amount (for 6m width)	Amount (for 7m width)
100	**SITE INSTALLATION**						
101	Installation and withdraw of site	FF	1	1	40,000,000	40,000,000	40,000,000
	S/Total					**40,000,000**	**40,000,000**
200	**TOPOGRAPHY**						
201	Topography (before, during and after completion of works	FF	1	1.24	15,000,000	15,000,000	18,600,000
	S/Total					**15,000,000**	**18,600,000**
300	**PRELIMINARY WORKS**						
301	Trees cutting without removing roots	Item	314	342	15,000	4,710,000	5,130,000
302	Removing roots of trees	Item	196	230	15,000	2,940,000	3,450,000
303	Clearing of undergrowth-cleaning of road surface	m2	198,896	263,924	200	39,779,200	52,784,800
304	Top soil stripping	m3	52,340	90,048	600	31,404,000	54,028,800
305	Displacement of water pipes, electrical cables and fiber optic	lm	4,500	4,500	2,500	11,250,000	11,250,000
306	Demolition of existing masonry and concrete structures	m3	396	722	3,500	1,386,000	2,527,000
	S/Total					**91,469,200**	**129,170,600**
400	**EARTHWORKS**						
401	Excavation of any nature and removal in final deposit	m3	45,549	44,996	1,500	68,323,500	67,494,000
402	Excavation of any nature to use for embankment	m3	2,700	29,536	2,500	6,750,000	73,840,000
403	Rocks excavation put in final deposit	m3	0	0	3,000	0	0
404	Extra cost for prices 401 and 403 (> 5000ml)	m3*km	85,000	105,121	300	25,500,000	31,536,300
405	Scarification, adjustment, compaction and completion of the platform	m2	164,498	299,012	1,100	180,947,800	328,913,200
405 bis	Adjustment of the platform in rock ground	m2	0	0	2,500	0	0
406	Removal of heap rocks	m3	0	0	3,500	0	0
407	Repairing of dump area	m2	12,400	12,400	800	9,920,000	9,920,000
408 a	Embankment from excavated soil	m3	17,138	43,136	1,500	25,707,000	64,704,000
408 b	Embankment from borrowing pits	m3	5,625	24,098	1,500	8,437,500	36,147,000
409	Extra cost for transport to apply to price 408 (> 5000 ml)	m3*km	34,029	42,464	300	10,208,700	12,739,200
410	Purge marshy soil	m3	26,125	26,125	2,000	52,250,000	52,250,000
	S/Total					**388,044,500**	**677,543,700**
500	**ROADWAY**						
501	Wearing course thickness 20cm	m3	39,479	68,357	4,000	157,916,000	273,428,000
502	Extra cost for transport >	m3*k	35,600	70,970	200	7,120,000	14,194,000

	5Km	m					
	S/Total					**165,036,000**	**287,622,000**
600	**DRAINAGE AND CROSSINGS**						
601	Cleaning of the existing under road crossings	lm	290	350	1,500	435,000	525,000
602	Cleaning-reshaping of the existing water drainage	lm	150	150	500	75,000	75,000
	S/Total					**510,000**	**600,000**
603	**Supply and installation of concrete culverts**						
603 a	Supply and install of concrete culvert Ø 80cm	lm	371	800	110,000	40,810,000	88,000,000
603 b	Supply and install Culvert Ø 100cm	lm	42	60	160,000	6,720,000	9,600,000
604	Reinforced concrete proportioned at 350 Kg/m3 for all works	m3	80	80	180,000	14,400,000	14,400,000
605	Stone masonry works for culverts head	m3	793	793	35,000	27,755,000	27,755,000
606	Paving jointed with the mortar	m2	680	994	3,000	2,040,000	2,982,000
607	Stone riprap of 30 to 50Kg	m3	2,285	2,285	10,000	22,850,000	22,850,000
608	Various works in gabions	m3	2,700	2,700	57,000	153,900,000	153,900,000
609	Ground water drainage to be created	lm	15,356	21,256	1,000	15,356,000	21,256,000
609 bis	Ground water drainage in rock soil	lm	0	0	2,000	0	0
610	Discharge system for under way crossing	lm	3,200	3,200	2,000	6,400,000	6,400,000
611	Discharge in the excavated soil	lm	1,500	1,500	2,000	3,000,000	3,000,000
612	Stone masonry works for various works	m3	700	700	35,000	24,500,000	24,500,000
613	Mattress	lm	0	0	1,500	0	0
614	Plantation of trees and shrubs	pce	780	780	1,000	780,000	780,000
615	Grass plantation	m2	9,000	13,000	1,500	13,500,000	19,500,000
616	Improvement of the existing bridges	FF	1	1	5,000,000	5,000,000	5,000,000
616 a	Beacons out of wooden	pce	440	440	20,000	8,800,000	8,800,000
	S/Total					**345,811,000**	**408,723,000**
617	**Masonry drainage**						
617 a	Masonry drainage type I	lm	3,050	3,050	19,000	57,950,000	57,950,000
617 b	Masonry drainage type II	lm	4,248	4,248	23,000	97,704,000	97,704,000
617 c	Masonry drainage type III	lm	9,770	9,770	25,000	244,250,000	244,250,000
618	Intercepting ditch	lm	5,000	11,000	6,000	30,000,000	66,000,000
	S/Total					**429,904,000**	**465,904,000**
619	**Passage for pedestrian**						
619 a	Oven walls in rubble work for pedestrian	m3	146	153	35,000	5,110,000	5,355,000
619 b	RC slab thickness 10cm	m3	184	187	100,000	18,400,000	18,700,000
	S/Total					**23,510,000**	**24,055,000**

