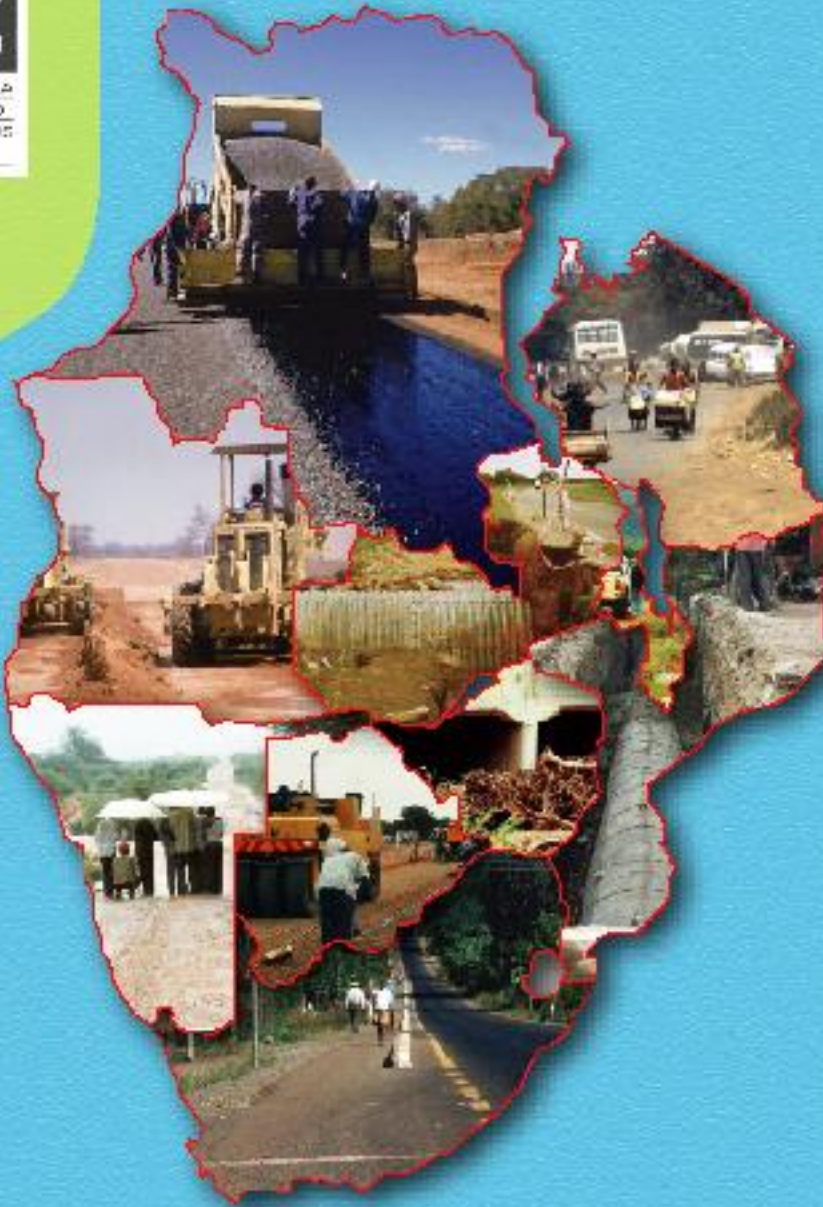




# Guideline



Seychelles

Mauritius

**Low-volume Sealed Roads**  
2003



# Guideline

## Low-Volume Sealed Roads

July 2003

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## Foreword

*The SADC road network of just over one million kilometres provides the dominant mode of freight and passenger transport and thus plays a vital role in the economy of the region. Unsurfaced low-volume roads constitute a substantial proportion of that network and impact on the lives of the majority of the region's population who live and work in rural areas. Many of these roads are being upgraded to a sealed standard following strategies that focus on poverty alleviation in pursuit of the region's broader goals of socio-economic growth and development.*

*The main purpose of the Guideline is to provide stakeholders with a synthesis of best regional and international practice in all aspects of low-volume sealed roads. In so doing, it will correct a shortcoming of other available guidelines and manuals which tend to be more narrowly focused on the technical aspects of relatively more heavily trafficked roads and, as a result, have limited applicability to low-volume sealed roads.*

*Funding for this Guideline has been provided by the UK Department for International Development (DFID), the Norwegian Agency for Development Cooperation (NORAD) and the Swedish International Development Agency (SIDA). These cooperating partners continue to provide development assistance to the region in the transport sector aimed, in part, at improving the sustainability of low-volume sealed roads coupled with direct poverty alleviation.*

*By promoting the adoption of a more holistic approach to the provision of low-volume sealed roads and the use of innovative best practice from the region, the Guideline will undoubtedly lead to a more efficient use of available road funding. This will result in direct benefits to all SADC countries and facilitate socio-economic growth and development leading to a reduction in poverty.*

*I wish to thank our cooperating partners for co-funding this project as well as the UK Transport Research Laboratory (TRL) and the Norwegian Public Roads Administration (NPRA) for managing it. I also wish to thank all those who contributed their knowledge and experience to enable this Guideline to be produced; in particular, the Lead Authors, representatives from member states who were closely involved in its development and the international panel of experts who reviewed the document. I am convinced that all stakeholders will find the Guideline to be a valuable source of information for the more efficient and effective provision of low-volume sealed roads in the SADC region.*

Sakhe Silo  
Director - SATCC Technical Unit  
Maputo, Mozambique



## **Dedication**

This guideline is dedicated to the memory of the late Eric Msolomba, former director of the SATCC Technical Unit, whose vision provided the motivation for this project, and whose dedication and leadership made this document possible.

# Acknowledgements

The Project Team gratefully acknowledges the contributions and comments received from a large number of professionals representing a wide range of disciplines, in organisations from both the public and private sectors, who participated in the workshops held in connection with the compilation of the Guideline. These organisations included Government ministries (including Roads Departments and Traffic Safety Units), National Roads Authorities, consultants, contractors and materials suppliers. Particular thanks are due to the SATCC Technical Unit, the CSIR and the authors for their contributions, and to the Peer Reviewers for their comments on the drafts. Thanks are also due to the workshop facilitators and presenters who also made valuable contributions to the project.

## SADC Road Sector Organisations

The high level of support and guidance provided by the road sector organisations in the SADC member states in the development of the Guideline and in the hosting of country workshops is gratefully acknowledged. The following organisations are expected to be the main agencies involved in the implementation of the Guideline:

Angola	Angolan Road Agency (INEA), Ministry of Public Works, Luanda
Botswana	Roads Department, Ministry of Works and Transport, Gaborone
DRC	Office des Routes, Kinshasa/Gombe
Lesotho	Roads Department, Ministry of Public Works and Transport, Maseru
Malawi	National Roads Authority, Lilongwe
Mauritius	Road Development Authority, Ministry of Public Infrastructure, Phoenix
Mozambique	National Roads Administration (ANE), Maputo
Namibia	National Roads Authority, Windhoek
Seychelles	Land Transport Division, Ministry of Transport and Tourism, Mahé
South Africa	South African National Roads Agency (SANRA), Pretoria
Swaziland	Roads Department, Ministry of Public Works and Transport, Mbabane
Tanzania	Tanzania National Roads Agency (TANROADS), Dar es Salaam
Zambia	Roads Department, Ministry of Works and Supply, Lusaka
Zimbabwe	Department of State Roads, Ministry of Transport, Harare

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### A new approach

The successful provision of a low-volume sealed road requires ingenuity, imagination and innovation. It entails “working with nature” and using locally available, non-standard materials and other resources in an optimal and environmentally sustainable manner.

It will rely on planning, design, construction and maintenance techniques that maximize the involvement of local communities and contractors.

When properly engineered, a LVSR will reduce transport costs and, through its impact on rural production and on trade between regions, facilitate socio-economic growth and development and reduce poverty in the SADC region.

The criteria for defining a “Low-volume road” varies significantly in various parts of the world. In the SADC region, such roads may be primary, secondary or tertiary/access roads. They typically carry less than 200 vehicles per day, including up to 20% commercial vehicles, and often include non-motorised traffic, particularly near populated areas.



Extensive research has been undertaken in the SADC region over the past 20 – 30 years. This has enabled local, “non-standard” materials to be successfully incorporated in appropriate pavement design for LVSRs.

## Provision of Low-volume sealed roads: Time for a re-think by decision-makers!



### Low-volume roads, economic development and poverty alleviation

- ◆ The majority of rural roads, and a significant proportion of the main roads in the SADC region are currently unsurfaced and are relatively lightly trafficked. These low-volume roads are important in that they:
  - impact significantly on the livelihoods of the majority of the population of many countries in the region, who live and work in rural areas where poverty levels are generally very high
  - are central to sustained socio-economic growth and development of the region and are a key component of development programmes targeted by donors and governments in which poverty reduction strategies feature
- ◆ Unfortunately, the poor condition of these roads, which can be largely attributed to the way in which they have customarily been provided and maintained, has acted as a brake on economic development and hindered poverty alleviation efforts.
- ◆ New, more appropriate, approaches to the provision of low-volume sealed roads (LVSRs) are now required if the region is to improve road transport efficiency and attain its broader goals of socio-economic growth, development and poverty alleviation.

### The inappropriateness of traditional methods

- ◆ Traditional approaches to the provision of low-volume sealed roads have stemmed from technology and research carried out in Europe and the USA over 40 years ago in very different environments.
- ◆ Locally prevailing circumstances are usually very different in terms of climate, traffic, materials and road users. It is therefore not surprising that many of the imported approaches, designs and technologies are inappropriate for application in the region.
- ◆ Technology, research and knowledge about LVSRs have advanced significantly in the region and not only question much of the accepted wisdom on LVSR provision but also show quite clearly the need to revise conventional approaches.
- ◆ Unfortunately, there has been little effective dissemination and uptake of the results of research carried out in the region. This has triggered the need for this SADC Guideline on Low-Volume Sealed Roads.



Unpaved roads generate dust in dry weather causing health hazard, damage to crops, vehicles and natural habitats and adversely affecting the safety of pedestrians and vehicles. Is a sealed surface an affordable option?

**Yes! It certainly can be.**



A substantial amount of gravel is extracted annually from borrow pits in all countries of the SADC region. Is this sustainable? **No! It is not.**

Achieving sustainability in all aspects of LVSR provision is absolutely critical, if the SADC region's long term goals of sustained economic growth and poverty alleviation are to be attained. In the past, attempts to achieve such sustainability have failed because one or more of the seven key dimensions has been missing or inadequate. The result has been that LVSRs have fallen into disrepair and, consequently, have not only failed to serve the needs of the poor but, also, have often adversely affected the environment.

### Why sealed roads?

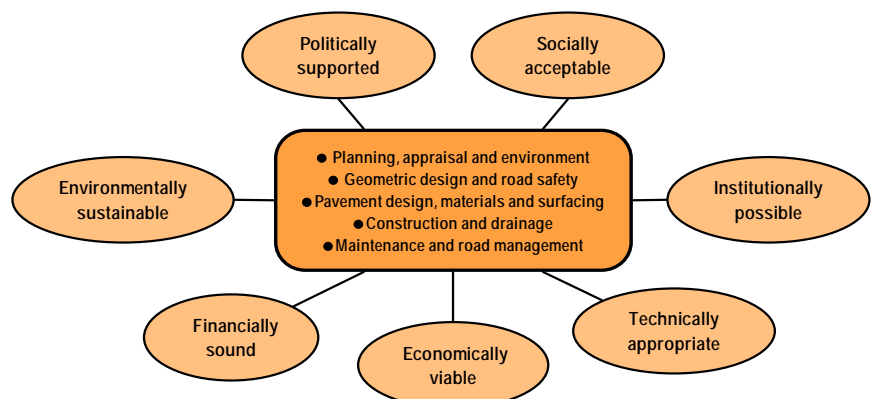
- ◆ The substantial length of unsurfaced, particularly gravel, roads in the region is becoming increasingly difficult to sustain in that such roads:
  - impose a logistical, technical and financial burden on most road agencies due to constraints on physical, human, financial and natural resources
  - require the continuous use of a non-renewable resource (gravel) which is being seriously depleted in many countries and, in the process, is causing serious environmental problems
- ◆ Implementing the results of regional research (for example, that reduce construction costs through the increased use of natural gravels), enable the sealing of gravel roads to be economically justified at less than 100 vehicles per day (vpd). This figure is in contrast to the previously recommended threshold values for sub-Saharan Africa, which were in excess of 200 vpd and is a figure that still persists in the minds of many practitioners.
- ◆ Failure to observe the optimal timing for sealing gravel roads can be very costly to national economies, not only in terms of incurring excess transport costs but, also, in the continuing excessive maintenance burden and adverse socio-environmental effects. This provides a strong impetus for policy change and the adoption of alternative, cost-effective, surfacing strategies promoted in this Guideline.

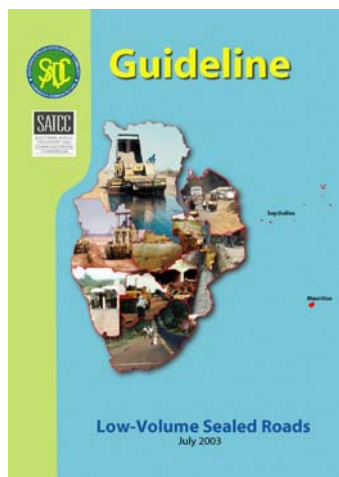
### The benefits of sealed roads

- ◆ The whole-life benefits of sealed roads include:
  - lower transport (construction, maintenance and vehicle operating) costs
  - increased social benefits (more reliable access to schools, clinics, etc)
  - reduced adverse environmental impacts and health and safety problems
- ◆ Based on a conservative rate of upgrading gravel roads to a sealed standard of 100 km/year, the annual benefits of adopting the recommendations of this Guideline will be of the order of US \$35 million.
- ◆ The above benefits hinge critically on the ability of the responsible authority to maintain the sealed roads to the level of service for which they were designed. This requires provision of adequate, sustainable and timely funding for the sub-sector which, increasingly, is being provided by road users on a “fee-for-service” basis.

### Key dimensions of sustainability

- ◆ There has been a tendency to focus predominantly on the technical and economic aspects of LVSR provision and inadequate attention has been given to other aspects of sustainability. The result has often been a lack of responsiveness to various other requirements and a reduced likelihood of achieving sustainable solutions, even when substantial funding is made available.
- ◆ The seven key dimensions of a sustainable system, which should always be observed in the provision of LVSRs, are shown below.





*Promotion of labour-based methods where feasible, is a key factor in creating productive employment and reducing poverty.*

*The new idea either finds a champion or dies.....No ordinary involvement with a new idea provides the energy required to cope with the indifference and resistance that major technological change provokes... Champions of new ideas must display persistence and courage of heroic quality.*

- ◆ Sustainability in all aspects of LVSR provision should now become the basis of a more demanding policy of SADC governments. This will require that practitioners adopt a more broadly-based approach than hitherto which pays full attention to all seven dimensions of sustainability.

### ***Meeting new challenges – the SADC Guideline on LVSRs***

- ◆ The main objective of the Guideline is to capture best regional and international practice in all aspects of LVSR provision. It is not a prescriptive document but, rather, provides guidance to users so as to ensure that well-considered decisions are made. The development of the Guideline has benefited from the close involvement of practitioners in the region.
- ◆ The Guideline presents a major departure from traditional practice in all aspects of LVSR provision by examining procedures, practices and methods used in:
  - planning, appraisal and environment
  - construction and drainage
  - geometric design and road safety
  - maintenance
  - pavement design, materials and surfacing
- ◆ The Guideline promotes the use of a holistic approach to LVSR's, which recognizes that criteria need to be satisfied in the different and often interacting dimensions of road provision.

### ***The benefits of using the Guideline***

- ◆ There are a number of benefits to be derived from adopting the approaches advocated in the Guideline. These include providing LVSRs that:
  - are less expensive in economic terms to build and to maintain through the adoption of more appropriate, locally-derived technology and design/construction techniques that are better suited to local conditions
  - minimize adverse environmental impacts, particularly as regards the use of non-renewable resources (gravel)
  - increase employment opportunities through the use of more appropriate technology, including the use of labour-based methods where feasible
  - improve road safety in all aspects of road provision
  - take better account of the needs of all stakeholders, particularly the local communities served by these roads
  - foster local road building and maintenance capacity through the greater use of small-scale, local contractors
  - ultimately, facilitate the longer-term goal of socio-economic growth, development and poverty alleviation in the region
- ◆ In addition to the above, the Guideline will also generate awareness and disseminate the knowledge required for these benefits to be enjoyed more widely in the region.