620	**Passage for vehicles**						
620 a	Oven walls in stones work for vehicles	m3	174.72	184	35,000	6,115,200	6,440,000
620 b	RC slab thickness 15cm	m3	138.6	146	120,000	16,632,000	17,520,000
	S/Total					**22,747,200**	**23,960,000**
	DYKE/ CYARUHOGO VALLEY (4KM)+GISAYA DYKE						
408 a	Embankment from excavated soil	m3	0	0	2,500	0	0
408 b	Embankment from borrowing pits	m3	29,194	34,690	4,000	116,776,000	138,760,000
603 b	Supply and install Culvert Ø 100cm (Reinforced)	ml	0	0	150,000	0	0
610	Discharge system for under way crossing	ml	0	0	2,200	0	0
	S/Total					**91,469,200**	**138,760,000**
	GENERAL TOTAL					**1,613,501,100**	**2,214,938,300**
	ADDITIONAL AMOUNT						**601,437,200**
	PERCENTAGE OF INCREASE						**37.27%**

Source: Hycogec Consultant, 2013

Appendix 4.3: Estimated Bill of Quantities for the Rehabilitation of Gasiza-Kibisabo-Pinus II road

PRICE No	DESCRIPTION OF WORK	UNIT	QTY 6m	QTY 7m	UNIT PRICE(FRW)	AMOUNT (for 6m)	AMOUNT (for 7m)
	Serial 01 - GENERAL PRICES						
101	Site installation	Ls	1	1	16,612,713	16,612,713	16,612,713
102	Surveying before, during and after works	Ls	1	1	2,768,776	2,768,776	2,768,776
	Total Serial 01 - GENERAL PRICES					**19,381,489.00**	**19,381,489**
	Serial 02 - PREPARATORY WORKS						
201	Bushes removal, site clearing and top soil removal	m2	136,776.39	170,691.40	180	24,619,750	30,724,452
202	Cutting of trees of circumference > 30 cm and derooting	no	175	238	7,190	1,258,250	1,711,220
203	Demolition of existing structures in masonry or RCC	m3	134.22	134.22	27,500	3,691,050	3,691,050
	Total Serial 02 - PREPARATORY WORKS					**29,569,050.20**	**36,126,722**
	Serial 03 - DRAINAGE WORKS						
301	Cleaning of existing drainage channels (channels, culverts, box culverts)	Lm			290		
302	Lateral drainage channel in stone masonry	Lm	231	231	31,100	7,184,100	7,184,100
303	Exit channels towards ravines in stone masonry	Lm			31,100		
304	Excavation for outlet structures	m3	396	396	6,100	2,415,600	2,415,600
305	Stone Ripraps protection of 30 to 50 kg on downstream outlets	m3	200	200	35,000	7,000,000	7,000,000
306	Blinding concrete of grade 250kg/m3	m3	36.83	36.83	143,000	5,266,690	5,266,690
307	Concrete of grade 300kg/m3	m3			174,000		
308	RCC of grade 350kg/m3 for various structures	m3			305,000		
309	Stone masonry	m3	325.71	325.71	60,750	19,786,883	19,786,883
310	**Longitudinal masonry lined ditches B x b x H (Trapezoidal type)**						
a	Type B : 1.30m x 0.50m x 0.80m (thick = 0.25m)						
b	Type A : 1.00m x 0,40m x 0.60m (thick = 0.25m)						
311	**Triangular earth channels B x h**						
a	In soft area 1.00m x 0.40m x 0.60m	Lm	15,125.00	15,125.00	900	13,612,500	13,612,500
b	In rocky area 1.00m x 0.40m x 0.60m	Lm			1,200		
312	**Crest non lined trapezoidal ditch (intercepting) B x b x H**						
a	*In soft ground 0.65m x 0,25m x 0.40m*	Lm	*15,125.00*	*15,125.00*	*1,500*	22,687,500	22,687,500
313	**Crossing culvert in concrete**						
a	Ø 60, for river crossing	Lm			57,200		

b	Ø 80, for water conveyance and road crossings	Lm	72	90	79,900	5,752,800	7,191,000
e	Ø 100, for water conveyance and road crossings	Lm	126	189	111,000	13,986,000	20,979,000
	Total Serial 03 - DRAINAGE WORKS					**97,692,073**	**106,123,273**
	Serial 04 - ROAD SURFACE						
401	Cuttings plus haulage in soft ground	m3	135,712.00	237,457.00	2,500	339,280,000	593,642,500
402	Cuttings plus haulage in rocky ground	m3			15,000		0
403	Bad soil drain off	m3			2,500		0
404	Levelling, compaction and finishing of the sub grade	m2	73,488.22	107,403.00	800	58,790,576	85,922,400
405	Compacted backfills from borrow pits	m3	5,582.50	9,211.13	4,000	22,330,000	36,844,520
406	Fill from cut materials	m3	5,582.50	8,347.58	3,000	16,747,500	25,042,740
407	Wearing course in selected gravel material	m3	13,567.06	20,452.20	9,285	125,970,115	189,898,677
408	Gabion boxes for protection	m3	200	340.00	72,000	14,400,000	24,480,000
409	Gabion boxes Geotextile	m2	1,800.00	3,060.00	9,000	16,200,000	27,540,000
410	Extra transport cost for prices 405 & 406	m3.km	101,752.92	161,089.10	500	50,876,460	80,544,550
411	Layouts and implementation of junctions (T form or Gyration)	No			267,012	0	0
	Total Serial 04 - ROAD SURFACE					**644,594,651**	**1,063,915,387**
	Serial 05 -OTHER MISCELLANEOUS STRUCTURES						
501	Stone riprap of 30 to 50 kg for protection of abutments	m3			35,000		
502	Concrete works dosed at 250kg/m3	m3			143,000		
503	Concrete works dosed at 300kg/m3	m3			174,000		
504	Structures in reinforced concrete dosed at 350kg/m3	m3			305,000		
505	Stone masonry or rockfill	m3			60,750		
506	Squared timber deck	m2			30,000		
507	Paint for signs	m2			60,750		
	Total Serial 05 - OTHER MISCELLANEOUS STRUCTURES					-	
	TOTAL					**791,237,263.2**	**1,225,546,871.00**

Source: Hycogec, Technical studies for the construction of GWLM access road network (2012)

Appendix 5.1.A : Annual Road Condition - CS1-2 (with project alternative)

Study Name: Widening by 3m CS 1: Byimana-Buhanda -Kaduha unpaved road

Run date: 02-09-2013

Section Details:ID: CS 1-2 Buhanda - Kaduha Road Class: Secondary or Main

Length: 27.00km 6.00m Rise + Fall: 65.00m/km Curvature: 50.00deg/km

With Project: Widenning by 3m Gravel Road CS1 Unsealed Pavement

Year	MT		Pavement Type	Gravel Thickness	Mean Roughness IRI
	AADT			(mm) THG	IRI (m/km) Rlav
2012	78	Before works	Gravel	175.73	6.07
		After works	Gravel	175.73	
2013	82	Before works	Gravel	151.38	6.05
		After works	Gravel	151.38	
2014	87	Before works	Gravel	126.96	6.79
		After works	Gravel	126.96	
2015	92	Before works	Gravel	102.44	7.37
		After works	Gravel	102.44	
2016	97	Before works	Gravel	77.83	8.33
		After works	Gravel	118.55	
2017	102	Before works	Gravel	93.84	7.20
		After works	Gravel	200.00	
2018	108	Before works	Gravel	175.19	6.19
		After works	Gravel	175.19	
2019	114	Before works	Gravel	150.27	6.39
		After works	Gravel	150.27	
2020	120	Before works	Gravel	125.23	7.33
		After works	Gravel	125.23	
2021	127	Before works	Gravel	100.07	7.98
		After works	Gravel	100.07	
2022	134	Before works	Gravel	74.79	8.26
		After works	Gravel	200.00	
2023	141	Before works	Gravel	174.58	6.31
		After works	Gravel	174.58	
2024	149	Before works	Gravel	149.01	6.75
		After works	Gravel	149.01	
2025	158	Before works	Gravel	123.29	7.86
		After works	Gravel	123.29	
2026	166	Before works	Gravel	97.41	8.56
		After works	Gravel	105.17	

Appendix 5.1.B : Annual Road Condition - CS1-2 (without project alternative)

Section Details:

ID: **CS 1-2** **Buhanda - Kaduha** **Road Class: Secondary or Main**

Length: **27.00km** **6.00m** **Rise + Fall: 65.00m/km** **Curvature:** **50.00deg/km**

Without Project: Maintain Existing Gravel Road CS1 Unsealed Pavement

Year	**MT**		**Pavement Type**	**Gravel Thickness**	**Mean Roughness IRI**
	AADT			(mm) THG	**IRI (m/km) Rlav**
2012	78	Before works	Gravel	175.73	6.07
		After works	Gravel	175.73	
2013	82	Before works	Gravel	151.38	6.05
		After works	Gravel	151.38	
2014	87	Before works	Gravel	126.96	6.79
		After works	Gravel	126.96	
2015	92	Before works	Gravel	102.44	7.37
		After works	Gravel	102.44	
2016	97	Before works	Gravel	77.83	7.64
		After works	Gravel	85.21	
2017	102	Before works	Gravel	60.50	7.78
		After works	Gravel	67.92	
2018	108	Before works	Gravel	43.10	7.89
		After works	Gravel	200.00	
2019	114	Before works	Gravel	175.08	6.21
		After works	Gravel	175.08	
2020	120	Before works	Gravel	150.04	6.46
		After works	Gravel	150.04	
2021	127	Before works	Gravel	124.89	7.43
		After works	Gravel	124.89	
2022	134	Before works	Gravel	99.60	8.09
		After works	Gravel	107.19	
2023	141	Before works	Gravel	81.76	8.37
		After works	Gravel	89.39	
2024	149	Before works	Gravel	63.82	8.52
		After works	Gravel	71.49	
2025	158	Before works	Gravel	45.77	8.64
		After works	Gravel	200.00	
2026	166	Before works	Gravel	174.12	6.41
		After works	Gravel	174.12	

Appendix 5.1.C : Annual Road Condition - CS1-1 (with project alternative)

Section Details:

ID: CS 1-1 Byimana - Buhanda Road Class: Secondary or Main

Length: 20.00km 6.00m Rise + Fall: 55.00m/km Curvature: 100.00deg/km

With Project: Widenning by 3m Gravel Road CS1 Unsealed Pavement

Year	MT		Pavement Type	Gravel Thickness	Mean Roughness IRI
	AADT			(mm) THG	**IRI (m/km) Rlav**
2012	274	Before works	Gravel	172.89	7.13
		After works	Gravel	172.89	
2013	289	Before works	Gravel	145.44	8.84
		After works	Gravel	145.44	
2014	306	Before works	Gravel	117.65	10.69
		After works	Gravel	117.65	
2015	323	Before works	Gravel	89.48	11.50
		After works	Gravel	97.93	
2016	341	Before works	Gravel	69.38	12.84
		After works	Gravel	119.27	
2017	361	Before works	Gravel	90.30	10.13
		After works	Gravel	200.00	
2018	381	Before works	Gravel	170.59	7.58
		After works	Gravel	170.59	
2019	403	Before works	Gravel	140.72	9.81
		After works	Gravel	140.72	
2020	426	Before works	Gravel	110.36	11.70
		After works	Gravel	110.36	
2021	450	Before works	Gravel	79.48	12.38
		After works	Gravel	200.00	
2022	476	Before works	Gravel	168.57	7.96
		After works	Gravel	168.57	
2023	503	Before works	Gravel	136.56	10.50
		After works	Gravel	136.56	
2024	532	Before works	Gravel	103.93	12.34
		After works	Gravel	103.93	
2025	562	Before works	Gravel	70.66	12.90
		After works	Gravel	200.00	
2026	594	Before works	Gravel	166.04	8.39
		After works	Gravel	166.04	