### ***Moving from vision to practice***

- ◆ The full benefits of the Guideline will be realised only if the approaches recommended are implemented in practice. However, there are a number of barriers which will tend to frustrate this process. They include:
  - an inevitable and natural tendency to resist change and the conservative nature of public-sector organisations which tend to institutionalize this resistance
  - many of the recommendations contained in the Guideline may be in conflict with existing, often out-dated, country manuals and standards

- ◆ Ultimately, the successful move from vision to practice will require endorsement at political level, as well as full support of all stakeholders. In addition, it will require considerable technology transfer effort including:
  - support and technical assistance to facilitate the implementation of the Guideline
  - updating country documents to suit specific local conditions
  - technical staff training to address potential internal resistance to change
  - careful monitoring of acceptance, adoption, refinement and satisfaction amongst users of the Guideline

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# Abbreviations

## Organisations

AID	Agency for International Development
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ARRB	Australian Road Research Board
ASIST	Advisory Support Information Services And Training (For Employment – Intensive Infrastructure)
ASTM	American Society for Testing and Materials
CAPSA	Conference on Asphalt Pavements for Southern Africa
CEBTP	Centre Experimental de Recherches et D'études du Batiment et des Travaux Publics
CSIR	Council for Scientific and Industrial Research
CSRA	Committee of State Road Officials
DFID	Department for International Development
DLO	Direct Labour Organisations
DoR	Department of Roads
ILO	International Labour Organisation
IRF	International Road Federation
MOW	Ministry of Works
NAASRA	National Association of Australian State Road Authorities
NIRR	National Institute for Road Research
NITRR	National Institute for Transport and Road Research
NORAD	Norwegian Agency for International Development
NPRA	Norwegian Public Roads Administration
NRRL	Norwegian Road Research Laboratory
NSW	New South Wales (Australia)
ODA	Overseas Development Administration
PIARC	Permanent International Association of Road Congresses (World Road Association)
RA Board	Roads Agency Board
RF Board	Road Fund Board
SABITA	Southern Africa Bitumen and Tar Association
SADC	Southern Africa Development Community
SADCC	Southern African Development Coordination Conference
SAICE	South African Institution of Civil Engineering
ATC	Annual Transportation Conference
SANRA	South African National Roads Agency
SATCC	Southern Africa Transport and Communications Commission
SIDA	Swedish International Development Agency
TANROADS	Tanzania National Roads Agency
TRB	Transportation Research Board
TRL	Transport Research Laboratory
TRRL	Transport and Road Research Laboratory
UK	United Kingdom
UN	United Nations
UNESCO	United Nations Educational Scientific & Cultural Organisation
USA	United States of America
WA	Western Australia

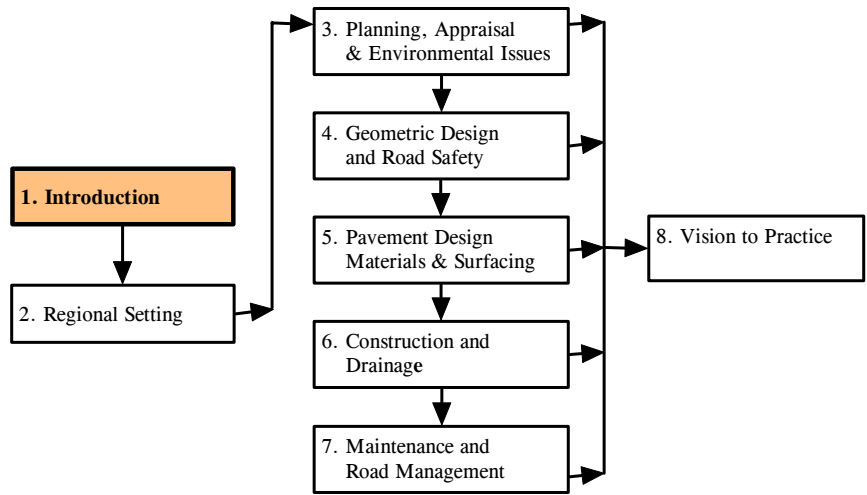
# Abbreviations

## Technical

AADT	Annual Average Daily Traffic
AIV	Aggregate Impact Value
AC	Asphalt Concrete
ACV	Aggregate Crushing Value
ADT	Annual Daily Traffic
BCR	Benefit Cost ratio
BOQ	Bill of Quantities
BS	British Standards
CBA	Cost-benefit analysis
CaSE	Cost and Safety Efficient Design
CBR	California Bearing Ratio
CEO	Chief Executive Officer
DMI	Durability Mill Index
elv	Equivalent Light vehicles
DCP	Dynamic Cone Penetrometer
Es	Elastic Stiffness
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ESA	Equivalent Standards Axle (based on 80 kN standard)
FACT	Fines Aggregate Crushing Test
FMC	Field Moisture Content
FWD	Falling Weight Deflectometer
GDP	Gross Domestic Product
HDM-4	Highway Development and Management Model-4
HIV/AIDS	Human Immune Deficiency Virus/Acquired Immune Deficiency Syndrome
HVR	High-volume road
HVS	Heavy Vehicle Simulator
HVSR	High-Volume Sealed Roads
IQL	Information Quality Level
IRAP	Integrated Rural Accessibility Planning
IRI	International Roughness Index
IRR	Internal Rate of Return
KPI's	Key Performance Indicators
LAA	Los Angeles Abrasion
LBM	Labour Based Methods
LVR	Low-Volume Road
LVSR	Low-Volume Sealed Road
MC	Moisture Content
MDD	Maximum Dry Density
NMT	Non Motorised Traffic
NPV	Net Present Value
OMC	Optimum Moisture Content
ORN	Overseas Road Note (TRL series of publications)
PI	Plasticity Index
PSD	Passing Site Distance
PSV	Polished Stone value
R & W	Riedel and Weber
RED	Road Economic Decision model



# Chapter 1



# Contents

## Introduction

**1**

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# Introduction

## 1

### 1.1 Background

*“The body of highway engineering knowledge remains empiric rather than rigorously scientific. So, the knowledge taught in our [UK, USA] universities is generally derived from a synthesis of local experience. No wonder it is often irrelevant and sometimes downright misleading in other parts of the world”.*

Ray Millard, Highways Advisor, World Bank. 2<sup>nd</sup> Int. Conf. on Low-volume Roads, 1979<sup>1</sup>.



*Research carried out in the SADC region has catalysed the re-thinking of the whole approach to low-volume sealed roads<sup>2,3,4</sup>.*

Many aspects of the documentation on low-volume road provision in the SADC region have stemmed from technology and research carried out in Europe and the USA some 30 – 40 years ago in vastly different environments. Although some of this documentation has been modified to some extent in the intervening years, the basic philosophy of road provision has remained essentially the same. Whilst these standard approaches may still be appropriate for the more heavily trafficked SADC trunk road network, they are clearly inappropriate for use on low-volume roads which make up a large proportion of national road networks. This has prompted a number of international research organizations, as well as government departments and local agencies, to undertake research into various aspects of low-volume sealed roads.

#### Box 1.1 – Road research in the SADC region

Research carried out in the SADC region by a number of international, regional and local organisations, which is conservatively estimated to have cost US \$20 – 30 million, has questioned many of the accepted assumptions about the planning, design, construction and maintenance of low-volume sealed roads. This research has quite clearly shown:

- the importance of adopting a more holistic, sustainable approach to the provision of low-volume roads
- the need to revise conventional approaches to planning, economic appraisal and the environment
- the shortcomings of conventional specifications and, to some extent, test methods, in assessing the adequacy of local materials for use in low-volume roads
- the advantages of adopting more appropriate geometric and pavement design standards
- the economic success of innovative construction methods
- the importance of paying greater attention to the environmental aspects of road provision

*“Probably the most important and critical issue (in technology transfer) is **information dissemination**. Presenting all available and relevant information to practitioners is essential to implementing improved procedures and new techniques. Given the amount of research and development that is still being undertaken, the ability to disseminate this information quickly is the key to advancing the low-volume road situation”.*

Transport Research Circular No. 446, May 1995<sup>5</sup>.

Unfortunately, because of a lack of funding, there has been very little effective dissemination of the research carried out in the region. This has led to:

- a lack of awareness of the results of research
- a lack of understanding of the often satisfactory performance of innovative solutions
- an aversion to the use of “non-standard” designs, particularly by foreign consultants and contractors who are often unfamiliar with local conditions
- poor technology transfer
- little implementation of innovative technology

In recognition of the need for raising awareness of recent developments in low-volume sealed road technology in the region, the Southern African Transport and Communications Commission (SATCC) commissioned the preparation of this *Guideline on Low-volume Sealed Roads (LVSRs)* which was funded by DFID, NORAD and SIDA.

## 1.2 Purpose and Scope

**T**he main purpose of the Guideline is to provide a synthesis of practical, state-of-the-art approaches to LVSR provision based largely on regional knowledge and experience, but also takes into account international best practice. In so doing, the primary goal is to reduce the cost of constructing and maintaining LVSRs leading to:

- increased public and commercial transport through lower road user costs
- improved access to schools, clinics, jobs, urban centres and neighbouring rural areas
- improved environmental, health and social conditions
- reduced depletion of finite materials resources - regravelling is an inherently unsustainable activity
- enhanced socio-economic growth, development and poverty alleviation

The means of achieving the above hinges on cost-effective provision of sealed roads in rural and peri-urban areas by the transfer of technology developed through research. The Guideline therefore seeks to:

- act as a vehicle for the dissemination and implementation of appropriate innovative LVSR technology in the SADC region
- promote the use of a holistic approach to LVSR provision
- encourage optimal utilization of local resources and “non-standard”, but appropriate, designs for all aspects of LVSR provision
- promote greater local public and private sector involvement and participation in road projects
- ultimately, act as the standard consultative document for LVSRs

Adoption of the above is expected to lead to an increase in sealed roads constructed at an affordable cost and to an appropriate standard by applying proven, sometimes unconventional, methods and innovative technology.

### Contrasting examples of low-volume roads in the SADC region



Earth/gravel road (Tanzania)



Old "strip" road (Zimbabwe)



Old "narrow-mat" road (Zimbabwe)



New sealed low-volume road (Botswana)

The Guideline is aimed at a wide range of stakeholders, from politicians to practitioners, including consultants, contractors, materials suppliers, donors, road users and the general public who, in various ways, are all involved in different but complementary aspects of low-volume road provision.

Because the SADC region is a diverse one, it would be impractical and inappropriate to provide recipe solutions for specific situations. Instead, emphasis has been placed on guiding the practitioner towards evaluating alternative options and considering their pros and cons as a basis for decision making and application to country-specific situations. This is achieved by collating together in one document key background knowledge and experience in the application and performance of tried and tested, new and innovative solutions in all aspects of LVSR provision.

The Guideline provides a compendium of recent approaches to the following aspects of low-volume sealed road provision:

- Planning, appraisal and environment
- Geometric design and road safety
- Pavement design, materials and surfacing
- Construction and drainage
- Maintenance

The Guideline does not deal in detail with slope stability, geotechnical and hydrological issues and standard drainage details. However, it provides a source of comprehensive references which provide additional details and more fully documented examples of local and international experience.

Although the Guideline has been produced specifically for the SADC environment, there are many aspects of it which, with sound engineering judgement, could apply in similar environments elsewhere.

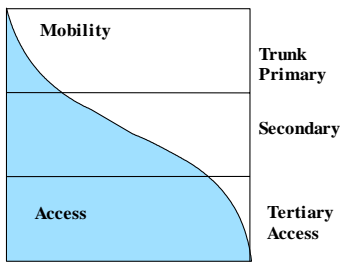
## 1.3 Focus

The focus of the Guideline is on *low-volume sealed roads* (LVSRs) – a term for which there is no standard definition. Typical criteria for defining such roads include traffic volume, road function, administrative classification as well as management and financing arrangements. The concept of a low volume road (LVR) also varies from country to country simply because this type of road serves different functions and operates in different socio-economic environments. In the context of this Guideline, LVSRs are characterized by the following features that pertain to the SADC region:

Table 1.1 – LVSR Characteristics

• <b>Ownership</b>	Mostly local governments/communities but also provincial/ central governments.
• <b>Classification and function</b>	Mostly secondary or tertiary/access roads but can also be main/ primary roads. Serve predominantly rural populations of most countries – typically more than 75% of the population.
• <b>Management and financing</b>	Local government for tertiary/access roads, central government for primary/secondary roads.
• <b>Function</b>	Economic/social/administrative/political.
• <b>Physical features</b>	Majority are unsealed, partly engineered, single or 2-lane, earth/sand or gravel roads with elevated running surfaces, side drains and cross-drainage structures, including low or high level water crossings.
• <b>Traffic</b>	Relatively "low-volume", typically up to about 200 vpd, carrying both motorised and non-motorised traffic.

### The multi-functional nature



LVRs are multi-faceted. At one extreme, they serve as a mobility link in the road transport chain from the main highway network to the local market. At another extreme, they serve as an access link in a road transport chain with one end in the agricultural fields or villages and the other in the town market.

Low-volume roads in the region cut across a wide range of environments. In practice, there will be many overlaps in classification and function and clear distinctions will not always be apparent on functional terms alone. Nonetheless, the focus will be secondary/tertiary/access roads in rural and peri-urban areas.

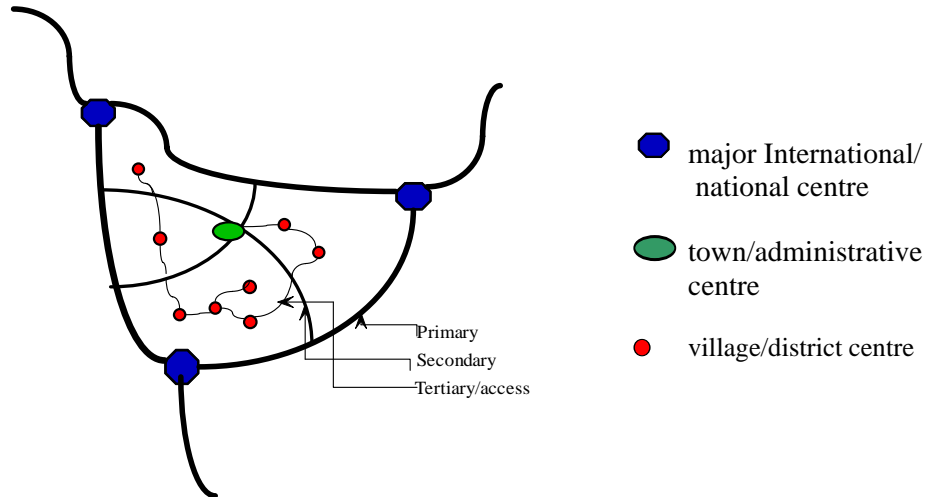


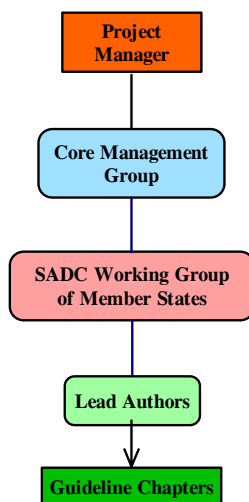
Figure 1.1 – Road hierarchy and function

## 1.4 Development of Guideline

The Guideline draws on the accumulated knowledge and practical experience of international research organizations, consultants and others who have long experience of working in the region. It was produced by a team comprising key specialists in each technical field, together with experts from SADC countries.

The Guideline is unique in the following important aspects:

1. It was developed with a high level of "local" participation. As a result, it has been possible to capture and incorporate a significant amount of local knowledge in the document. The benefits of this approach include a document that:
  - reflects the needs of the region
  - has an emphasis on local ownership
  - facilitates wider application
  - improves prospects for sustainable implementation
2. It draws extensively on the output of a 4-year SADC regional programme of research in highway engineering materials<sup>2</sup>.
3. It focuses on the multi-dimensional nature of LVSR provision, giving balanced attention to aspects of LVR provision that are often neglected in most other guidelines, such as the political, social, institutional and funding aspects.



Organisational chart for management and development of the Guideline.

## 1.5 Structure and Content

The Guideline is divided into eight chapters which collectively address various aspects of LVSR provision as presented below.

### 1 Introduction

Comprises the introduction to the Guideline, including an overview of the focus of the document and the approach advocated in contrast to previous approaches to road provision. Against this background, the purpose, scope, development and structure of the guideline are highlighted.

### 2 Regional Setting

Provides the geographic setting for the SADC region. Gives an overview of the regional road network and its various details. Highlights the challenge faced in providing LVSRs in a sustainable manner and the developments taking place in road sector reform. Outlines the main components of LVSR provision.

### 3 Planning, Appraisal and Environment

Provides a holistic framework for planning and appraising LVSRs and highlights the key external factors that affect their provision. Covers the process of life-cycle costing and the appropriateness of the available appraisal tools for doing so. Presents various environmental issues including the importance of the EIA process in the planning process.

### 4 Geometric Design and Road Safety

Presents factors relevant to the selection of appropriate standards for LVSRs and the steps involved in selecting suitable solutions. Summarises both conventional techniques and low cost 'design-by-eye' methods, and the cost, environmental and safety implications of each. Highlights measures for improving road safety on LVSRs.

### 5 Pavement Design, Materials and Surfacing

Provides a systems approach to the design of LVSR pavements and surfacings derived from regional research work and practice. Highlights the importance of using local materials selected on the basis of appropriate specifications. Emphasises the importance of catering for both internal and external drainage of pavements to enhance performance.

### 6 Construction and Drainage

Provides guidance on the choice of methods available for the construction of LVSRs with a focus on labour-based methods. Includes examples aimed at optimising the use of local labour and equipment technologies within a conducive contracting environment aimed at maximizing the use of small-scale local contractors.

## **7 Maintenance and Road Management**

Highlights the importance of maintenance and the challenges faced in carrying it out effectively and efficiently. Presents the particular characteristics of LVSRs, including their deterioration characteristics. Outlines typical maintenance management functions and considers the contractual aspects of undertaking maintenance works. Outlines the role, function and selection criteria for Road Management Systems.

## **8 From Vision to Practice**

Summarises the motivation for producing the Guideline and the benefits of adopting the approaches proposed. Outlines the pathway to implementation of the Guideline, the barriers that need to be overcome in the course of so doing and the need to take account of many non-technical factors that often influence the manner in which LVSRs are provided.

### **1.6 Updating**

**H**ighway engineering technology, and improved methods of low-volume road provision are continually being researched and changed, and therefore it will be necessary to update the Guideline at periodic intervals to reflect improvements in practice.

The Guideline has been produced in a loose-leaf format to allow notes pages to be inserted as and when necessary. In addition, it has been produced in electronic CD format and has also been posted on the SATCC website [www.sadc.int](http://www.sadc.int). The Guideline is produced in all three official SADC languages – English, French and Portuguese.