Appendix 5.1.D: Annual Road Condition - CS1 (without project alternative)

Section Details:

ID:	CS 1-1	Byimana - Buhanda		Road Class:	Secondary or Main
Length:	20.00km	6.00m	Rise + Fall: 55.00m/km	Curvature:	100.00deg/km
		With Project: Widenning by 3m Gravel Road CS1 Unsealed Pavement			

Year	**MT**		**Pavement Type**	**Gravel Thickness**	**Mean Roughness IRI**
	AADT			(mm) THG	**IRI (m/km) Rlav**
2012	274	Before works	Gravel	172.89	7.13
		After works	Gravel	172.89	
2013	289	Before works	Gravel	145.44	8.84
		After works	Gravel	145.44	
2014	306	Before works	Gravel	117.65	10.69
		After works	Gravel	117.65	
2015	323	Before works	Gravel	89.48	11.50
		After works	Gravel	97.93	
2016	341	Before works	Gravel	69.38	11.75
		After works	Gravel	77.94	
2017	361	Before works	Gravel	48.97	11.90
		After works	Gravel	200.00	
2018	381	Before works	Gravel	170.59	7.58
		After works	Gravel	170.59	
2019	403	Before works	Gravel	140.72	9.81
		After works	Gravel	140.72	
2020	426	Before works	Gravel	110.36	11.70
		After works	Gravel	110.36	
2021	450	Before works	Gravel	79.48	12.38
		After works	Gravel	88.74	
2022	476	Before works	Gravel	57.31	12.57
		After works	Gravel	66.74	
2023	503	Before works	Gravel	34.73	12.70
		After works	Gravel	200.00	
2024	532	Before works	Gravel	167.38	8.17
		After works	Gravel	167.38	
2025	562	Before works	Gravel	134.10	10.86
		After works	Gravel	134.10	
2026	594	Before works	Gravel	100.14	12.64
		After works	Gravel	100.14	

Appendix 5.1.E : Annual Road Condition - CS2 (with project alternative)

Study Name: **Widening by 3m CS 2: Rwamagana -Zaza unpaved road**
Run Date: **03-09-2013**

Section Details:

ID: CS 2 Description: Rwamagana - Zaza Road Class: Secondary or Main
Length: 31.00km Width: 6m Rise + Fall: 57.00m/km Curvature: 100.00 deg/km
Alternative: With Project: Widening by 3m Gravel road in 2013 and maintain after Unsealed Pavement

Year	**MT**		**Pavement Type**	**Gravel Thickness**	**Mean Roughness IRI**
	AADT			(mm) THG	**IRI (m/km) Rlav**
2013	232	Before works	Gravel	0.00	15.12
		After works	Gravel	75.29	
2014	245	Before works	Gravel	49.23	8.87
		After works	Gravel	200.00	
2015	258	Before works	Gravel	173.69	6.86
		After works	Gravel	173.69	
2016	272	Before works	Gravel	147.12	8.16
		After works	Gravel	147.12	
2017	287	Before works	Gravel	120.27	9.92
		After works	Gravel	120.27	
2018	303	Before works	Gravel	93.14	10.75
		After works	Gravel	200.00	
2019	320	Before works	Gravel	172.56	7.12
		After works	Gravel	172.56	
2020	337	Before works	Gravel	144.80	8.75
		After works	Gravel	144.80	
2021	356	Before works	Gravel	116.70	10.58
		After works	Gravel	116.70	
2022	376	Before works	Gravel	88.24	11.34
		After works	Gravel	200.00	
2023	396	Before works	Gravel	171.16	7.42
		After works	Gravel	171.16	
2024	418	Before works	Gravel	141.91	9.39
		After works	Gravel	141.91	
2025	441	Before works	Gravel	112.24	11.23
		After works	Gravel	112.24	
2026	466	Before works	Gravel	82.13	11.89
		After works	Gravel	200.00	
2027	492	Before works	Gravel	169.41	7.77
		After works	Gravel	169.41	

Appendix 5.1.F : Annual Road Condition - CS2 (without project alternative)

Study Name: **Widening by 3m CS 2: Rwamagana -Zaza unpaved road**
Run Date: 03-09-2013

Section Details:
ID: CS 2 Description: Rwamagana - Zaza Road Class: Secondary or Main
Length: 31.00km Width: 6m Rise + Fall: 57.00m/km Curvature: 100.00 deg/km
Alternative: Without Project: Maintain Gravel road with existing 6m width Unsealed Pavement

Year	MT		Pavement Type	Gravel Thickness	Mean Roughness IRI
	AADT			(mm) THG	IRI (m/km) Rlav
2013	232	Before works	Earth	0.00	15.12
		After works	Earth	0.00	
2014	245	Before works	Earth	0.00	13.24
		After works	Gravel	200.00	
2015	258	Before works	Gravel	173.69	6.86
		After works	Gravel	173.69	
2016	272	Before works	Gravel	147.12	8.16
		After works	Gravel	147.12	
2017	287	Before works	Gravel	120.27	9.92
		After works	Gravel	120.27	
2018	303	Before works	Gravel	93.14	10.75
		After works	Gravel	101.28	
2019	320	Before works	Gravel	73.84	11.02
		After works	Gravel	82.07	
2020	337	Before works	Gravel	54.31	11.17
		After works	Gravel	62.64	
2021	356	Before works	Gravel	34.54	11.31
		After works	Gravel	200.00	
2022	376	Before works	Gravel	171.54	7.34
		After works	Gravel	171.54	
2023	396	Before works	Gravel	142.70	9.22
		After works	Gravel	142.70	
2024	418	Before works	Gravel	113.45	11.07
		After works	Gravel	113.45	
2025	441	Before works	Gravel	83.78	11.76
		After works	Gravel	92.68	
2026	466	Before works	Gravel	62.56	11.96
		After works	Gravel	71.60	
2027	492	Before works	Gravel	41.01	12.08
		After works	Gravel	50.19	