### **1.7 Sources of Information**

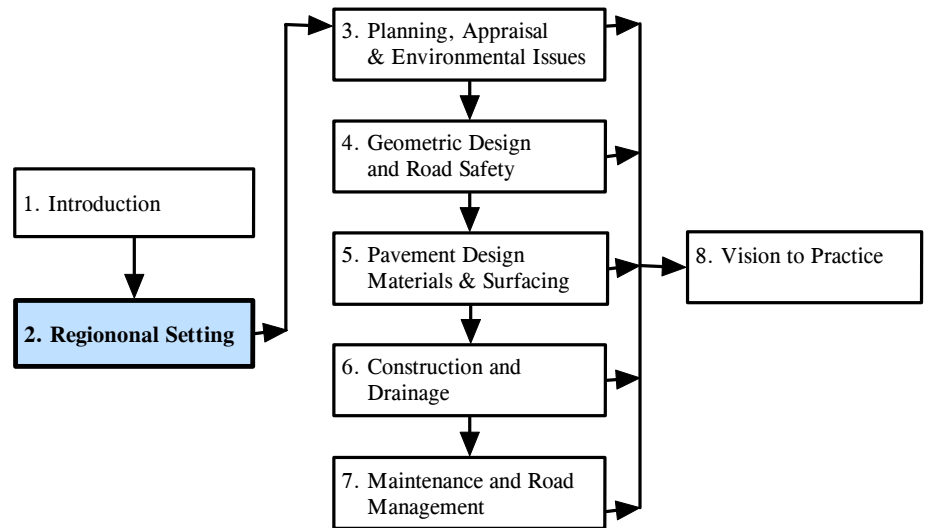
**I**n addition to the references cited in the text of each chapter, an extensive bibliography has also been provided for those readers who wish to obtain additional information about many of the topics included. A list of the main organizations producing relevant publications is also provided, including their contact details.

## 1.8 References and Bibliography

### References

1. Transportation Research Board (1979). *Low-volume Roads: Second International Conference*. Transportation Research Record 702. National Academy of Sciences, Washington, D.C. August 1979.
2. Gourley C S and PAK Greening (1999). *Performance of Low-volume Sealed Roads: Results and Recommendations from Studies in Southern Africa*. Project Report PR/OSC/167/99. TRL November 1999.
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5. Transport Research Board/National Research Council (1995). *Assessing Worldwide Low-volume Roads: Problems, Needs and Impacts*. Transport Research Circular No. 446, May 1995.

# Chapter 2



# Regional Setting

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# Regional Setting

2

*Agriculture is the predominant activity in the rural areas of all SADC countries.*



## 2.1 Introduction

### 2.1.1 Background

Road transport is essential for the operation of the SADC economy and for the development of national and regional markets. With a total fleet of over 10 million vehicles in 2002, it provides the dominant mode of freight and passenger transport and carries about 80% of the region's total trade in goods and services. It also accounts for about 20% of the region's cross-border trade.

In common with many other developing countries a high percentage of the population in the SADC region live in rural areas, where agriculture is the predominant economic activity. In this context, low-volume roads fulfil a critical function in that they generally provide the only form of access to these communities and provide for the mobility of people and movement of goods from the fields to the market place. A good rural road network is therefore essential for improving rural livelihoods and socio-economic growth and development.

Unfortunately, despite the substantial investments made in road transport infrastructure, the cost of road transport services is still inordinately high, especially in rural areas where inadequate transport infrastructure and lack of mobility still impose important constraints on development. There are many reasons for this unsatisfactory situation, some of which are attributable to the questionable nature of various approaches adopted in the provision of LVSRs, which have proved to be unsustainable.

### 2.1.2 Purpose and Scope of Chapter

The main purpose of this chapter is to set the background to the SADC region against which the characteristics of the regional road network are presented. Issues relating to the sustainability of the gravel road network and the challenges of alternative approaches for the delivery of low-volume sealed roads are described. A new, more sustainable, multi-dimensional approach is proposed that is set in the context of the reforms taking place in the road sector in the SADC region. These initiatives are designed primarily to improve the management and financing of roads but will also facilitate the implementation of the approaches recommended in this Guideline.

## 2.2 The SADC Region

### 2.2.1 Geographic Setting

The vision of SADC is to transform the fourteen countries of southern Africa from operating as individual fragmented markets into a single integrated vibrant and globally competitive market characterised by free movement of goods, services and labour. Transport, particularly road transport, is an integral component of this vision.

One of the first institutional priorities identified by SADC was the creation of the **Southern African Transport and Communications Commission SATCC** to coordinate the use of existing systems and the planning and financing of additional regional transport facilities. Transport is, therefore, the major initial focus for regional action.

The bulk of the SADC rural road network is still unsurfaced and in relatively poor condition.



The Southern Africa Development Community (SADC) is an economic grouping of fourteen countries located in the Southern African region with a collective land area of about 10 million square kilometers and a population of nearly 200 million people in 2002. Six of the fourteen countries are land-locked while two are island states as shown in Figure 2.1.



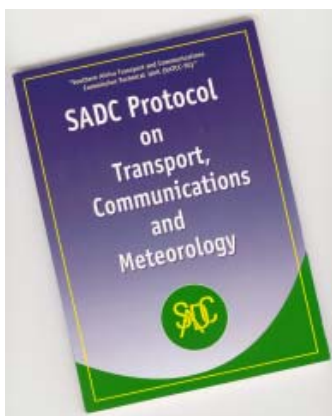
Figure 2.1 – The Southern African Development Community

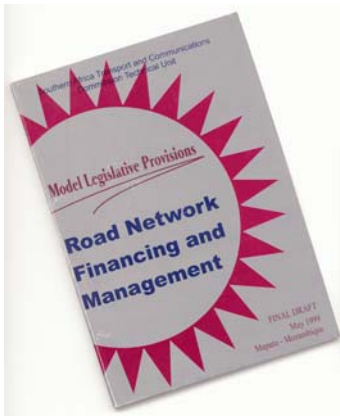
The SADC region is diverse with climates varying from true deserts through savannah to rainforests. While the natural resource base is varied, the economies of the various countries are mostly agrarian with approximately 80% of the population living and working in the rural areas. In such a setting, rural roads play a critical role in support of socio-economic growth and development and, ultimately, poverty alleviation - an over-arching goal of all SADC governments.

### 2.2.2 Road Sector Reform

Since the late 1990s, the SADC region has experienced a “wind of change” in its approach to road management and financing. It has become increasingly apparent that traditional approaches, which have relied on managing roads through a government department and financing them through general budget allocations, have generally not worked satisfactorily. This has led to the development of the SADC Protocol on Transport, Communications and Meteorology<sup>1</sup>.

The SADC Protocol promotes perhaps the most far-reaching set of changes ever contemplated in the roads sector in Sub-Saharan Africa. Its strategic vision is to provide a “safe, sustainable, efficient and effective road transport system” in support of regional socio-economic growth and development. Since its ratification by all member states, the SADC Protocol has been implemented to varying extents and with varying degrees of success. All member states are required to fully comply with the requirements of the protocol by 2010.





### Box 2.1 – The main features of the SADC Protocol on Transport, Communications and Meteorology.

The SADC Protocol commits member states to the development of a harmonised regional road sector policy with the following main features:

- Clear *demarkating* and *allocating* of authority and responsibilities for *road funding* and *road management*.
- Establishing *accountable* and *autonomous roads authorities* with public and private sector participation in key decision-making and the ability to source expertise outside civil service restrictions.
- Adopting *commercial management practices* to foster institutional, economic and technical efficiency, amongst others, by introducing competition in undertaking any road related activity and adopting a preference for the contracting out of all types of road construction and maintenance activities.
- Adopting *appropriate financing principles* and practices to secure adequate and sustainable sources of funding through incremental expansion of road user charging.
- *Dedicating revenues* from roads to their provision, operation and maintenance.
- Identifying *sustainable funding sources* to ensure a regular flow of funds.

### SADC Institutional Framework

The agreed SADC institutional framework clearly and unambiguously differentiates between the separate and discrete roles played by key road sector stakeholders in terms of policy formulation, policy delivery and works execution as illustrated in Figure 2.2.

*The restructuring of road management and financing in the SADC region, within a more commercialised institutional framework, is meant to ensure that institutional capacity exists to support improvements in technical capability, such as maintenance operations and management.*

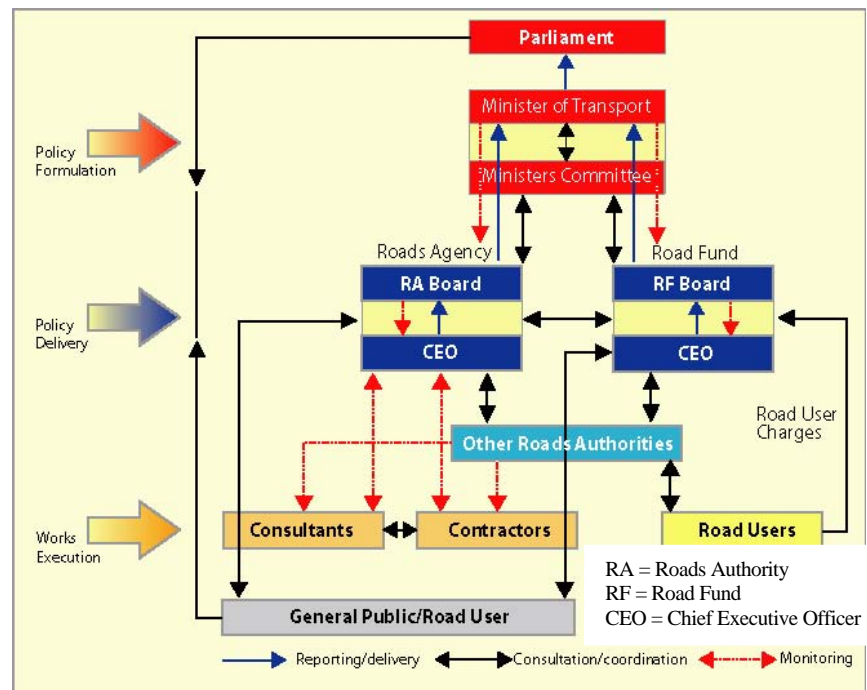


Figure 2.2 – SADC institutional framework for management and financing of roads<sup>2</sup>

Within the new SADC institutional framework, policy, management, financing and operations are treated as follows:

**Policy formulation:** The overall legal authority for the road network is vested in a *single Ministry* with responsibility for all regulatory, policy, standards and legislative matters. The Ministry has authority over the Transport/Traffic Agency. The authority over the National Roads Board is limited to approving the level of road user charges recommended by the Board to finance road maintenance and improvement works, and to monitoring the Board's compliance with the terms set out in the legislation under which it was established.

A Ministers' Committee fulfils the function of a policy co-ordination forum in respect of national, regional and local road authorities. The committee also plays an important role in promoting transparency and accountability and democratizing decision-making with regard to roads.

**Management:** An "arms-length" autonomous or semi-autonomous *Roads Agency* has replaced (or commercialised) the former Roads Department in the Ministry of Transport. Its functions are basically the same as the previous Roads Department in terms of strategic management and planning of the development, maintenance and rehabilitation of the national road network, except that they are carried out in a commercial manner. The Agency is overseen by a majority private sector Board and managed on a day-to-day basis by a Chief Executive Officer (CEO).

**Financing:** An "arms-length" autonomous or semi-autonomous *Road Fund* operates as a commercial agency with responsibility for road financing. In so doing, it:

- acts as a channel for the receipt of all revenues destined for roads
- disburses funds to roads agencies based on simple, transparent procedures
- audits compliance with well defined financial auditing principles.

Sustainable funding for road maintenance is based on the "user pays" principle and is secured through the levying of a *Road User Charge*. Such a charge reflects the usage of roads and typically consists of a fuel levy on petrol, diesel, vehicle license fees including supplementary heavy vehicle license fees, fines imposed on overloaded vehicles, and any other user charges that may be allocated from time to time by Parliament.

The funds available from road user charges should not necessarily be spent directly according to traffic level. Low-volume "social" roads will probably need to be subsidised to some extent from the revenues from high-volume "economic" roads.

**Operations:** All types of road construction and maintenance works are to be contracted to the private sector through competitive bidding processes rather than undertaken in-house by Force Account or Direct Labour operations. The procurement of works through performance-specified term contracts and the use of Petty Contractors is increasingly being viewed as the preferred method of contracting out maintenance works in contrast to the traditional type of contract which, typically, is based on rather prescriptive input specifications and utilise large, foreign contractors.

## 2.3 Regional Road Network

### 2.3.1 The Road Network

The total length of the SADC classified road network (Figure 2.3) is just over 930,000 km of which approximately 20 per cent is paved. More than half of the region's total network (511,000 km) is in South Africa. There is also a large network of rural roads in the SADC region, approximately 430,000 km, which consists of mainly 2-lane, all-weather gravel roads and seasonal earth tracks. Most of these roads were constructed in the post independence era of the 1960s and 1970s and is one of the region's biggest assets with current replacement costs in excess of US \$50 billion.

The SADC Regional Trunk Road Network (RTRN) comprises approximately 50,000 kms of strategic, intra-regional routes linking capital cities, major regional ports and other areas of economic importance. In addition to the unpaved rural road network, a significant proportion of the RTRN (approximately 30 per cent) also carries relatively low levels of traffic and, hence, these roads are also classified as "low-volume roads".

Sub-Saharan Africa, including the SADC region, lags considerably behind Asia and Latin America in terms of road coverage and density<sup>3</sup>.

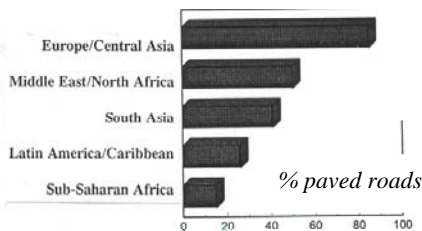


Figure 2.3 – The SADC Regional Trunk Road Network (2001) (excludes the Democratic Republic of the Congo)

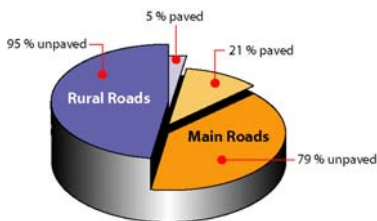
The current main road length averages about 5.6 kilometres for every 100 square kilometers, which is low compared to other developing regions such as Latin America (12 km/100 sq. km) and Asia (18 km/sq. km).

Table 2.1 – Inventory of SADC Regional Road Network

Main Roads			Rural Roads			Total Network		
Paved (km)	Unpaved (km)	Total (km)	Paved (km)	Unpaved (km)	Total (km)	Paved (km)	Unpaved (km)	Total (km)
105,122	395,900	501,022	21,559	409,626	431,185	126,681	805,526	932,207
21.0%	79.0%	100.0%	5.0%	95.0%	100.0%	13.6%	86.4%	100.0%

Source: Report by SAGP consultants; Updates from SADC member states (2001)<sup>4</sup>. (Note: Classification is inconsistent. Main roads can include trunk, regional, main, primary and secondary.)

\* Excludes the Democratic Republic of the Congo



A substantial proportion of both the main and rural road networks in the SADC region is unpaved.

### 2.3.2 Roads and Economic Development

Road transport investment should be viewed as part of an integrated approach considering the economic and social context where improvements take place, and including additional policies on other fronts (e.g. marketing, education, stimulus to demand) that would lead to higher social returns from investment.

The precise role that roads play in economic development is complex but the fact that there is a link is widely accepted and most economists agree that investment in transport infrastructure makes a positive contribution. However, the provision of road transport infrastructure alone is not enough to reap all the possible benefits from interventions. Indeed, recent research<sup>5</sup> highlights two major aspects that should be considered by policy makers: *the access to transport means, and the market organisation for goods and transport services.* Thus, SADC governments should also address the need for credit, low cost vehicles, and intermediate means of transport, and also be prepared to intervene in markets to ensure that benefits become widespread..

The benefits from road investment vary greatly depending upon the type of interventions, and the social and economic context where they take place. For example, in those rural areas in southern Africa where infrastructure is so basic that vehicle use is difficult or near impossible, facilitating the change to motorised transport would carry large benefits.

In terms of the relationship between km of paved roads/million persons and GDP per capita, the SADC region occupies a relatively low position (Figure 2.4). Thus, improving the efficiency of LVSR provision by providing them at lower and more affordable costs than hitherto, has the *potential* (together with other complementary interventions) for providing considerable benefits to the region's economy and, in so doing, for reducing poverty.

Road network density in developed countries is generally much higher than in developing countries. However, the cost of building roads is not proportional to the wealth of a nation in terms, for example, of the GDP per inhabitant. Thus, with the GDP per inhabitant being 10 to 20 times lower in developing countries, the cost of road provision is two to three times higher than in developed countries. It is therefore critically important that paved road construction costs are minimized through the selection of appropriate standards and implementation strategies.

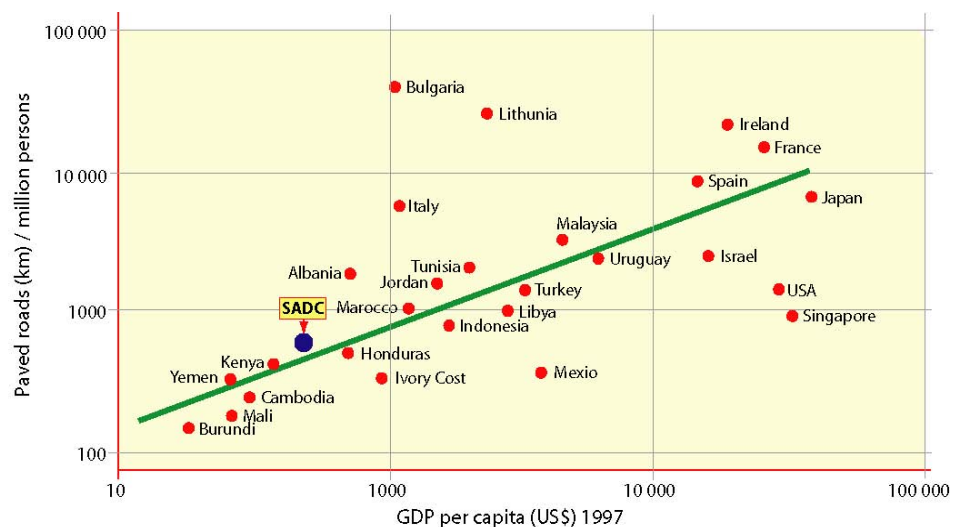


Figure 2.4 – International comparison of paved road density and GDP per capita

## 2.4 Road Network Details

### 2.4.1 Classification and Traffic Flows

Roads in the SADC region are classified according to function typically as shown in Table 2.2 and illustrated in Figure 1.1.