Appendix 5.1.G : Annual Road Condition - CS3 (with project alternative)

Study Name: **Widening by 3m CS 3: Gasiza-Kibisabo-Pinus II unpaved road**
Run Date: **05-09-2013**

Section Details:

ID: CS3 Description: Gasiza-Kibisabo-Pinus II Road Class: Tertiary or Local
Length: 11.30km Width: 6.00m Rise + Fall: 40.00m/km Curvature: 500.00deg/km
Alternative: With Project: Widening by 3m unpaved gravel road in 2013 and maintain after widening
Unsealed Pavement

Year	**MT**		**Pavement Type**	**Gravel Thickness**	**Mean Roughness**
	AADT			(mm) THG	**IRI (m/km) Rlav**
2013	42	Before works	Gravel	181.09	8.43
		After works	Gravel	187.39	
2014	46	Before works	Gravel	168.48	7.70
		After works	Gravel	168.48	
2015	50	Before works	Gravel	149.56	8.76
		After works	Gravel	149.56	
2016	55	Before works	Gravel	130.65	9.24
		After works	Gravel	130.65	
2017	60	Before works	Gravel	111.73	9.53
		After works	Gravel	111.73	
2018	65	Before works	Gravel	92.82	9.76
		After works	Gravel	92.82	
2019	71	Before works	Gravel	73.90	9.98
		After works	Gravel	73.90	
2020	78	Before works	Gravel	54.99	10.20
		After works	Gravel	54.99	
2021	86	Before works	Gravel	36.08	10.43
		After works	Gravel	41.75	
2022	94	Before works	Gravel	22.84	10.68
		After works	Gravel	200.00	
2023	103	Before works	Gravel	181.09	6.60
		After works	Gravel	181.09	
2024	113	Before works	Gravel	162.17	7.63
		After works	Gravel	162.17	
2025	124	Before works	Gravel	143.26	9.71
		After works	Gravel	143.26	
2026	137	Before works	Gravel	124.34	11.24
		After works	Gravel	124.34	
2027	150	Before works	Gravel	105.43	12.00
			Gravel	105.43	

Appendix 5.1.H : Annual Road Condition - CS3 (without project alternative)

Study Name: **Widening by 3m CS 3: Gasiza-Kibisabo-Pinus II unpaved road**
Run Date: **05-09-2013**

Section Details:

ID: CS3 Description: Gasiza-Kibisabo-Pinus II Road Class: Tertiary or Local
Length: 11.30km Width: 6.00m Rise + Fall: 40.00m/km Curvature: 500.00deg/km
Alternative:Without Project: Maintenance of existing unpaved gravel road Unsealed pavements

Year	**MT**		**Pavement Type**	**Gravel Thickness**	**Mean Roughness**
	AADT			(mm) THG	**IRI (m/km) Rlav**
2013	42	Before works	Gravel	181.09	7.63
		After works	Gravel	181.09	
2014	46	Before works	Gravel	162.17	8.62
		After works	Gravel	162.17	
2015	50	Before works	Gravel	143.26	9.08
		After works	Gravel	143.26	
2016	55	Before works	Gravel	124.34	9.35
		After works	Gravel	124.34	
2017	60	Before works	Gravel	105.43	9.57
		After works	Gravel	105.43	
2018	65	Before works	Gravel	86.51	9.77
		After works	Gravel	86.51	
2019	71	Before works	Gravel	67.60	9.98
		After works	Gravel	67.60	
2020	78	Before works	Gravel	48.69	10.20
		After works	Gravel	54.36	
2021	86	Before works	Gravel	35.45	10.43
		After works	Gravel	41.12	
2022	94	Before works	Gravel	22.21	10.68
		After works	Gravel	200.00	
2023	103	Before works	Gravel	181.09	6.60
		After works	Gravel	181.09	
2024	113	Before works	Gravel	162.17	7.63
		After works	Gravel	162.17	
2025	124	Before works	Gravel	143.26	9.71
		After works	Gravel	143.26	
2026	137	Before works	Gravel	124.34	11.24
		After works	Gravel	124.34	
2027	150	Before works	Gravel	105.43	12.00
		After works	Gravel	105.43	

Appendix 5.2.A : Road Work Summary/timing of works CS1 (with project alternative)

Widening by 3m CS 1: Byimana-Buhanda-Kaduha unpaved road
Run Date: 30-10-2013

All costs are expressed in the following currency: US Dollar.

With Project: Widenning by 3m Gravel Road CS1

Year	*Section*	*Works Description*	*Code*	*Economic Cost*	*Financial Cost*	*Work Quantity*
2012	Byimana - Buhanda	Grading before widening CS	GBW	16,000.00	18,800.00	40.00 km
	Buhanda - Kaduha	Grading before widening CS	GBW	21,600.00	25,380.00	54.00 km
Total Annual Cost:				37,600.00	44,180.00	
2013	Byimana - Buhanda	Grading before widening CS	GBW	16,000.00	18,800.00	40.00 km
	Buhanda - Kaduha	Grading before widening CS	GBW	21,600.00	25,380.00	54.00 km
Total Annual Cost:				37,600.00	44,180.00	
2014	Byimana - Buhanda	Grading before widening CS	GBW	16,000.00	18,800.00	40.00 km
	Buhanda - Kaduha	Grading before widening CS	GBW	21,600.00	25,380.00	54.00 km
Total Annual Cost:				37,600.00	44,180.00	
2015	Byimana - Buhanda	Grading before widening CS	GBW	16,000.00	18,800.00	40.00 km
		Spot Regraveling before widening	SRBW	46,133.73	54,921.11	1,098.42 cu. m
	Buhanda - Kaduha	Grading before widening CS	GBW	21,600.00	25,380.00	54.00 km
Total Annual Cost:				83,733.73	99,101.11	
2016	Byimana - Buhanda	Prep. Grading		0.00	0.00	20.00 km
		Prep. Spot Regravelling		0.00	0.00	1,333.33 cu. m
		Widening by 3m CS 1-1 in 2016	W CS11	1,868,360.00	2,335,440.00	60,000.00 sq. m
	Buhanda - Kaduha	Prep. Grading		0.00	0.00	27.00 km
		Prep. Spot Regravelling		0.00	0.00	0.00 cu. m
		Widening by 3m CS 1-2 in 2016	WCS12	2,522,286.00	3,152,844.00	81,000.00 sq. m
Total Annual Cost:				4,390,646.00	5,488,284.00	

Year	*Section*	*Works Description*	*Code*	*Economic Cost*	*Financial Cost*	*Work Quantity*
2017	Byimana - Buhanda	Grading after widening	GAWID	22,160.00	26,080.00	40.00 km
		Gravel Resurfacing after widening	GRAWID	833,749.00	979,655.13	20,843.73 cu. m
	Buhanda - Kaduha	Grading after widening	GAWID	29,916.00	35,208.00	54.00 km
		Gravel Resurfacing after widening	GRAWID	1,060,498.63	1,246,086.00	26,512.47 cu. m
Total Annual Cost:				1,946,323.63	2,287,029.13	
2018	Byimana - Buhanda	Grading after widening	GAWID	22,160.00	26,080.00	40.00 km
	Buhanda - Kaduha	Grading after widening	GAWID	29,916.00	35,208.00	54.00 km
Total Annual Cost:				52,076.00	61,288.00	
2019	Byimana - Buhanda	Grading after widening	GAWID	22,160.00	26,080.00	40.00 km
	Buhanda - Kaduha	Grading after widening	GAWID	29,916.00	35,208.00	54.00 km
Total Annual Cost:				52,076.00	61,288.00	
2020	Byimana - Buhanda	Grading after widening	GAWID	22,160.00	26,080.00	40.00 km
	Buhanda - Kaduha	Grading after widening	GAWID	29,916.00	35,208.00	54.00 km
Total Annual Cost:				52,076.00	61,288.00	
2021	Byimana - Buhanda	Grading after widening	GAWID	22,160.00	26,080.00	40.00 km
		Gravel Resurfacing after widening	GRAWID	915,986.88	1,076,284.63	22,899.67 cu. m
	Buhanda - Kaduha	Grading after widening	GAWID	29,916.00	35,208.00	54.00 km
Total Annual Cost:				968,062.88	1,137,572.63	
2022	Byimana - Buhanda	Grading after widening	GAWID	22,160.00	26,080.00	40.00 km
	Buhanda - Kaduha	Grading after widening	GAWID	29,916.00	35,208.00	54.00 km
		Gravel Resurfacing after widening	GRAWID	1,250,866.63	1,469,768.25	31,271.66 cu. m
Total Annual Cost:				1,302,942.63	1,531,056.25	
2023	Byimana - Buhanda	Grading after widening	GAWID	22,160.00	26,080.00	40.00 km
	Buhanda - Kaduha	Grading after widening	GAWID	29,916.00	35,208.00	54.00 km
Total Annual Cost:				52,076.00	61,288.00	

Year	Section	Works Description	Code	Economic Cost	Financial Cost	Work Quantity
2024	Byimana - Buhanda	Grading after widening	GAWID	22,160.00	26,080.00	40.00 km
	Buhanda - Kaduha	Grading after widening	GAWID	29,916.00	35,208.00	54.00 km
Total Annual Cost:				52,076.00	61,288.00	
2025	Byimana - Buhanda	Grading after widening	GAWID	22,160.00	26,080.00	40.00 km
		Gravel Resurfacing after widening	GRAWID	982,985.13	1,155,007.50	24,574.63 cu. m
	Buhanda - Kaduha	Grading after widening	GAWID	29,916.00	35,208.00	54.00 km
Total Annual Cost:				1,035,061.13	1,216,295.50	
2026	Byimana - Buhanda	Grading after widening	GAWID	22,160.00	26,080.00	40.00 km
	Buhanda - Kaduha	Grading after widening	GAWID	29,916.00	35,208.00	54.00 km
		Spot Regraveling after widening	SRAWID	81,440.62	96,953.12	1,939.06 cu. m
Total Annual Cost:				133,516.62	158,241.12	
Total Costs for Alternative:				**10,233,466.62**	**12,356,559.74**	

Appendix 5.2.B : Road Work Summary/timing of Works CS1 (without project alternative)

Widening by 3m CS 1: Byimana-Buhanda-Kaduha unpaved road
RunDate: 30-10-2013

All costs are expressed in the following currency:
US Dollar.

Without Project: Maintain Existing Gravel Road CS1

Year	*Section*	*Works Description*	*Code*	*Economic Cost*	*Financial Cost*	*Work Quantity*
2012	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
Total Annual Cost:				37,600.00	44,180.00	
2013	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
Total Annual Cost:				37,600.00	44,180.00	
2014	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
Total Annual Cost:				37,600.00	44,180.00	
2015	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
		Spot Regravelling CS 11 and CS 12	SR 1	46,133.73	54,921.11	1,098.42 cu. m
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
Total Annual Cost:				83,733.73	99,101.11	
2016	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
		Spot Regravelling CS 11 and CS 12	SR 1	46,775.19	55,684.75	1,113.69 cu. m
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
		Spot Regravelling CS 11 and CS 12	SR 1	52,326.99	62,294.04	1,245.88 cu. m
Total Annual Cost:				136,702.18	162,158.79	
2017	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
		Gravel Resurfacing CS 11 and CS 12	GR 1	785,342.44	922,777.38	19,633.56 cu. m
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
		Spot Regravelling CS 11 and CS 12	SR 1	52,534.98	62,541.64	1,250.83 cu. m
Total Annual Cost:				875,477.42	1,029,499.02	