Table 2.2 – Typical road functions and classification

Road Function				Design Class	Traffic Flow (AADT)	Typical Surface Type
Tr	P	S	Te			
				A	> 2000	Paved
				B	500 – 2000	Paved
				C	200 – 500	Paved/ Unpaved
				D	50 – 200	Unpaved
				E	<50	Unpaved

Key Tr = Trunk P = Primary S = Secondary Te =Tertiary/access



Pedestrians and non-motorised traffic often constitute a significant proportion of traffic near villages.

With the exception of South Africa, and apart from a few heavily trafficked international routes, most of the main roads carry modest volumes of traffic with little more than about 10 per cent carrying over 2000 vpd, approximately 25 per cent of which consists of heavy, often over-loaded, commercial vehicles. On rural roads, traffic volumes are relatively very low and much of this network carries traffic in the range of 50 – 200 vpd. Near village centres non-motorised traffic, including bicycles, often comprises a significant proportion of the total traffic.

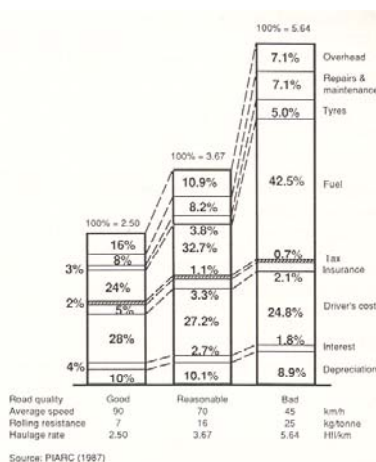
*The “low traffic” characteristics of much of the rural road networks in the SADC region have implications for geometric design, pavement and drainage structures, road furniture and maintenance practice and, indeed, the manner in which investment appraisals are carried out.*

### 2.4.2 Design Standards

Road design standards in the SADC region vary considerably, reflecting either the practice of the developed countries, with which member states have had previous ties, or the preferences of international consultants, usually donor funded, who have worked in the country. Thus, British, American, Portuguese, French, German and other standards have left their mark on the road infrastructure. In many instances, these standards have been inappropriate for cost-effective application in the SADC region where physiographic, socio-economic and environmental conditions vary tremendously from the countries of origin of the standards.

### 2.4.3 Road Conditions

About 50% of the paved main road network is currently (2001) in good condition, with the remainder classified as only fair or poor, as shown in Table 2.3. The unpaved main road network is considerably worse than the paved road network with less than 40% in good condition. The net result is that transport costs are very high with estimates of four to five times of those in developed countries and, for some landlocked countries, as high as 30 – 40 per cent of the price of goods.<sup>6</sup>



The influence of road conditions on haulage costs – both the operating and maintenance costs of vehicles escalate with increasing rapidity as the surface condition worsens(PIARC, 1987).

Can any country afford this?



*“My country was never so rich that it could afford poor roads”*(William the Conqueror, Doomsday Survey, 1086).

**Table 2.3 - Condition of main roads in the SADC region**

Main Roads	Road Condition (Weighted Average)		
	Good	Fair	Poor
Paved	49	36	15
Unpaved	38	31	31

Sources: Report by SAGP consultants to SATCC<sup>4</sup>; Updates from member states (2001)

Notes:

*Good:* Substantially free of defects and requiring only routine maintenance  
Unpaved roads need only routine grading and spot repairs

*Fair:* Having significant defects and requiring resurfacing or strengthening  
Unpaved roads need reshaping or re-gravelling and spot repair of drainage

*Poor:* Having extensive defects and requiring immediate rehabilitation or reconstruction  
Unpaved roads need reconstruction and major drainage works

Rural poverty in the SADC region is exacerbated by the prevailing poor road conditions which adversely affect accessibility and, as a result, limit the facilitating role of transport in both production and consumption activities. Improvements in the quality and reliability of the rural road network are therefore critical for development and poverty eradication, the over-arching goal of all SADC governments.

*For these reasons, most of the current investment in the roads sub-sector involves upgrading these predominantly low volume, rural secondary and feeder roads to an improved standard at minimum life cycle cost – which is the main focus of this Guideline.*

#### 2.4.4 Road Safety

**T**here is a serious road safety problem in all countries of the SADC region. This is characterised by a high rate of road accidents involving pedestrian and other vulnerable road users, particularly on rural roads where vehicle speeds tend to be relatively high. Fatality rates, in relation to vehicle fleets, are estimated to be 30 – 40 times higher than those of industrialised countries and cost the region between one and three per cent of their annual GDP<sup>7</sup>.

Fortunately, there is now a widespread recognition that much more can be done to improve the poor road safety situation. This includes improvements in road design and the more widespread use of road safety audits. These issues, amongst others, are dealt with in Chapter 4 of the Guideline.



*The high accident rate in the SADC region is a source of loss and damage to trade and one of the major causes of injury and death.*

## 2.5 Low-Volume Sealed Roads

### 2.5.1 The Challenge

A number of factors combine to pose a major challenge to road authorities in the provision of LVSRs. In this regard:

- They generally constitute a high proportion (typically 80%) of the road network for which available resources are severely limited.
- Limited funding tends to be allocated in favour of HVRs which are perceived as fulfilling an important economic role even though LVRs fulfill at least equally important social and development functions.
- Social and developmental benefits are often dealt with inadequately in traditional investment appraisal methodology.
- There has been a tendency to focus predominantly on the technical aspects of LVSRs with inadequate attention to the other environments within which they operate and which influence their long-term sustainability.
- Traditional highway engineering, planning and standards that are applied to roads with higher volumes of traffic are often not appropriate for LVSRs and, when used, result in unnecessarily expensive solutions.
- While traffic volumes may be relatively low, vehicle loads are often high, with significant over-loading. This makes the relatively light pavement structures, that would otherwise be appropriate, vulnerable to overloading.
- The allocation of limited research funding tends to be prioritized in favour of high volume roads which are perceived to offer higher rates of return.

In addition to the challenges faced by road agencies in providing LVSRs, transport agencies also face a major challenge of providing affordable transport services to rural communities. However, although closely related, this topic is outside the scope of this Guideline.

### 2.5.2 Gravel Road Issues

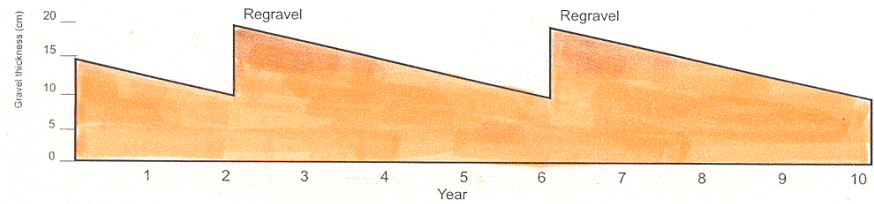
A substantial proportion of the rural road networks, and to a lesser extent, the main road networks in the SADC region, are currently unpaved. These roads need to be continuously regravelled utilizing naturally occurring gravels, a finite, often scarce, non-renewable resource.

In practice, many countries do not have the necessary financial resources to sustain their gravel road networks. As illustrated in Figure 2.5, this quickly leads to the total loss of the investment as well as to all-weather access for the communities that these roads serve.

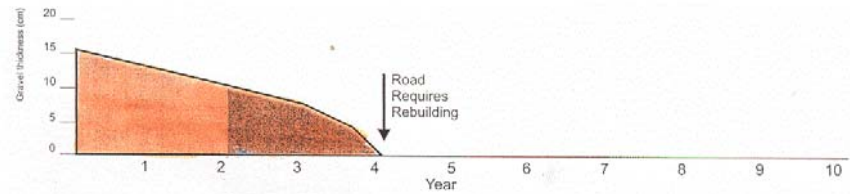
*In the past, geometric design standards were not specifically addressed in the SADC region. Both road planners and designers were faced with either using “national” imported standards that were developed for a higher classification of roads or reducing these higher classification standards to meet economic constraints, usually without a logical basis for doing so.*



*Based on a typical regravelling cycle of 3 – 4 years and a replacement gravel thickness of 100 mm over a 6.5 m carriageway, the annual consumption of gravel in the region is of the order of 150 million cubic metres. Is this process sustainable in the medium to long term? NO!*



(a) Gravel thickness with preventative maintenance (timely regravelling).



(b) Gravel thickness without preventative maintenance (no timely re-gravelling)

**Figure 2.5 – Periodic maintenance (regravelling) of unsurfaced roads<sup>10</sup>.**

**Sustainability considerations**

There are a number of very serious concerns to national governments, development agencies and rural communities regarding the use of gravel road surfaces. These are summarized in Table 2.4.

**Table 2.4 – Gravel road sustainability considerations**

Issue	Sustainability Factor
<ul style="list-style-type: none"> <li>● <b>Financial and economic</b></li> </ul>	<ul style="list-style-type: none"> <li>○ Gravel is a sacrificial layer and replacement is at a high cost:                             <ul style="list-style-type: none"> <li>- 30 to 150 mm can be lost per annum</li> <li>- regravelling operations cost US \$5,000 to 30,000 per/km/year</li> <li>- periodic maintenance costs US \$2,000 to \$3,000/km/year</li> <li>- continuous regravelling is a significant recurrent financial burden</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>● <b>Institutional and management</b></li> </ul>	<ul style="list-style-type: none"> <li>○ Unpaved roads:                             <ul style="list-style-type: none"> <li>- typically constitute 70 to 90% of the main road network and most of the undesignated network</li> <li>- generate a continuous cycle of deterioration and backlog maintenance</li> </ul> </li> <li>○ Roads agencies:                             <ul style="list-style-type: none"> <li>- suffer logistical, technical and financial constraints</li> <li>- often have limited physical, human and natural resources</li> <li>- have little capacity to intervene in maintenance activities as required</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>● <b>Standards and technology</b></li> </ul>	<ul style="list-style-type: none"> <li>○ Wastage of finite resources (selective gravelling difficult in practice).</li> <li>○ Expensive mechanised approaches required for regravelling result in:                             <ul style="list-style-type: none"> <li>- operational, support and technical problems</li> <li>- local financing burden</li> </ul> </li> <li>○ Potential longer term sustainability of labour based methods</li> </ul>
<ul style="list-style-type: none"> <li>● <b>Social</b></li> </ul>	<ul style="list-style-type: none"> <li>○ Land take and rehabilitation of borrow pits.</li> <li>○ Wet weather access problems for communities continue.</li> <li>○ Generation of dust in dry weather with adverse impacts including:                             <ul style="list-style-type: none"> <li>- health hazard</li> <li>- pedestrian and vehicle safety</li> <li>- crop, natural habitat and vehicle damage</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>● <b>Environmental</b></li> </ul>	<ul style="list-style-type: none"> <li>○ Continuous demand for use of non-renewable natural resources which are being seriously depleted</li> <li>○ Haul distances and cost continually increase</li> <li>○ Land take continues</li> <li>○ Roads susceptible to erosion (siltng of drains and water courses)</li> <li>○ Chemical treatment options can be hazardous</li> </ul>



*Due to loss of fines, gravel roads often become very rough which make driving conditions hazardous and, in addition to severe driver discomfort, impose very high vehicle operating*



*Generation of dust is a constant hazard to over-taking motorists as well as to inhabitants living nearby and their crops.*

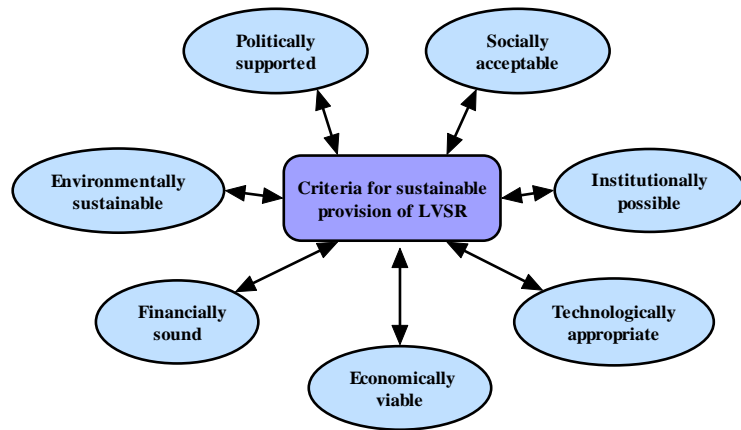
*For the above reasons, it is now abundantly clear that the time has come to provide more sustainable solutions to low-volume roads in many SADC countries by sealing them, where viable, at an affordable cost. Meeting this challenge is the main focus of this Guideline.*

### 2.5.3 Need for Sustainable Strategies

Traditional approaches to LVSR provision have tended to focus somewhat narrowly on the technical environment with inadequate consideration of the other inter-related environments shown in Figure 2.5. The result has often been a lack of responsiveness to the needs of various stakeholders' and a reduced likelihood of achieving sustainable solutions<sup>8,9</sup>.

Lessons learned from the region indicate if LVSRs are to be provided in a more sustainable manner than hitherto then new approaches are required that focus in a more holistic way on a number of factors operating within multi-dimensional, inter-acting environments.

*By their nature, LVSRs fulfil a variety of economic and social functions and their provision is influenced by a number of complex, inter-acting environments in which non-technical factors play a crucial role. Thus, it is of paramount importance that emphasis is placed on a multi-disciplinary, participatory approach in the planning, design, construction, maintenance, etc., of LVSRs.*



**Figure 2.5 – A new framework for sustainable provision of LVSRs**

Achieving sustainability in the provision of LVSR requires an important shift of emphasis from a relatively narrow focus to a more broadly focused, multi-dimensional approach in which a number of influential factors need to be considered as indicated in Table 2.5.

**Table 2.5 – Factors affecting the provision of LVSRs in the SADC region**

Environment	Sustainability factors
<ul style="list-style-type: none"> <li>● <b>Political</b></li> </ul>	<p><i>Government policy: Often no coherent policy in place.</i></p> <ul style="list-style-type: none"> <li>● Need to highlight the key benefits to be derived from LVSRs leading to the development of a comprehensive policy that:                             <ul style="list-style-type: none"> <li>○ promotes sustainability in all aspects of LVSR provision</li> <li>○ covers wider social and economic goals of poverty alleviation and, by implication, employment creation</li> <li>○ promotes use of appropriate technology and environmental awareness</li> </ul> </li> </ul> <p><i>Political and public perceptions: Tendency to favour conventional approaches and standards with perceived minimum “risk” attached to them.</i></p> <ul style="list-style-type: none"> <li>● Need to maintain continuous dialogue with political and public stakeholders in order to:                             <ul style="list-style-type: none"> <li>○ highlight pros and cons of alternative solutions in a balanced and transparent manner</li> <li>○ more determinedly “sell” proven innovative approaches and appropriate, non-traditional standards on the basis of quantified benefits</li> </ul> </li> </ul>

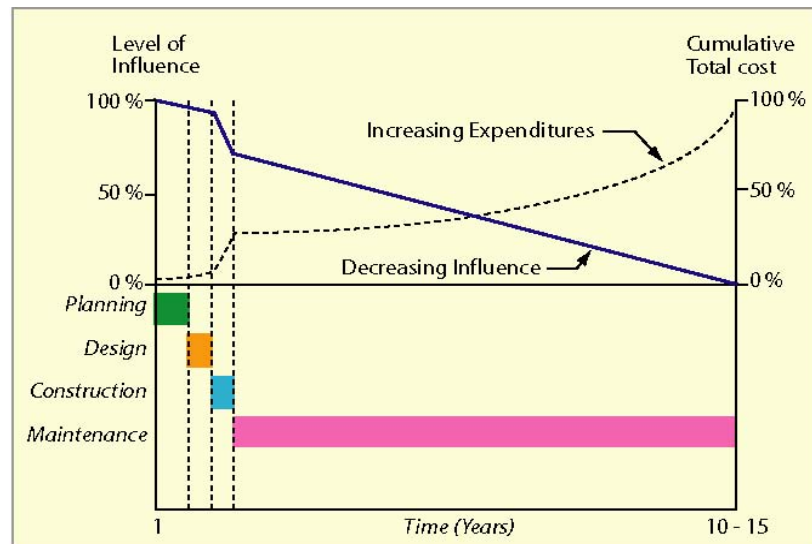
<ul style="list-style-type: none"> <li>• <b>Social</b></li> </ul>	<p><i>Social issues: Tend to be neglected or to be subordinate to technical and economic issues</i></p> <ul style="list-style-type: none"> <li>• Adopt strategies that: <ul style="list-style-type: none"> <li>○ support cost-effective labour-based methods of construction and maintenance</li> <li>○ ensure community participation in mainstream policy, planning and decision making</li> <li>○ eliminate gender biases and promote participation by women in labour-based activities</li> <li>○ promote activities and investment for sustainable enhanced livelihoods</li> <li>○ minimise the amount of resettlement and, where unavoidable, mitigate the effects by expeditious and compensated resettlement.</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>• <b>Institutional</b></li> </ul>	<p><i>Institutional capacity: Often inadequate. Growing trend towards establishment of more autonomous central and local road authorities.</i></p> <ul style="list-style-type: none"> <li>• Adopt strategies that: <ul style="list-style-type: none"> <li>○ promote commercial management practices to foster institutional, economic and technical efficiency in the provision of LVSRs</li> <li>○ reduce and eventually phase out in-house, force account operations in favour of contracting out of works to the private sector</li> <li>○ define and develop the optimal environment for the development of local contractors</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>• <b>Technical</b></li> </ul>	<p><i>Technology choice: A wide range of options is available for designing, constructing and maintaining LVSRs.</i></p> <ul style="list-style-type: none"> <li>• Adopt strategies that: <ul style="list-style-type: none"> <li>○ employ appropriate design standards and specifications.</li> <li>○ utilise technologies that create employment</li> <li>○ use types of contract that support the use of local contractors</li> <li>○ promote road safety in all aspects of LVSR provision</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>• <b>Economic</b></li> </ul>	<p><i>Economic analysis: Traditional approaches are often unable to capture the full benefits of LVSR provision.</i></p> <ul style="list-style-type: none"> <li>• Adopt strategies that: <ul style="list-style-type: none"> <li>○ integrate social, environmental and economic elements in project appraisal.</li> <li>○ use appropriate evaluation tools capable of quantifying social, economic and environmental costs and benefits</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>• <b>Financial</b></li> </ul>	<p><i>Funding: Usually inadequate to meet minimum requirements.</i></p> <ul style="list-style-type: none"> <li>• Adopt strategies that: <ul style="list-style-type: none"> <li>○ promote commercialisation in the roads sector</li> <li>○ establish sustainable sources of funding</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>• <b>Environmental</b></li> </ul>	<p><i>Environment: Generally regarded as the price to be paid for development and often neglected.</i></p> <ul style="list-style-type: none"> <li>• Adopt strategies that: <ul style="list-style-type: none"> <li>○ minimise the physical impacts of construction and maintenance</li> <li>○ take account of socio-cultural impacts (community cohesion)</li> <li>○ resource management (recycling of non-renewable materials)</li> <li>○ recognise that climate change should be taken into account in the design process</li> </ul> </li> </ul>

#### 2.5.4 Main Components of LVSR Provision

The four major components of LVSR provision that will typically be undertaken within the new SADC institutional framework are as follows:

- Planning
- Design
- Construction
- Maintenance

These components have important but changing impacts on the end result – a *Low-Volume Sealed Road* – in terms of their “level of influence”<sup>11</sup>. Figure 2.6 illustrates the essential features of the “level of influence” concept in terms of how the effect on the total life cycle costs of a LVSR project decreases as the project evolves.



**Figure 2.6 – Influence level of LVSR components on total costs**

In essence:

- Costs during the planning and design phases are relatively small compared with the total expenditure and are incurred during a relatively short period of the project's life. However, their downstream level of influence is very large in terms of decisions and commitments made during the early phases of the project.

*This emphasizes the importance of employing a broadly-based, holistic approach to the planning of LVSR's with the main stakeholders being involved in the decision-making process. In addition, the designs employed (geometric and pavement) should be appropriate and relevant to the environment in which the road is being constructed.*

- The capital costs for construction are a fraction of the operating and maintenance costs associated with a pavement life cycle. However, the decisions made during the construction phase, and the methods of construction adopted, can have a great impact on the cost of maintaining the road.

*This emphasizes the importance of ensuring a high degree of quality control in the use of local materials and the adoption of construction methods that are appropriate to the multi-dimensional environment in which the road is being provided.*

- Maintenance occupies a significant number of years in the life of the project and the type and cost of maintenance required is influenced significantly by the preceding planning, design and construction phases.

*This emphasizes the importance of ensuring that the maintenance phase is prolonged as much as possible to extend the useful life of the road and the period of time during which benefits are incurred.*

- At the beginning of the project, the roads agency controls all factors (100 per cent influence) in determining future expenditures. The key issue is how to optimize the use of scarce resources in the provision of LVSRs in an efficient, effective, appropriate and sustainable manner.

The subsequent chapters of the Guideline deal in turn with the main components of LVSR provision - planning, design, construction and maintenance – with particular emphasis on the “level of influence” concept described above.

## 2.6 Summary

The key points raised in this chapter are:

1. Roads are central to economic development and poverty alleviation as well as creating opportunities for employment in the SADC region. Despite the substantial investments made in road infrastructure, road transport costs remain very high, particularly in rural areas, and this has had an adverse impact on the regional economy.
2. The road network of about one million kilometres is characterised by relatively low traffic levels (< 200 vpd) outside of urban areas, variable design standards, poor road conditions and a very serious road safety problem.
3. More than 80% of the regional road network is unpaved. In the medium to long term, continuous gravelling or regravelling of these roads is unsustainable. Consideration must be given to sealing them, where viable, at an affordable cost.
4. New, more sustainable, broadly focused, multi-dimensional approaches are required to deal effectively and efficiently with the management of the large kilometrage of unsurfaced roads.
5. The region has embarked on major reforms of the road sector with the objective of managing and financing roads within a more commercialised environment. This will have a profound effect on the way in which the sector operates in future and provides the potential for substantial improvements in the provision of LVSRs.
6. The main components of LVSR provision – planning, design, construction and maintenance – have important but changing impacts on the end result in terms of their “level of influence”.

This chapter puts into context the challenges that road agencies in the region face in providing LVSRs in a sustainable manner - challenges that are addressed in subsequent chapters of the Guideline.

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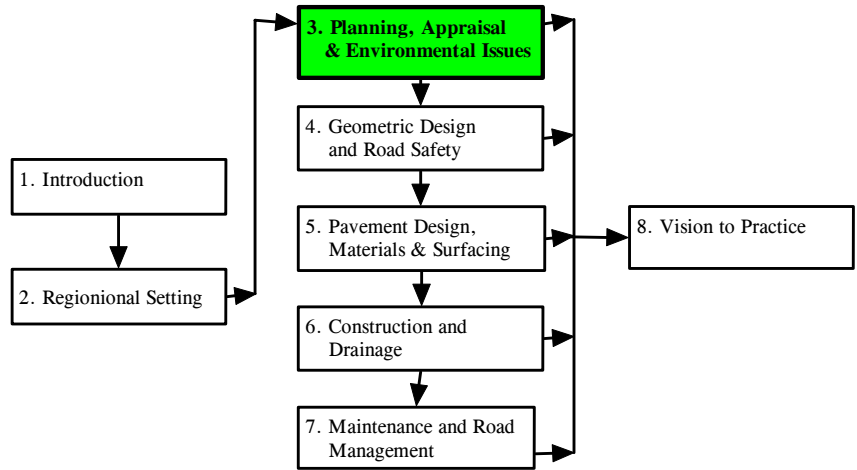
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# Chapter 3



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## Planning, Appraisal & Environmental Issues

**3**

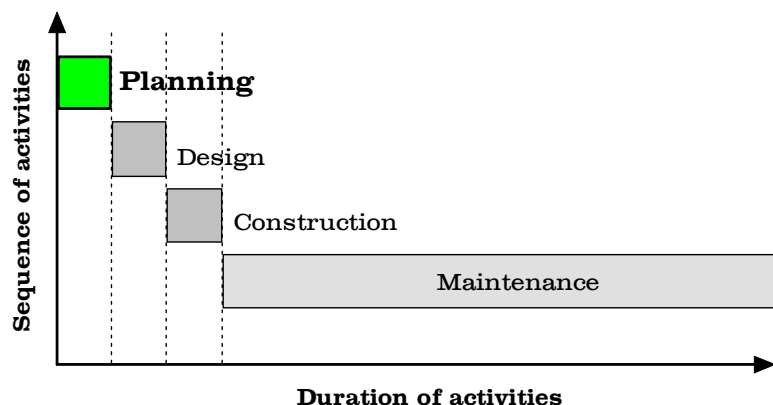
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# Planning, Appraisal & Environmental Issues

3

## 3.1 Introduction

### 3.1.1 Background



As indicated in Chapter 2, planning exerts a substantial level of influence on the downstream aspects of LVSR provision in terms of its impact on the subsequent design, construction and maintenance phases. The planning phase can therefore be rightly viewed as the foundation on which the subsequent phases are based. It is an activity aimed at considering a wide range of options with the objective of providing an optimal, sustainable solution, i.e. one which satisfies the multiple needs of stakeholders at minimum life-cycle costs.

It is noteworthy that planning technologies and techniques that are often applied in the region generally draw little distinction between low-volume and high-volume roads even though these roads have quite different characteristics. As a result, many aspects of LVSR sustainability are not adequately addressed. Failure to revise or adapt these planning approaches to cater specifically for low-volume roads can lead to the adoption and implementation of sub-optimal solutions that are unsustainable.

The appraisal of LVSRs also requires careful consideration. This is largely because the traditional tools that are available for their evaluation are generally not adequate for capturing the full range of benefits – often of a predominantly social rather than economic nature – that arise from their upgrading. This indicates the necessity for adopting methods of appraisal that include more socially oriented investment criteria so as to accord with the social objectives of poverty alleviation. Fortunately, new, customised economic evaluation models are being developed which are better suited than hitherto for appraising the upgrading of unpaved roads to a bituminous standard.

Prior to the start of the 1990's, environmental impact assessments of road projects were generally not required and, where carried out, were done largely at the insistence of donors. However, environmental issues are now assuming greater importance than hitherto and environmental degradation is no longer being regarded as the price to be paid for development. More and more environmental units are being established within parent ministries to ensure that appropriate mitigation measures are employed on road projects. This requires an integrated framework for dealing with environmental issues in a comprehensive and systematic manner.

### **3.1.2 Purpose and Scope of the Chapter**

**T**he main purpose of this chapter is to outline a generalised approach to planning which is holistic in nature, taking into account the many external factors that affect the process. The chapter also highlights approaches that are typically adopted in the appraisal of LVSRs and provides guidance on their adequacy for dealing with the full range of benefits arising from upgrading earth/gravel roads to a sealed standard. Finally, the chapter considers the environmental issues facing road authorities in the region and the various methods available for mitigating the adverse impacts of road construction and maintenance.

## 3.2 Planning

### 3.2.1 General Approach

Current approaches to the planning of LVSRs place greater emphasis than hitherto on the important issue of *sustainability*. Achieving sustainability in the provision of roads continues to elude transport professionals in many countries. There are still many examples of roads being constructed which, because of lack of sustainability in one way or another, often as a result of inadequate maintenance, have resulted in wasted investments.

As highlighted in Chapter 2, a holistic approach is required in which all dimensions of sustainability are addressed at the planning stage. This places more weight on multi-disciplinary planning, in which teams consisting of planners, engineers, environmentalists, etc. work together with stakeholders in order to reach optimal solutions in the most cost-effective way. Such an approach provides the best chance of achieving long-term sustainability of projects and is strongly promoted in this Guideline.

Planning for labour-based construction and maintenance works has also taken on a new emphasis as more and more SADC governments recognise the benefits of adopting this approach, where viable, as a means of providing much needed employment.

### 3.2.2 Planning Framework

A major challenge faced by planners and engineers in the SADC region is to ensure that the planning and appraisal procedures produce outputs that have the full support of decision makers. Such a framework should be transparent, relatively simple to carry out, unambiguous and equitable. Table 3.1 presents a generalised framework for this purpose.

**Table 3.1 – Framework for planning and appraisal**

Project Cycle	Planning Activity	Typical Evaluation Tools	Output
Identification	Selection	Policy resource analysis Master Plans Local/regional plans	Long list of projects
Feasibility	Screening	Livelihoods analysis Integrated Rural Accessibility Planning	Shorter list of projects
Design	Evaluation	Cost-benefit analysis - consumer surplus (e.g. RED) - producer surplus - compound ranking - multi-criteria analysis	Short list of projects
Commitment and negotiation	Prioritisation	Budget considerations - ranking by economic or socio-economic criteria	Final list of projects

In principle, the planning and appraisal processes are structured activities which start from the general and work towards the particular in relation to both data and project ideas<sup>1</sup>. The main features of the planning and appraisal processes are as follows:



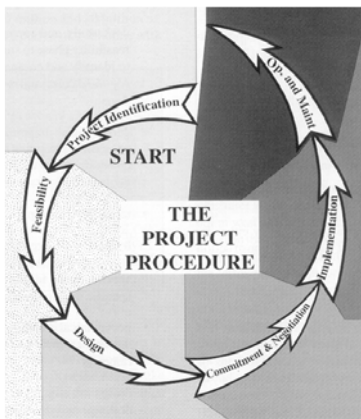
*A road where one or more of the seven dimensions of sustainability is missing.*

*When needs are great and resources limited, selection methods are necessary to make sure that only the roads with the greatest impact are constructed. Such methods should not be too costly to apply in proportion to the investment involved, nor should they be so complicated that few understand how they work. Ideally, selection methods should ensure that few good candidate projects will be rejected and not too many poor ones accepted.*



A proper selection and screening of candidate road projects at an early stage of the planning process is important.

### Typical Project Cycle



It is important that both the client and the contractor share a common vision on the standard of the road to be constructed.

### Box 3.1 – Planning and appraisal processes

- **Selection:** This is a multi-sectoral and multi-disciplinary process which should generate sufficient projects to ensure that no potentially worthwhile ones are excluded from consideration. The output is a long list of projects determined on the basis of an *unconstrained policy resource analysis* that satisfy national road transport policy.
- **Screening:** Defines the constraints within which specific planning solutions must be found, i.e. a *constrained policy resource analysis*. The output is a shorter list of projects that justify further, more detailed, analysis.
- **Evaluation:** The shorter list of projects is subjected to a detailed cost-benefit appraisal for which various methods are available. The output is a final list of projects which satisfy a range of criteria – political, social, economic, environmental – at least cost.
- **Prioritisation:** Ranks the “best” projects in order of merit up to a cut-off point dictated by the budget available.

### 3.2.3 Planning Considerations

The procedures described in the planning and appraisal framework shown in Table 3.2 are common to any type of road project. However, there are aspects of it that are of particular significance in the planning and appraisal of LVSRs that often do not emerge from conventional approaches. These are summarised below:

Table 3.2 – Project cycle and related activities

Stage	Issues to be considered
<b>Project identification</b> <ul style="list-style-type: none"> <li>• Project objectives</li> </ul>	<ul style="list-style-type: none"> <li>• Are the strategies being adopted supportive of government policy? (e.g. employment creation).</li> <li>• Are they relevant to the current and future needs of beneficiaries?</li> <li>• Are they cognisant of the multiple objectives and views of stakeholders?</li> <li>• Have effective communication channels with stakeholders been created? Are they gender sensitive?</li> </ul>
<b>Feasibility</b> <ul style="list-style-type: none"> <li>• Design criteria</li> <li>• Cost-benefit analysis</li> <li>• Socio-economic assessment</li> <li>• Road safety assessment</li> <li>• Environmental assessment</li> <li>• Livelihoods</li> </ul>	<ul style="list-style-type: none"> <li>• Is there adequate participatory planning and consultation with public and private sector stakeholders?</li> <li>• Do the design criteria take full account of the specificities of LVSRs, including non-motorised traffic?</li> <li>• Are appropriate evaluation tools being used?</li> <li>• Has a base line environmental survey been undertaken?</li> <li>• Has a road safety audit been incorporated in the project?</li> </ul>
<b>Design</b> <ul style="list-style-type: none"> <li>• Design standards</li> <li>• Pavement/surfacing design</li> </ul>	<ul style="list-style-type: none"> <li>• Are the geometric, pavement design and surfacing standards technically appropriate?</li> <li>• Are they environmentally sound?</li> <li>• Are specifications and test methods appropriate to local materials being used?</li> </ul>
<b>Commitment &amp; negotiation</b> <ul style="list-style-type: none"> <li>• Contract documentation</li> </ul>	<ul style="list-style-type: none"> <li>• Do designs accommodate construction by labour-based methods?</li> <li>• Do they include environmental protection measures?</li> <li>• Have tender documents been prepared and contract strategies adopted that facilitate involvement of small contractors?</li> </ul>



The end result – a successfully completed project that meets the requirements of all stakeholders by satisfying the seven key dimensions of sustainability.

**Labour-based construction:** The economically efficient employment of as much labour as is technically feasible to produce as high a standard of construction as demanded by the specification and allowed by the funding available. This implies an optimal balance between labour and equipment.

**Labour-intensive construction:** The use of as much labour as possible by substituting men for machines often to satisfy short-term needs. This implies an imbalance between labour and equipment and, invariably, an economically inefficient end product.

“We know that employment is the first step towards escaping from poverty”.

Juan Somavia, Director General of the International Labour Organisation (ILO), 2001.

**Implementation**

- Construction
- Inspection and monitoring
- Environmental mitigation

- Have labour-based rather than equipment based methods of construction been adopted where feasible?
- Are environmental mitigation measures contained in the contracts? Are they enforceable?
- Have specific measures been included in the contract to cater for health and safety matters such as HIV/AIDS?

**Operations and maintenance**

- Performance evaluation
- Maintenance operations

- Have the various indicators of socio-economic well being been monitored and evaluated?
- Are there adequate arrangements for community participation in road maintenance?
- What are the lessons for the future?

Thus, in the planning and appraisal of LVSRs, it is necessary to carefully consider the multi-dimensional range of issues highlighted in Table 3.2 that can significantly influence the output of the process.

### Labour-Based Projects

In view of the emergence of labour-based approaches as a viable alternative to some aspects of the more traditional plant-based approaches, the planning of such projects merits special consideration. Without appropriate technical and financial planning from the inception of a project, serious problems may ensue, which may ruin the initiative and bring into disrepute the practicability and objectives of labour-based projects.

Many items need to be investigated in terms of their suitability for labour-based methods of construction or maintenance. Contractual aspects need to be established and appropriate designs undertaken. Such planning must extend beyond engineering technology and the practicality of construction and also consider such factors as the financing and management of labour-based projects. Guidance and training on such issues is provided by a number of international organisations in the SADC region, including the International Labour Organisation Advisory Support, Information Services and Training (ILO/ASIST).

#### Box 3.2 – Why labour-based construction?

The primary objective of labour-based projects is to complete construction efficiently and economically within a specified time. Secondary objectives include:

• Employment creation	• Creation of skills
• Creation of local entrepreneurs	• Improvement of labour productivity
• Optimization of the use of local resources	• Construction of a technically sound, economically efficient product

For many people, labour-based work may be their first formal job and a future doorway to other forms of work. Moreover, money which would go out of the community is retained and the skills attained can be applied later in the maintenance of the project throughout its life, or on other similar projects.

### 3.2.4 External Factors

There are a number of external factors, many of them of a non-technical nature, that directly or indirectly affect the planning process itself or the outcomes from that process. It is important to be aware of them when devising an appropriate planning procedure and, where possible, to take them into account. These various factors are listed in Table 3.3.