Year	Section	Works Description	Code	Economic Cost	Financial Cost	Work Quantity
2018	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
		Gravel Resurfacing CS 11 and CS 12	GR 1	1,059,047.75	1,244,381.13	26,476.19 cu. m
Total Annual Cost:				1,096,647.75	1,288,561.13	
2019	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
Total Annual Cost:				37,600.00	44,180.00	
2020	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
Total Annual Cost:				37,600.00	44,180.00	
2021	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
		Spot Regravelling CS 11 and CS 12	SR 1	50,583.44	60,218.38	1,204.37 cu. m
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
Total Annual Cost:				88,183.44	104,398.38	
2022	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
		Spot Regravelling CS 11 and CS 12	SR 1	51,482.32	61,288.48	1,225.77 cu. m
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
		Spot Regravelling CS 11 and CS 12	SR 1	53,765.84	64,006.96	1,280.14 cu. m
Total Annual Cost:				142,848.16	169,475.44	
2023	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
		Gravel Resurfacing CS 11 and CS 12	GR 1	859,413.31	1,009,810.63	21,485.33 cu. m
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
		Spot Regravelling CS 11 and CS 12	SR 1	54,055.53	64,351.82	1,287.04 cu. m
Total Annual Cost:				951,068.84	1,118,342.45	
2024	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
		Spot Regravelling CS 11 and CS 12	SR 1	54,361.71	64,716.33	1,294.33 cu. m
Total Annual Cost:				91,961.71	108,896.33	

Year	*Section*	*Works Description*	*Code*	*Economic Cost*	*Financial Cost*	*Work Quantity*
2025	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
		Gravel Resurfacing CS 11 and CS 12	GR 1	1,041,030.63	1,223,211.00	26,025.77 cu. m
Total Annual Cost:				1,078,630.63	1,267,391.00	
2026	Byimana - Buhanda	Grading CS 11 and CS 12	Grd 1	16,000.00	18,800.00	40.00 km
	Buhanda - Kaduha	Grading CS 11 and CS 12	Grd 1	21,600.00	25,380.00	54.00 km
Total Annual Cost:				37,600.00	44,180.00	
Total Costs for Alternative:				4,770,853.86	5,612,903.65	

Appendix 5.2.C : Road Work Summary/timing of Works CS2 (with project alternative)

Widening by 3m CS 2: Rwamagana -Zaza unpaved road
Run Date: 10/30/2013

All costs are expressed in the following currency: US Dollar.

With Project: Widening by 3m Gravel road in 2013 and maintain after

Year	*Section*	*Works Description*	*Code*	*Economic Cost*	*Financial Cost*	*Work Quantity*
2013	Rwamagana - Zaza	Prep. Grading		0.00	0.00	31.00 km
		Prep. Spot Regravelling		0.00	0.00	2,406.34 cu. m
		Widening by 3m CS 2 in 2013	WICS 2	2,726,078.00	3,407,613.00	93,000.00 sq. m
Total Annual Cost:				2,726,078.00	3,407,613.00	
2014	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
		Gravel Resurfacing after widening	GRAWID	1,682,646.50	1,977,109.75	42,066.16 cu. m
Total Annual Cost:				1,716,994.50	2,017,533.75	
2015	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
Total Annual Cost:				34,348.00	40,424.00	
2016	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
Total Annual Cost:				34,348.00	40,424.00	
2017	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
Total Annual Cost:				34,348.00	40,424.00	
2018	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
		Gravel Resurfacing after widening	GRAWID	1,192,560.38	1,401,258.38	29,814.01 cu. m
Total Annual Cost:				1,226,908.38	1,441,682.38	
2019	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
Total Annual Cost:				34,348.00	40,424.00	
2020	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
Total Annual Cost:				34,348.00	40,424.00	

Year	Section	Works Description	Code	Economic Cost	Financial Cost	Work Quantity
2021	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
Total Annual Cost:				34,348.00	40,424.00	
2022	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
		Gravel Resurfacing after widening	GRAWID	1,247,292.25	1,465,568.38	31,182.31 cu. m
Total Annual Cost:				1,281,640.25	1,505,992.38	
2023	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
Total Annual Cost:				34,348.00	40,424.00	
2024	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
Total Annual Cost:				34,348.00	40,424.00	
2025	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
Total Annual Cost:				34,348.00	40,424.00	
2026	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
		Gravel Resurfacing after widening	GRAWID	1,315,477.88	1,545,686.63	32,886.95 cu. m
Total Annual Cost:				1,349,825.88	1,586,110.63	
2027	Rwamagana - Zaza	Grading after widening	GAWID	34,348.00	40,424.00	62.00 km
Total Annual Cost:				34,348.00	40,424.00	
Total Costs for Alternative:				8,644,927.01	10,363,172.14	

Appendix 5.2.D : Road Work Summary/timing of Works CS2 (without project alternative)

Widening by 3m CS 2: Rwamagana -Zaza unpaved road

Run Date: 10/30/2013

All costs are expressed in the following currency: US Dollar.

Without Project: Maintain Gravel road with existing 6m width

Year	*Section*	*Works Description*	*Code*	*Economic Cost*	*Financial Cost*	*Work Quantity*
2014	Rwamagana - Zaza	Gravel Resurfacing CS 2	GR 2	1,488,000.00	1,748,400.00	37,200.00 cu. m
		Prep. Spot Regravelling		86,799.99	103,333.33	2,066.67 cu. m
Total Annual Cost:				1,574,799.99	1,851,733.33	
2015	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
Total Annual Cost:				24,800.00	29,140.00	
2016	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
Total Annual Cost:				24,800.00	29,140.00	
2017	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
Total Annual Cost:				24,800.00	29,140.00	
2018	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
		Spot Regravelling CS 2	SR 2	63,589.98	75,702.36	1,514.05 cu. m
Total Annual Cost:				88,389.98	104,842.36	
2019	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
		Spot Regravelling CS 2	SR 2	64,305.60	76,554.28	1,531.09 cu. m
Total Annual Cost:				89,105.60	105,694.28	