**Table 3.3 – External factors that affect the planning of LVSRs**

Environment	Factor	Implications on approach to LVSR provision
Political	<ul style="list-style-type: none"> <li>● Government policy</li> <li>● Political perceptions</li> <li>● Political involvement</li> </ul>	<ul style="list-style-type: none"> <li>● Influences practice. Covers issues such as poverty alleviation, sustainable socio-economic development, technology choice, employment creation, standards, sources of funding.</li> <li>● Tendency to favour conventional approaches and standards with perceived minimum “risk” attached to them. There is a need to communicate effectively, quantify and “sell” innovative approaches and appropriate, non-traditional standards.</li> <li>● To be expected. Will tend to influence decision-making. Highlight pros and cons of alternative solutions in a balanced, transparent manner and maintain continuous dialogue with stakeholders.</li> </ul>
Social	<ul style="list-style-type: none"> <li>● Poverty alleviation</li> <li>● Sustainable livelihood</li> <li>● Gender considerations</li> </ul>	<ul style="list-style-type: none"> <li>● Implies use of labour-based rather than fully plant-based methods where feasible.</li> <li>● Enhance local participation and resource mobilisation by involving the people who will ultimately benefit from the projects.</li> <li>● Understanding the community strengths and weaknesses, assets, vulnerability to shocks and constraints, governance issues and policies needed.</li> <li>● Eliminate gender biases by integrating the transport needs of women in the mainstream of policy and planning.</li> <li>● Promote participation by women in labour-based construction and maintenance programmes and training to assume supervisory roles.</li> </ul>
Institutional	<ul style="list-style-type: none"> <li>● Organisation</li> </ul>	<ul style="list-style-type: none"> <li>● Growing trend towards establishment of more autonomous central and local roads authorities.</li> <li>● Greater scope for generating accountability for results in road programmes and moving from force account to contracting out of work to the private sector.</li> </ul>
Technological	<ul style="list-style-type: none"> <li>● Technology choice</li> </ul>	<ul style="list-style-type: none"> <li>● Need for cost-effective strategies that utilise the dual output of road infrastructure and employment creation.</li> </ul>
Economic	<ul style="list-style-type: none"> <li>● Evaluation</li> </ul>	<ul style="list-style-type: none"> <li>● Road benefits are often not limited to use of road, but also from the way in which the road is financed, designed, constructed and maintained. There is a need to capture monetary and non-monetary benefits in the evaluation framework.</li> </ul>
Financial	<ul style="list-style-type: none"> <li>● Funding</li> <li>● Sustainability</li> </ul>	<ul style="list-style-type: none"> <li>● Usually very scarce. Financing proposals must look increasingly at minimum standards, limited donor funding and local funding of recurrent maintenance costs.</li> <li>● Sustainability of funding has become a critical issue. There is a need to commercialise operations where possible and involve stakeholders in the maintenance of facilities.</li> </ul>
Environmental	<ul style="list-style-type: none"> <li>● Impact</li> </ul>	<ul style="list-style-type: none"> <li>● Need to capture social as well as environmental impacts in the evaluation of LVSRs.</li> <li>● Address health-threatening impacts as a high priority.</li> </ul>

*Decision making should be based on rational technical, economic or social factors which, ultimately, should be coincident with the best political options. However, frequently, the political factors precede technical, economic or social factors.*

### 3.2.5 Planning Tools

#### Policy Analysis

The objective of the policy analysis is to define, in general terms, the constraints within which specific planning solutions must be found. Constraints may relate to such factors as government policy on employment, provision of accessibility, income distribution and regional development as well as technical factors such as type of terrain and transport facilities, level of existing traffic, capacity and expertise of the local construction industry, availability of finance, etc.

#### Master Plans

Master plans or regional plans are used in many SADC countries to help in determining priorities for the future. These plans are not transport specific but relate to all sectors and help to identify investment requirements and priorities over a defined period. It is at this stage that new road projects will first be identified.

During the preparation of a master plan it is important that transport planners liaise closely with other Ministries. In the rural context particular priorities will include education, health and agriculture. It is also important that extensive consultation is undertaken with local communities and opinion leaders.

#### Livelihoods Framework

“Livelihoods Analysis” is a useful approach to adopt in order to identify the ways in which any particular investment intervention will impact, benefit or disadvantage the local community<sup>2</sup>. A rural livelihoods analysis provides a framework for understanding how any proposed changes will affect personal or community livelihoods in the longer term. It focuses directly on how the local community uses and develops its social (S), human (H), financial (F), natural (N) and physical (P) asset structure (see Figure 3.1).

It is clear that transport interacts with many aspects and dimensions of a person’s or a community’s livelihood. For example, substantial benefits could therefore be obtained if the labour requirements involved in collecting water, firewood or taking crops to market could be reduced. The provision of all-season road access could reduce the vulnerability of rural communities by removing seasonal isolation, and reducing transport costs and travel times to essential economic and social services.

*“A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the long and short term.”*

Chambers and Conway, 1992<sup>2</sup>.



**H = human capital:** the skills, knowledge, ability to work and good health important to the ability to pursue different livelihood strategies.

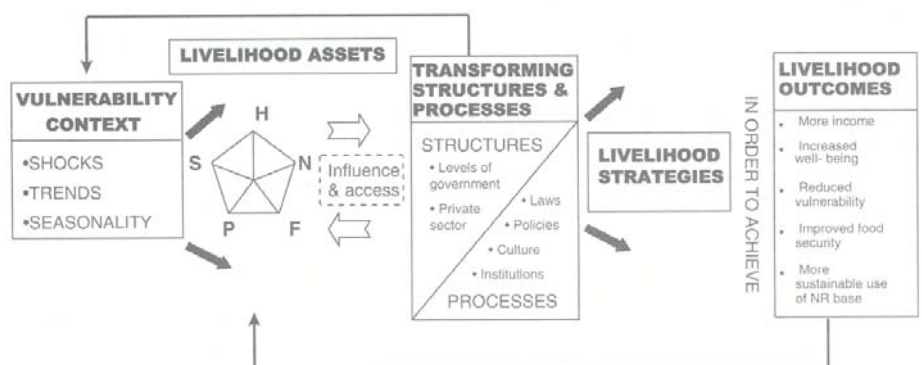
**P = physical capital:** the basic infrastructure (transport, shelter, water, energy and communications) and the production equipment and means that enable people to pursue livelihoods.

**S = social capital:** the social resources (networks, membership of groups, relationships of trust, access to wider institutions of society) upon which people draw in pursuit of livelihoods.

**F = financial capital:** the financial resources which are available to people (whether savings, supplies of credit or regular remittances or pensions) and which provide them with different livelihood options.

**N = natural capital:** the natural resource stocks from which resource flows that are useful for livelihoods are derived (e.g. land, water, wildlife, biodiversity, environmental resources).

Figure 3.1 - Sustainable livelihoods framework



### **Integrated Planning Techniques for Transport**

Master plans and the sustainable livelihoods approach are both general multi-sectoral planning tools but the specific focus is not on transport interventions. Transport may or may not be one of the interventions that are identified. However, there are a number of integrated planning techniques that specifically address transport issues. Their common thread is that planners need to address a range of issues in improving the accessibility of rural people to essential economic and social services through a combination of improved infrastructure, improved transport services and the improved location of the services themselves.

Integrated Rural Accessibility Planning (IRAP) has been developed by the ILO<sup>3</sup> and is probably the most widely used planning technique of its type. IRAP has been used in many countries in the region, including Tanzania and Malawi. The approach integrates rural households' mobility needs, the siting of essential social and economic services, and the provision of appropriate transport infrastructure. Communities are involved at all stages of the planning procedure. It is based on a thorough but easy to execute data collection system that seeks to rank the difficulty with which communities access various facilities.

#### **Box 3.3 – Integrated Rural Accessibility Planning**

In this approach, an Accessibility Indicator (AI) is calculated for various facilities in each community. It is a function of the number of households (N), the average travel time to a facility (T), the target travel time (T<sub>m</sub>) and the frequency of travel (F):

$$AI = N * (T - T_m) * F$$

Typical facilities included are health, education, water and fuel. The accessibility indicators are ranked in descending order and interventions are prioritised in this way. Results of this process are discussed at a participatory workshop and interventions identified which most effectively reduce time and effort spent.

### **Network-Based Planning**

Traditionally, investments in roads have been evaluated on a link by link basis with less consideration given to the contribution which links – competing for investment – make to the connectivity or accessibility of the entire network. To overcome such short-comings, network-based planning approaches are increasingly being used to analyse the road system as a whole in order to prepare long-term strategic planning expenditure for road development and maintenance under various budgetary and economic scenarios.

Unfortunately, the situation confronting many SADC countries is one in which funding is available for maintenance of only part of the road network. In such situations it has become necessary to identify a “core road network” which is reviewed periodically and will expand or contract depending on local circumstances. Such networks often include roads of different classes that are considered to be an essential part of the total network so that links are maintained between all the communities throughout the country.

Models such as HDM-4 can be used for network-based planning purposes. However, as is often the case in many rural network situations, the necessary data required by such models is often not available, making such models inappropriate. Thus, procedures that involve a high level of stakeholder consultation are likely to be more effective for rural network planning purposes. However, there seems to be little information in the form of manuals on community-based network planning procedures.



*Benefits of engaging in consultations with local communities at all stages of the project cycle include local knowledge of risks such as flood levels, location of resources, traffic flows, etc.*



*Stakeholder involvement in the decision-making process is critical for long-term sustainability of any road project.*

### 3.2.6 Stakeholder Consultations

#### Why Have Stakeholder Involvement?

The objective of consultation is to ensure that the road planning process is undertaken in an accountable and transparent manner. This is important for the overall benefit of the affected stakeholders and for the country at large. Consultations should be carried out throughout all stages of the project cycle and should be undertaken in such a manner as to allow full participation of the authorities and the public with the following typical aims.

- establishing background information on the project from all possible sources
- identifying viable alternatives for the project
- taking on board the views of stakeholders at all stages of the project
- reaching a consensus on the preferred choice of project(s)

Decisions on transport planning and prioritisation in the SADC region have often been taken without considering the transport requirements of the people being affected by the investment. Insufficient consultation has led to the inappropriate use of resources both in terms of their usefulness to rural communities but also in terms of their impact on social and cultural traditions. To rectify this shortcoming it should be ensured that:

- local people are involved in the selection, design, planning and implementation of programmes and projects that will affect them
- local perception, attitudes, values and knowledge are taken into account
- a continuous and comprehensive feedback process is made an integral part of all development activities

#### Who are the Stakeholders?

Many people have an interest in road projects and all interested groups need to be identified and consulted in the road selection process. The primary stakeholders are those people whose social and economic livelihoods will be directly affected by the project and include:

- rural communities
- farmers groups
- market traders
- transport operators

Some other interest groups are important in the decision-making process, even though their own lives may not be affected directly by the project. These include:

- district leadership
- district's works agencies
- national roads department
- local and national politicians

Because leaders' standpoints can differ significantly from the experiences of "average" village members, it is important for any consultation process to go beyond the leadership to the grass roots.

### Consultation Techniques

There are a number of recognised participatory techniques for working with communities to determine their transport needs. These usually entail the use of trained facilitators to visually represent community livelihoods to identify constraints and needs. Typical techniques include:

- Participatory Rural Appraisal (PRA)
- Rapid Rural Appraisal (RRA).

Other methods include public hearings through political leaders, and direct community consultation. Workshops are often a good way of undertaking initial prioritisation exercises, delivering key messages and receiving feedback. It is important that all consultation techniques are well organised, that all the relevant stakeholders have been invited and that the deliberations take place in an interactive and transparent manner.

### 3.2.7 Surveys

Following from the first two phases of the project cycle there will be an initial selection of roads put forward for possible improvement and funding. Before final decisions can be made it is important to obtain information that is specific to the roads concerned. This involves conducting various road transport surveys which can help to pinpoint measures (technical, institutional and financial) for improving efficiency. These surveys may also provide supporting evidence for community perceptions on transport or, exceptionally, may provide some contradictory arguments that would need to be resolved. Participatory enquiry also supports a much greater focus on poverty issues and the role of transport in livelihoods<sup>4</sup>.

#### Engineering Surveys

Engineering condition surveys need to be undertaken in order to identify the present condition of the road, the nature of proposed interventions, the quantities of work and the costs of the interventions and the future condition of the road. The interventions required for different treatments need to be identified and costed with the engineering surveys. It is important that alternative options are considered in the detailed appraisal.

Of particular importance to low-volume sealed roads is the provision of year round access and the social and economic benefits that arise from that. Therefore, it is important that there is some engineering judgement on the length of time that impassability or traffickability problems affect the road.

The term “traffickability” is relatively new and stems from research in Tanzania that showed that traffic levels tend to fall during the wet season even on roads in good condition. Typically, motorised traffic volumes will fall in the wet season to 80% of their dry season level. However, on poor quality roads this difference is even more marked and traffic can fall to 35% of dry season traffic levels, as shown in Figure 3.2. For the purposes of this guide it can be assumed that roads have traffickability problems when wet season traffic levels fall below 50% of dry season levels.

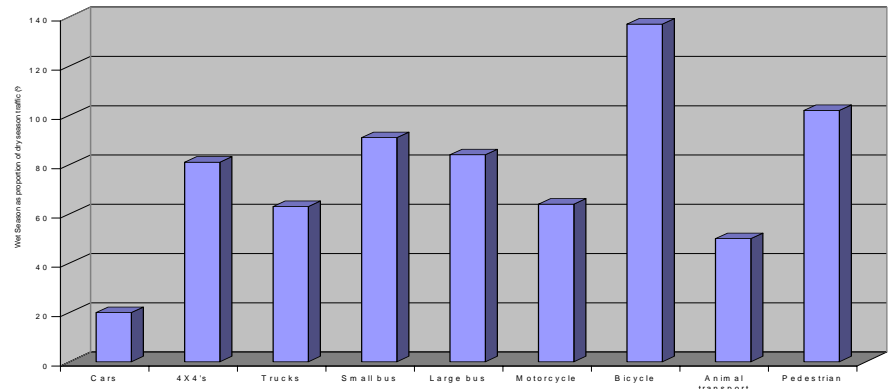


*Trafficability of unpaved roads is adversely affected during the wet season.*

#### Trafficability versus Passability:

**Trafficability:** A road is defined as having trafficability problems when the percentage of wet season traffic falls below 50% of the dry season traffic.

**Passability:** A road is defined as having passability problems when it is completely closed to motorised traffic for either or all of the year.



**Figure 3.2 - The difference in wet season and dry season traffic levels on poor quality roads in Tanzania**

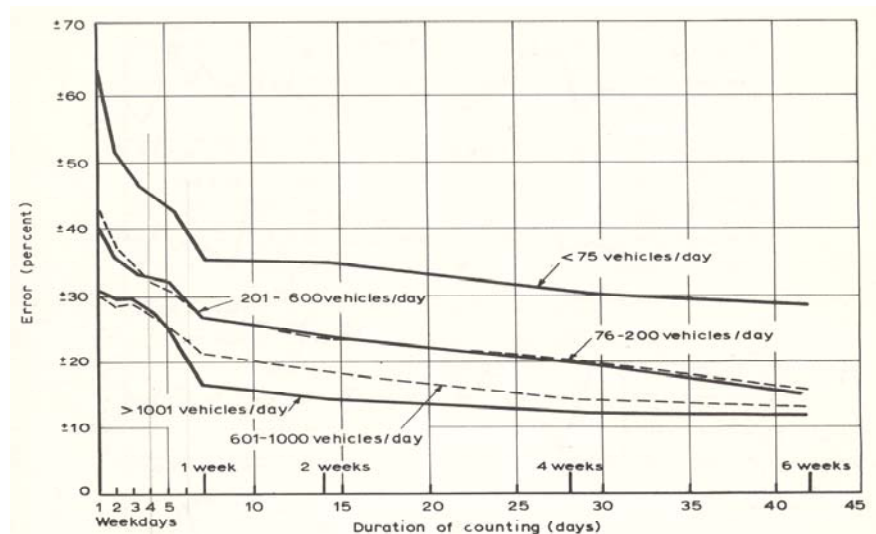
### Traffic Surveys

Traffic counts are one of the most important items of data for both geometric and pavement design as well as for planning purposes in terms of evaluation of economic benefits derived from construction of LVSRs. For these purposes, it is necessary to ascertain the volume and composition of current and future traffic in terms of motorcycles, cars, light, medium and heavy goods vehicles, buses, and, importantly, non-motorised vehicles and pedestrians.

The three most commonly used types of traffic surveys for LVRs are:

- Automatic Traffic Surveys
- Manual Traffic Survey
- Moving Observer Methods

Although the methods of traffic data collection may vary, the objective of the each method remains the same - essentially to obtain an estimate of the Annual Average Daily Traffic using the road, disaggregated by vehicle type. Prediction of such traffic is notoriously imprecise, especially where the roads serve a predominantly developmental or social function. Thus, the timing, frequency and duration of traffic surveys should be given very careful consideration in terms of striking a balance between cost and accuracy. As indicated in Figure 3.3, short duration traffic counts in low traffic situations can lead to large errors in traffic estimation and, in this respect, Moving Observer methods are likely to be particularly inaccurate.



**Figure 3.3 – Errors in ADT estimates from counts of varying duration<sup>5</sup>.**

The accuracy of traffic counts can be improved by increasing the count duration or by counting in more than one period of the year. Improved accuracy can also be achieved by using local knowledge to determine whether there are days within the week or periods during the year when the flow of traffic is particularly high or low.

Local knowledge should also be used to select appropriate locations for conducting the traffic counts to ensure a true reflection of the traffic using the road and to avoid under- or over-counting.

Origin and Destination Surveys, using a variety of survey techniques, are sometimes carried out to establish the nature of travel patterns in and around the area of enquiry. These surveys, which can be quite labour-intensive, serve a number of useful purposes including a quantitative assessment of the amount of traffic likely to be affected by the proposal and the consequent impacts on various elements in the road system.

### Axle Load Surveys

Axle load surveys provide critical and essential information that is required for both cost-effective pavement design as well as preservation of existing roads. The importance of this parameter is highlighted by the well-known “fourth power law” which exponentially relates increases in axle load to pavement damage (e.g. an increase in axle load of 20% produces an increase in damage of about 120%).

Axle load surveys can be expensive to undertake and should be carefully planned and organised in relation to the level of resources that can be committed to the survey (time, personnel and money) and the objective of the survey which could be:

- determination of vehicle equivalence figures (pavement design)
- overload control (pavement preservation)

The type of equipment which may be used for axle load surveys also varies widely and includes:

- static or dynamic weighing equipment
- manual or automatic recording of loads
- portable or fixed installation

The quality of the data obtained will depend on the type of equipment used, the duration of the survey and the degree of quality control performed. In general, the higher the quality of the data, the greater will be the resources required to collect them.

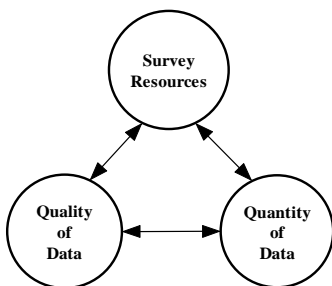
There is an almost inevitable trade-off between available resources and the accuracy obtainable from a sample survey. The art of good survey design is to know when the optimal value for money from the survey is achieved. Further constraints exist for the data analysis stage. Some analysis techniques require expertise, computer hardware and software which may not always be available. Thus, the choice of analysis procedures may also involve trade-offs.



Portable weighbridge system.



Installing portable weighbridge in pit



Trade-offs in undertaking an axle load survey.



Measurement of rear axle load using portable weighbridge.



Axle load survey in progress. Such surveys are typically carried out over a 24 hour period for seven days.

Ultimately, an appropriate choice of equipment should be made in relation to such factors as:

- accessibility to back-up support (technical and maintenance)
- ease of installation and use
- accuracy of measurement required
- acquisition and operational cost of equipment

It is also important that axle load surveys are carried out in a systematic and standardised manner and separated from weigh bridge measurements undertaken for the purpose of enforcing axle load limits. Guidelines currently exist in a number of SADC countries for carrying out axle load surveys.

### Box 3.4 – Minimum information typically derived from axle load surveys:

- Axle loads of all heavy vehicles whether empty or loaded.
- Vehicle category.
- Loading in each direction of the road.

Each axle in a multi-axle combination shall be measured separately. The survey point should also be equipped with sufficient capacity to weigh all heavy vehicles that are passing in one direction at a time, both empty and loaded.

### 3.3 Appraisal

#### 3.3.1 Investment in LVSRs

The road sector consumes a considerable part of the overall infrastructure investments made in the SADC region and, with an increased focus on poverty reduction, there is an increasing emphasis on those for LVSRs. However, investment in such roads should be based on a set of clearly understood *needs* for them. *The process of establishing those needs requires detailed consideration of both the economic and social roles of roads and these, in turn, must be seen in the context of larger community needs for accessibility and mobility.* Certainly the provision of roads will be only one of the mechanisms used to satisfy those needs.

The various short-term effects and longer-term impacts of such road investments may be depicted roughly as shown in Figure 3.4. They are not just a progression in time, they are also a progression in certainty with the more distant developments being more difficult to achieve and less certain to materialise.

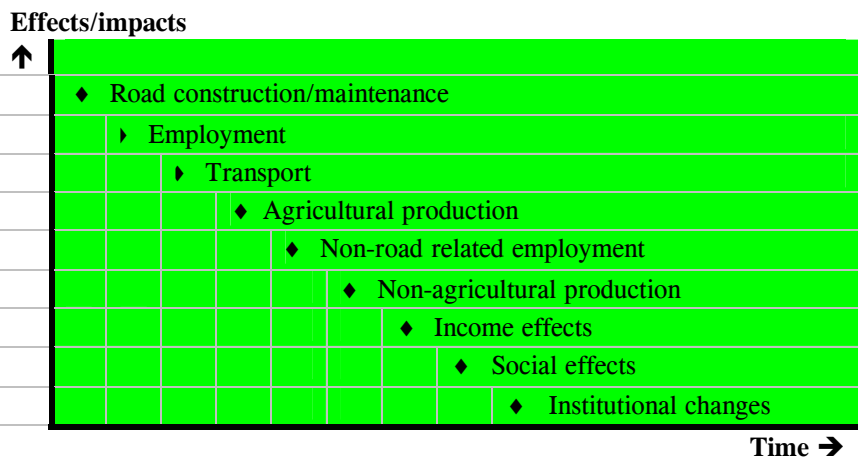


Figure 3.4 – Effects and impacts of road investments over time<sup>6</sup>

From the perspective of investment in roads only, employment is regarded as certain. *Such employment, and thus the potential for assisting the poor, is obviously enhanced by the use of labour-based methods.* With the exception of employment, all the rest of the other effects and impacts are indirect. Whether they occur or not depends on two factors:

- (1) that traffic materialises as a result of the road improvement
- (2) that this traffic is operating more efficiently

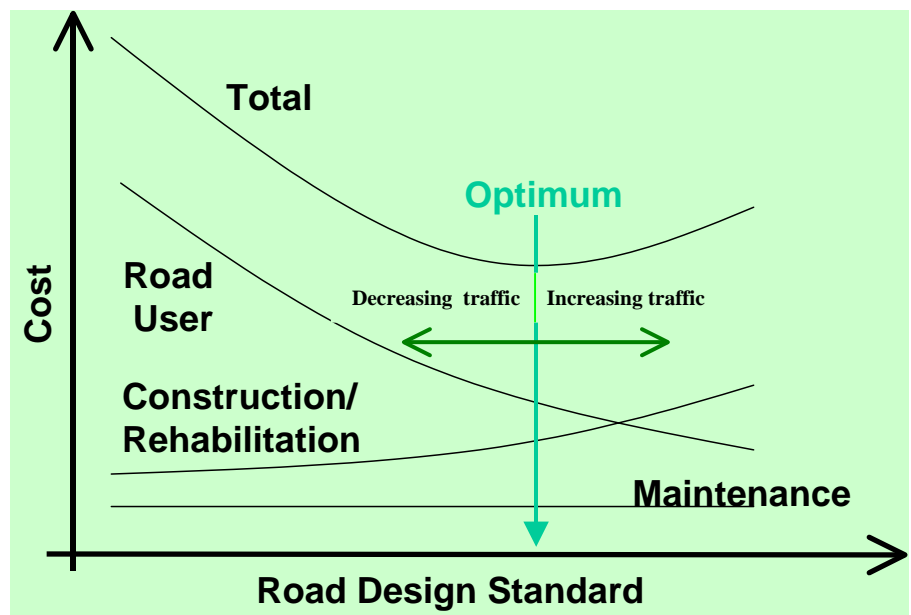
#### 3.3.2 Life-Cycle Costing

**H**aving identified a short list of projects, it is the purpose of an economic appraisal to ensure that the options considered represent a cost effective way of delivering the road. Appraisals driven by economic requirements will be relatively easy to identify via benefit-cost analyses. However, traditional appraisal frameworks do not cater well for economic justification of LVSRs as poverty reduction and other social benefit issues are more difficult to quantify and tend to be ignored.

*Life-cycle costing uses economic evaluation techniques to select, from a series of options, the most economically appropriate new road project and the maintenance and/or rehabilitation treatment to be applied to an existing road.*

In traditional approaches to undertaking an economic analysis, the basic objective is to determine the optimum mix between the costs of the project (related to the design standard) and the benefits from the project in terms of transport cost savings and other secondary benefits such as social and environmental benefits. The purpose is to find the investment option that *minimises life-cycle costs*.

Figure 3.5 shows the conceptual total road transport cost curve which is made up of the construction/rehabilitation costs, maintenance costs and road user costs. It shows that as construction/rehabilitation costs increase (because of higher design standards) road user costs are typically reduced. The optimum road design standard is attained where the sum of the project costs are minimised. This optimum standard varies in relation to traffic level and the associated relative mix of construction, maintenance and user costs.



**Figure 3.5 – Economic analysis of optimum road design standards**

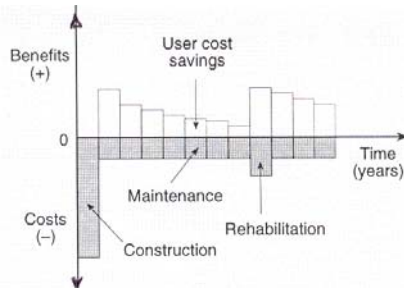
For a given traffic level, if the road were to be constructed to a standard higher than the optimum, then the benefits derived from a reduction in road user and maintenance costs would not sufficiently offset the costs of initial construction and the resulting investment would be sub-optimal. This highlights the importance of ensuring that appropriate standards are adopted in the planning, design, construction and maintenance of LVSRs. As might be expected, the optimum design standard for a LVR is lower than for a HVR.

### **Principles of Economic Appraisal**

Several methods exist for the economic appraisal of road paving projects for which the primary objectives are to determine:

- the appropriate size of investment and the returns to be expected from this investment
- the appropriate geometric and structural design standards for the size of investment in order to obtain the expected returns
- the economic and socio-economic impact of investments such as the improvement to the community of industrial, agricultural, educational and health services

Distribution of costs and benefits during the life-cycle of a road option.



Through identifying, quantifying in monetary terms, and comparing the costs and benefits of different options, this technique is able to provide guidance on the design, prioritisation and selection of candidate road projects by addressing a wide variety of key decision-making issues. For instance:

- is the investment economically justifiable?
- if there are a range of alternative investments, which option gives the best economic returns?
- is the timing of the proposed project optimal?
- should components of the project be phased in over a period of time?
- how does risk and uncertainty affect the choice of projects?
- if funds are limited and there are many worthwhile investments, which should be built first?

An economic analysis considers the project from a national point of view. In an economic cost benefit analysis, the total costs and benefits that arise from a project are identified and measured, irrespective of who incurs the costs or benefits from the project. In contrast to a financial analysis, no monetary transaction needs to take place for an economic benefit or cost to be incurred.

**Main components:** The main components of an economic evaluation are as follows<sup>7</sup>:

- The identification of at least two different cases or scenarios; this will involve one *base or “without investment” case* and at least one *project or “with investment case”*.
- The *planning time horizon* i.e. the period over which the evaluation is made.
- An estimate of the project *investment costs* specified in *economic price terms*.
- The *benefits* of the project or projects specified in *economic price terms* estimated from the differences in the costs of the with and without cases.
- A year-by-year determination of the costs and benefits of the different projects over their design life, using discounted cash flow techniques to bring them all to their *present value* in terms of *economic decision criteria* such as NPV, BCR or IRR.

An investigation of how robust or reliable the results are through the use of *sensitivity analysis* or *risk analysis*.

### 3.3.3 Quantification of Costs and Benefits

There are two principal methods of quantifying project costs and benefits and in economic terms, the Consumer Surplus approach and the Producer Surplus approach:

**(1) Consumer surplus approach:** This is the orthodox approach to estimating the economics of road investments which assumes a reduction in transport costs arising from savings in vehicle operating costs<sup>13</sup>. The direct benefits to road users – the *consumer surplus* – equals the product of the number of trips and the cost saving per trip.



Transporting bananas by bicycle.

The consumer surplus approach is normally used for those projects where traffic levels are likely to be sufficient for road user costs savings to justify funding of the project. The minimum traffic threshold which makes this approach appropriate to use is difficult to define beforehand but is likely to be of the order of 50 – 100 vpd.

**(2) Producer surplus approach:** In situations where no road exists and a substantial improvement in vehicle accessibility is planned to help develop an area, the producer surplus approach may be the most appropriate way of estimating agricultural benefits arising from road investment<sup>14</sup>. The producer surplus approach estimates the predicted benefits arising from the reduced cost of agricultural produce which will normally be the same as that predicted by a consumer surplus approach. However, when the producer surplus method is used, passenger benefits and other non-agricultural cost savings still need to be estimated separately.

The forecast in agricultural production and the size of the producer benefits are predicted from the rise in farm gate prices brought about by the decline in costs of transporting produce to market, as well as the decline in transport costs of agricultural inputs. However, several difficulties have been identified with the application of this method, including the need for substantial amounts of data, which may be either unavailable or of questionable reliability, and the fear of double counting methods. For such reasons, the use of the producer surplus method is not recommended unless there is a great deal of knowledge about agriculture and its likely response to changes in input and output prices.

### 3.3.4 Project Costs

**T**here are two main areas to address in calculating project costs:

- 1) The project costs for a range of alternative infrastructure standards.
- 2) Technology choice and the options available from labour based to equipment intensive.

The main project costs include:

- planning/design costs
- construction/supervision costs
- road agency costs (administration, operation and maintenance)
- road users' costs (VOC and TTC)

Construction and maintenance costs can vary significantly according to the standards to which the road is built. There are significant cost advantages from using the LVSR standards as set out in this guideline and it is important to have a detailed knowledge of these costs in the appraisal process. Table 3.4 gives the main ones and the likely impact on construction costs.

**Table 3.4 – Options for reducing construction costs**

Option	Potential Benefits
Replacing a conventional geometric design process by a “design by eye” approach, where appropriate, and minimising deviations from existing alignments.	Reduced earth works and environmental damage. Earthworks can be typically 30% of total construction costs in rolling terrain.
Use of more appropriate pavement designs and natural gravel rather than crushed stone.	Reduced pavement costs due to lesser haulage distances and reduced materials processing costs.
Considering a range of infrastructure standards.	Allows an optimum standard to be adopted which minimises total transport costs.
Utilising an existing gravel wearing course e.g. as base or sub-base .	Reduced haulage distances and materials costs.
Compacting subgrade and pavement layers to refusal, where feasible, rather than to arbitrary prescribed levels.	Increased density, reduced road deterioration and increased maintenance intervals.
Adopting appropriate surfacing technologies such as sand seals and Otta seals.	Reduced haulage distances, reduced processing costs.
Increasing the use of labour and local resources where appropriate.	Lower economic/financial costs for specific tasks.
Using seals as a spot improvement measure.	Reduced surfacing costs whilst maintaining year round access.



Short sections of road in poor condition can benefit significantly from spot improvement works.

The use of LVSR technology for spot improvements has, potentially, very significant applications on a wide range of roads that do not justify providing a seal over the entire length but could benefit from spot sealing works. These spots might include areas where there is significant seasonal difficulty in maintaining access such as on steep slopes or areas that are prone to flooding. They may also include stretches through towns and villages where, for social and environmental reasons, a sealed road would reduce dust nuisance and improve safety. Spot improvement strategies, particularly for the lower volume roads, provide a good way of meeting the planning objectives of maintaining basic access while minimising total transport costs.

### 3.3.5 Project Benefits

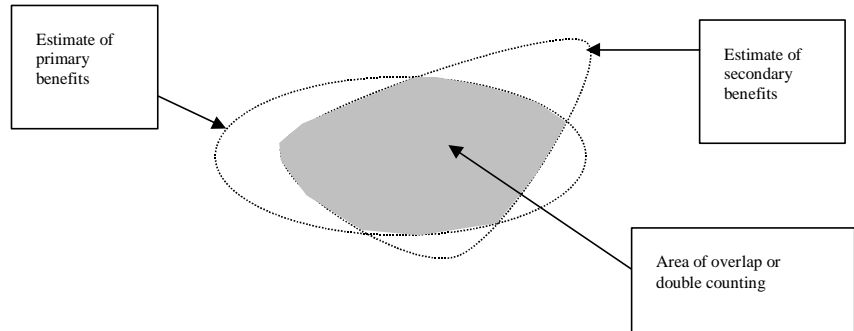
Changes in the *efficiency of transport* are the essential mechanism by which benefits from road building are transferred or released<sup>6</sup>. These changes are more than likely to occur with the sealing of an earth/gravel roads in the form of a reduction in vehicle operating costs (VOC). However, other benefits of a broader socio-economic nature are also likely to occur and, by meeting specified social objectives, offer scope for achieving poverty reduction.

The benefits arising from the upgrading of a LVR typically include:

- developmental benefits - such as benefits to generated traffic
- social benefits - access to facilities through improved passability
- road user cost savings - such as reduction in VOC and TTC
- road agency benefits – such as reduction in maintenance costs

In general, the more competitive and less distorted an economy, the more likely that the primary benefits will cover the full consequences of a road investment. However, for the purpose of this Guideline, there is a case for including secondary benefits, particularly in circumstances where:

- existing traffic volumes are relatively low
- new road investments are made in remote rural areas
- a relatively large change in transport costs is anticipated
- there are unemployed resources



**Figure 3.6 - Overlap of primary and secondary benefits**

### **Social Benefits**

Social benefits are not only some of the most difficult to quantify but, also, even if they were, there is no universally agreed method for incorporating them within an economic analysis. Furthermore, a simplistic addition of social and economic benefits is likely to lead to problems of double counting.

The following provides some of the options that could be considered for incorporating social benefits within an economic analysis.

- (1) Where roads suffer from impassability or traffickability problems there will be additional benefits from improved road provision that create year round access. The principal social benefits come from improved access to health facilities and education services, employment opportunities and social interaction. Little research has been done on the best way to quantify these benefits but practical approaches have tended to factor up conventional VOC savings for the period a road suffers either passability or traffickability problems.
- (2) It is possible to identify key social criteria such as targeting the poorest areas, reducing isolation to basic services and markets. These would have to be identified on a project by project basis following consultation with all the relevant stakeholders. In a similar way to the approach indicated above, VOC benefits could be factored up if the improvement of a particular road met these social criteria.
- (3) Benefits from education and health facilities can be estimated from improved access and the resulting improvements from income earning opportunities. For example, benefits from increased school enrolment levels can be estimated based on higher life earnings of the children who would have otherwise remained unskilled. Health benefits can be assessed based on reduced sick days away from work and the associated net income. However, such an approach may involve considerable field data collection and analysis.
- (4) Quantifying social benefits in the same units as economic benefits<sup>8</sup>: In this approach, it is assumed that the population within a distance of 5 kilometres on either side of the road will receive social benefits as a result of the road improvement. In so doing, social factors are converted to the same units as VOC savings.