Year	Section	Works Description	Code	Economic Cost	Financial Cost	Work Quantity
2020	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
		Spot Regravelling CS 2	SR 2	65,061.57	77,454.26	1,549.09 cu. m
Total Annual Cost:				89,861.57	106,594.26	
2021	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
		Gravel Resurfacing CS 2	GR 2	1,231,041.00	1,446,473.13	30,776.02 cu. m
Total Annual Cost:				1,255,841.00	1,475,613.13	
2022	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
Total Annual Cost:				24,800.00	29,140.00	
2023	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
Total Annual Cost:				24,800.00	29,140.00	
2024	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
Total Annual Cost:				24,800.00	29,140.00	
2025	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
		Spot Regravelling CS 2	SR 2	69,532.80	82,777.15	1,655.54 cu. m
Total Annual Cost:				94,332.80	111,917.15	
2026	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
		Spot Regravelling CS 2	SR 2	70,584.61	84,029.30	1,680.59 cu. m
Total Annual Cost:				95,384.61	113,169.30	
2027	Rwamagana - Zaza	Grading CS 2	Grd2	24,800.00	29,140.00	62.00 km
		Spot Regravelling CS 2	SR 2	71,696.13	85,352.53	1,707.05 cu. m
Total Annual Cost:				96,496.13	114,492.53	
Total Costs for Alternative:				3,533,011.68	4,158,896.34	

Appendix 5.2.E : Road Work Summary/timing of Works CS3 (with project alternative)

Widening by 3m CS 3: Gasiza-Kibisabo-Pinus II unpaved road

Run Date: 30-10-2013

All costs are expressed in the following currency: US Dollar.

With Project: Widening by 3m unpaved gravel road in 2013 and maintain after widening

Year	*Section*	*Works Description*	*Code*	*Economic Cost*	*Financial Cost*	*Work Quantity*
2013	Gasiza-Kibisabo-Pinus II	Prep. Grading		0.00	0.00	11.30 km
		Prep. Spot Regravelling		0.00	0.00	0.00 cu. m
		Widening by 3m CS 3 in 2013	WIDCS3	1,507,589.50	1,884,478.38	33,900.00 sq. m
Total Annual Cost:				1,507,589.50	1,884,478.38	
2014	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
Total Annual Cost:				12,520.40	14,735.20	
2015	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
Total Annual Cost:				12,520.40	14,735.20	
2016	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
Total Annual Cost:				12,520.40	14,735.20	
2017	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
Total Annual Cost:				12,520.40	14,735.20	
2018	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
Total Annual Cost:				12,520.40	14,735.20	
2019	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
Total Annual Cost:				12,520.40	14,735.20	
2020	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
Total Annual Cost:				12,520.40	14,735.20	
2021	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
		Spot Regraveling after widening	SRAWID	24,237.16	28,853.77	577.08 cu. m
Total Annual Cost:				36,757.56	43,588.97	

Year	*Section*	*Works Description*	*Code*	*Economic Cost*	*Financial Cost*	*Work Quantity*
2022	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
		Gravel Resurfacing after widening	GRAWID	720,703.06	846,826.06	18,017.58 cu. m
Total Annual Cost:				733,223.46	861,561.26	
2023	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
Total Annual Cost:				12,520.40	14,735.20	
2024	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
Total Annual Cost:				12,520.40	14,735.20	
2025	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
Total Annual Cost:				12,520.40	14,735.20	
2026	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
Total Annual Cost:				12,520.40	14,735.20	
2027	Gasiza-Kibisabo-Pinus II	Grading after widening	GAWID	12,520.40	14,735.20	22.60 km
Total Annual Cost:				12,520.40	14,735.20	
Total Costs for Alternative:				2,427,815.32	2,966,451.01	

Appendix 5.2.F : Road Work Summary/timing of Works CS3 (without project alternative)

Widening by 3m CS 3: Gasiza-Kibisabo-Pinus II unpaved road

Run Date: 30-10-2013

All costs are expressed in the following currency: US Dollar.

<u>Without Project: Maintenance of existing unpaved gravel road</u>

Year	*Section*	*Works Description*	*Code*	*Economic Cost*	*Financial Cost*	*Work Quantity*
2013	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
Total Annual Cost:				9,040.00	10,622.00	
2014	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
Total Annual Cost:				9,040.00	10,622.00	
2015	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
Total Annual Cost:				9,040.00	10,622.00	
2016	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
Total Annual Cost:				9,040.00	10,622.00	
2017	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
Total Annual Cost:				9,040.00	10,622.00	
2018	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
Total Annual Cost:				9,040.00	10,622.00	
2019	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
Total Annual Cost:				9,040.00	10,622.00	
2020	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
		Spot Regravelling CS 3	SR 3	16,158.11	19,235.84	384.72 cu. m
Total Annual Cost:				25,198.11	29,857.84	
2021	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
		Spot Regravelling CS 3	SR 3	16,158.11	19,235.84	384.72 cu. m
Total Annual Cost:				25,198.11	29,857.84	

Year	*Section*	*Works Description*	*Code*	*Economic Cost*	*Financial Cost*	*Work Quantity*
2022	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
		Gravel Resurfacing CS 3	GR 3	482,178.50	566,559.75	12,054.46 cu. m
Total Annual Cost:				491,218.50	577,181.75	
2023	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
Total Annual Cost:				9,040.00	10,622.00	
2024	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
Total Annual Cost:				9,040.00	10,622.00	
2025	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
Total Annual Cost:				9,040.00	10,622.00	
2026	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
Total Annual Cost:				9,040.00	10,622.00	
2027	Gasiza-Kibisabo-Pinus II	Grading CS 3	Grd3	9,040.00	10,622.00	22.60 km
Total Annual Cost:				9,040.00	10,622.00	
Total Costs for Alternative:				650,094.72	764,361.43	