Research from Tanzania suggests that, on average, just over 30% of the total tonne kilometres is carried by non-motorised transport on low-volume roads. This figure ranged from just over 8% for higher volume roads (over 150 vehicles per day) to over 60% for the lowest volume roads (less than 10 vehicles per day).

### Benefits to Non-Motorised Traffic

In many SADC countries non-motorised traffic constitutes a significant proportion of the traffic on low-volume roads and, in many cases, this traffic represents the majority of total tonne kilometres. *Benefits to non-motorised traffic represent significant savings that are not captured in a conventional consumer surplus analysis and therefore, alternative methods need to be considered.*

Although there has been limited research into the impacts of road improvements on non-motorised transport there are a number of sources of information that will help planners to make estimates of the potential benefits. Table 3.5 sets out the sources and the type of information available.

**Table 3.5 - Sources of information for non-motorised transport**

Source of information	Type of information
Roads Economic Decision Model (RED) <sup>9</sup>	Calculates VOCs for pedestrians, animal carts, and bicycles.
Appraisal of investments in improved rural access – Economist guide <sup>10</sup>	Contains a number of mini-guides including one on calculating VOCs for non-motorised transport based on HDM 4 relationships.
A handbook of rural transport vehicles in developing countries <sup>11</sup>	Contains look-up tables for a wide range of motorised and non-motorised vehicles for different infrastructure quality and distances.
Ghana prioritisation procedure <sup>12</sup>	Provides VOC savings for bicycles and pedestrians following road improvements (see Section D).

Where estimates of benefits to non-motorised transport are available it is appropriate to add these to the benefits from motorised transport.

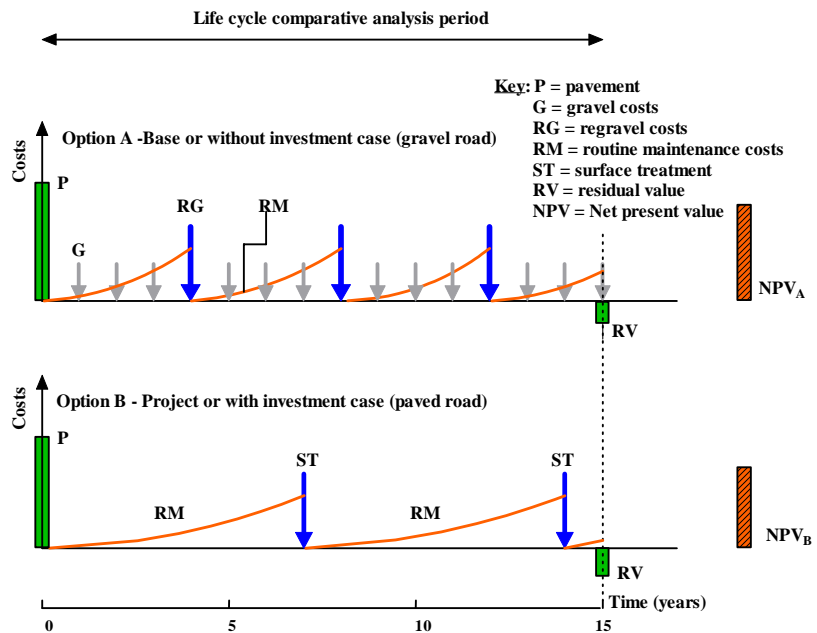
### 3.3.6 Cost-Benefit Analysis

#### Use of Investment Appraisal Models

The primary function of a road investment appraisal model is to calculate the costs and benefits of road construction, road maintenance and road user costs for a specified analysis period. This is accomplished by modelling the interrelationships between the environment, construction standards, maintenance standards, geometric standards and road user costs. Such models can be used to perform a number of economic analyses, one of which is to identify unpaved roads that may be potential candidates for paving.

Typical components of a life cycle cost analysis are shown in Figure 3.7 for a *base or “without investment” case* (gravel road) and a *project or “with investment case”* (paved road).

In very general terms, paving a gravel road would be economically justified when the net present value (NPV) of the sum of savings in VOCs and maintenance costs, relative to the well-maintained gravel road, is at least as great as the NPV of upgrading costs. Where not captured in the investment appraisal model, the inclusion of socio-economic benefits would need to be evaluated separately after the economic appraisal has been carried out.



**Figure 3.7 – Typical components of a life cycle cost analysis**

### Characteristics of Main Project Types

Candidate projects for upgrading typically fall in to the following categories, viz:

- Basic accessibility projects: including upgrading tracks and earth roads to gravel roads.
- Mobility projects: (a) bituminising existing gravel roads.  
(b) strengthening/expanding capacity of existing bitumenised roads.

Investment in the above types of project is generally motivated by quite different reasons and yields quite different types of benefits. For convenience, these project types may be categorised in relation to broad traffic bands as follows:

**Category I – less than 50 vpd:** Investments in this category of road are usually poverty-targeted with a focus on social rather than economic objectives. Thus, a least-cost or cost-effectiveness approach is usually adopted and investment models are generally not appropriate for such roads<sup>17</sup>.

**Category II – 50 to 200 vpd:** (Primary focus of this Guideline): Investments in this category of road give rise to a mix of economic, social and environmental impacts depending on their function and level of traffic carried, which can include a significant proportion of non-motorised traffic.

**Category III – more than 200 vpd:** investments in this category of road give rise to predominantly economic impacts in the form of reduced transport costs, as well as to environmental impacts.

### Suitability of Investment Appraisal Models

The economic evaluation of donor-funded road projects in the SADC region generally requires the use of an internationally recognised investment model. The following models which adopt the *consumer surplus* approach have been used for that purpose:

- Road Transport Investment Model (RTIM) developed by the UK Transport Research Laboratory<sup>18</sup>.
- PIARC's Highway Design and Maintenance Standards Model (HDM-4)<sup>19</sup>.

Unlike models such as the South African CB-Roads<sup>20</sup> and SURF<sup>21</sup> models, which were developed specifically for local conditions, models such as RTIM and HDM were developed to be applicable in a large number of countries covering a wide range of conditions. Moreover, they are the result of the collaboration of a number of international organisations and, as a result, the latest version of the HDM model, HDM-4, has become the *de facto* model for use in the region, together with a more recently developed and simplified derivative, the Roads Economic Decision Model (RED)<sup>8</sup>.

Whereas the HDM-4 model presents a very good framework for the economic analysis of road investments, it is neither customized for LVRs nor does it capture all the benefits associated with such roads. In contrast, RED has been customized for LVRs and offers a number of other advantages which are contrasted with HDM-4 in Table 3.6.

**Table 3.6 – Comparison of HDM-4 and RED appraisal investment models**

Model	Advantages	Disadvantages
HDM 4	<ul style="list-style-type: none"> <li>• Globally used model</li> <li>• Extensive research on VOC and deterioration relationships</li> <li>• Can be used for strategic planning i.e. can assess networks</li> <li>• Now includes NMTs</li> </ul>	<ul style="list-style-type: none"> <li>• High data requirements</li> <li>• Does not include social benefits<sup>1</sup></li> <li>• Cannot deal with passability and traffickability issues</li> <li>• Road roughness is often not an appropriate measure of condition for LVRs</li> <li>• Not well suited for low traffic levels</li> </ul>
RED	<ul style="list-style-type: none"> <li>• Has limited data requirements</li> <li>• Can accommodate NMT and some social benefits</li> <li>• Can be run from a spreadsheet</li> <li>• Can accommodate impassability issues</li> <li>• Can be used for ranking projects</li> <li>• Well suited for traffic levels in range 50 – 200 vpd</li> </ul>	<ul style="list-style-type: none"> <li>• NMT categories are limited to four</li> <li>• Would have to be calibrated for Low-volume sealed roads</li> </ul>

1 – to be included in a later version

Table 3.7 provides a general guide to the applicability of commonly used investment models in the SADC region for evaluating LVSRs. The preferred choice of model depends largely on the nature of the impact triggered by the investment intervention.

**Table 3.7 – Applicability of investment models to LVSR evaluation**

Factor	Project Type		
	Access	Mobility	
		Basic	Advanced
Motivation	Social	Socio-economic	Economic
Traffic band	< 50 vpd	50 – 200 vpd	> 200 vpd
Traffic type	NMT	NMT - MT	MT
Relative benefits	Social	High	Medium
	Economic	Low	Medium
Appropriate model	Least Cost	RED	HDM-4

### Least Cost Approaches

*The goal of the Least Cost Approach is to employ the most appropriate and cost-effective intervention which provides a minimum level of reliable, all-season passability for the locally prevailing means of transport.*

As indicated in Table 3.6, those road improvements in which economic impacts are dominant (traffic is typically > 200 vpd and is predominantly motorised) are best evaluated by investment models such as HDM-4. However, at lower traffic levels (traffic typically 50 – 200 vpd ) where NMT is significant and social benefits are dominant, RED would be the more appropriate investment model to apply.

### 3.3.7 Ranking Methods

Ranking Methods are important for two reasons. First of all it is unlikely that funds will be sufficient for all projects that are economically or socially justified and hence projects need to be placed in an order of priority. The use of investment appraisal models can facilitate this. Secondly, as discussed above, some important benefits cannot be easily quantified and may not be included in appraisal models. Therefore ranking methods that allow such benefits to be taken into account in the appraisal process are essential if the ‘best’ projects overall are to be selected for implementation.

**Multi-criteria Analysis:** These methods adopt a multi-objective approach which seeks to incorporate both economic and non-economic goals into an evaluation framework<sup>15</sup>. These methods adopt a multi-objective approach which seeks to incorporate both economic and non-economic goals into an evaluation. The approach assumes that the full set of attributes characterising a project cannot be expressed by a single parameter. Instead, the framework should include a number of criteria for evaluating the project in socio-economic terms such as economic benefits, economic costs, distribution of economic benefits, accessibility to social services, employment, etc. Quantitative measures of each of these criteria must then be defined in their own units to facilitate transforming the spectrum of physical measures for each criterion into utility value terms. Completion of the utility analysis depends upon the decision-maker’s articulation of his preferences amongst the various criteria.

As with other planning systems it is important that communities are fully informed both in the selection of relevant criteria and in the subsequent results. Problems may arise where consultation has not taken place or where the complexity becomes too great because of too many variables.

The advantage of adopting such an approach is that a number of factors can be included to reflect wider political and socio-economic needs. However, the disadvantages are that the addition of other factors complicates the analysis and more data needs to be collected.

**Compound Ranking Methods:** These methods rank projects according to factors that are considered to be relevant to the investment decision rather than derive economic benefits that can be used in a cost-benefit analysis. The approach enables social and political factors to be considered alongside economic factors and is based on the following principles<sup>16</sup>:

- factors included should reflect the objectives of the investment programme
- each factor is measured in its own units (for example, number of people gaining access to services)
- factors are weighted to reflect their impact on the programme objectives

Compound ranking methods utilise a points scoring system which is rather subjective. They are probably most appropriate when non-economic objectives are part of the investment objectives for which a “least cost” approach would be adopted.

### 3.3.8 Implications of Using Revised Approaches

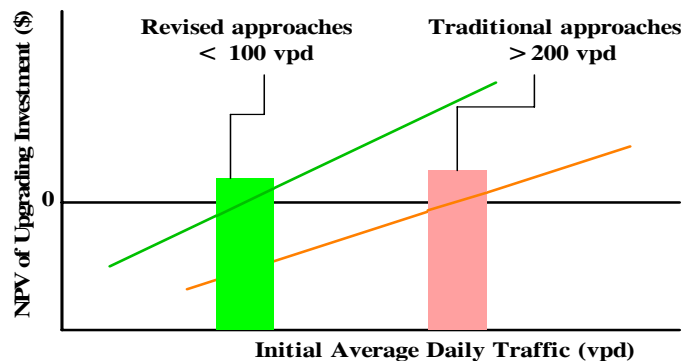
The implications of using the revised approaches recommended in this Guideline are to reduce significantly both the initial construction and longer terms maintenance costs. Coupled with the use of an investment model which is able to quantify important socio-economic benefits, the effect is to reduce the threshold level at which it is economically justified to pave an earth/gravel road (see Table 3.8).

**Table 3.8 - Factors influencing the traffic threshold for upgrading**

Parameter	Impact
Use of more appropriate pavement designs	Reduced costs
Use of more appropriate geometric design	Reduced costs
Increased use of natural/unprocessed gravels	Reduced costs
Quantified impacts of depleted gravel resources	Reduced costs
Benefits from non-motorised transport	Increased benefits
Quantified adverse impacts of traffic on gravel roads	Increased benefits
Reduced environmental damage	Increased benefits
Quantified assessments of social benefits	Increased benefits

The impact of these factors is illustrated conceptually in Figure 3.8 which reflects the outcome of recent research<sup>22</sup> and which indicates that, in some circumstances, bitumen sealing of gravel roads is economically justified at traffic levels of less than 100 vpd. This is in contrast to the previously accepted figures for sub-Saharan Africa, which indicated that it was only economic to provide a bitumen surface at traffic levels over 200 vpd.

*The Net Present Value (NPV) is simply the difference between the discounted benefits and costs over the project analysis period. A positive NPV indicates the project is economically justified at the given discount rate.*



**Figure 3.8 – Break-even traffic levels for paving a gravel road: traditional versus revised approaches**

## 3.4 Environmental Issues

### 3.4.1 Introduction

Any development brought about by man, such as the construction of roads, inevitably produces an impact on the environment. In practice, therefore, it must be accepted that modifications to the natural environment are an inevitable result of attempts to achieve social and economic progress, alleviate poverty and improve human welfare.

LVSRS in the region are generally constructed to improve the economic and social welfare of those using the roads or served by them. By their very nature, such roads are agents of change which can bring both benefit and damage to the existing balance between people and the environment. In the past, the attention of many SADC countries has been focused almost exclusively on the potential benefits from these new or improved road facilities. In contrast, the resulting environmental problems have received little attention, largely because they have been considered to be either unimportant or the price to be paid for development<sup>23</sup>.

More recently, all SADC governments have become increasingly conscious of the impact of unbridled development on the environment and the recognition that, in the long term, environmental conservation and economic development are not only compatible but interdependent and mutually reinforcing. This has raised a number of issues which must now be faced in an attempt to create a balance between much needed development on the one hand and environmental care on the other.

This section considers the environmental issues facing road authorities in the SADC region with a focus particularly on LVSRS. The importance of establishing appropriate policy guidelines and the role of environmental impact assessments in LVSR provision is considered together with the main environmental impacts likely to be encountered and mitigating measures for overcoming them.

### 3.4.2 The Environment

In its broadest sense, the term *environment* includes both the natural or “bio-physical” environment (flora, fauna and physical features) as well as the human environment (socio-economic and cultural factors) and the interaction between them. As illustrated in Table 3.9, there are four key cornerstones of the environment:

- ecological
- economic
- social and
- physical

Each of the cornerstones of the environment includes a range of factors which should be considered at all stages of the planning cycle as discussed further in this chapter.

#### Safeguarding the future

*All human activity depends on the Earth and its natural resources, but it sometimes threatens the delicate balance of the environment. The greatest challenge we face today is to bring about improvements in the living conditions of millions of people while protecting and safeguarding the environment for future generations.*

Overseas Development Administration (ODA), UK. Action for the Environment. May 1992.

## What price the environment?

The environment is not a free resource in infinite supply. It provides a wide range of services which underpin all productive activities and contributes to human welfare in a number of direct ways. Although it may not be possible to put a conventional price on the environment, it still has a value for those who work and live in it.



Elephants crossing a main road that traverses a game park.



Un-renovated borrow area – typical of many countries in the SADC region

Table 3.9 – Cornerstones of the environment

E N V I R O N M E N T	• Ecological	<ul style="list-style-type: none"> <li>- impact on flora and fauna</li> <li>- deforestation</li> <li>- disturbance of natural eco-system</li> <li>- decrease in bio-diversity</li> <li>- threats to exotic and non-indigenous species</li> <li>- depletion of scarce material resources</li> <li>- regressive or progressive soil erosion</li> </ul>
	• Economic	<ul style="list-style-type: none"> <li>- capital costs (design and construction)</li> <li>- maintenance costs</li> <li>- flood damage costs</li> <li>- loss/degradation of agriculture/arable land</li> <li>- sterilisation of land for future use</li> <li>- land value reduced (designated borrows, severed farms)</li> </ul>
	• Social	<ul style="list-style-type: none"> <li>- severance/dislocation of local communities</li> <li>- adverse impacts on women</li> <li>- destruction of cultural antiquities</li> <li>- conflicts arising from changing land use/ownership of land</li> <li>- traffic accidents</li> <li>- health and safety (e.g. danger to humans, especially children, and wildlife from drowning in borrow pits)</li> <li>- construction impacts</li> </ul>
	• Physical	<ul style="list-style-type: none"> <li>- aesthetic – e.g. loss of natural beauty and scars on landscape</li> <li>- natural vegetation is not, or cannot, be replaced</li> <li>- noise, air, water pollution</li> <li>- dust impact</li> <li>- disruption of drainage courses</li> </ul>

### 3.4.3 Typical Causes of Environmental Problems

The following are typical causes of environmental problems related to the provision of LVSRs.

• **Design defects:** These create problems when they are not anticipated and the project fails to include remedial measures. For example, measures taken to keep water off the road can cause problems elsewhere. Upstream preventative measures can interfere with natural river flows. Drains concentrate and speed up flow, sometimes causing flooding and soil erosion downstream.

• **Poor project documentation:** Unless remedial measures are clearly reflected in project documents (e.g. Terms of Reference or contract documents) they may not be fully implemented. This often results from use of standard contract documents which do not allow for the special circumstances of the project. For example, standard contract documents for roads often include specifications requiring the contractor to “cut and dispose of soil within the transverse profile”, or to “carry surplus material to spoil”. When such specifications are inadvertently applied in steep, mountainous terrain – particularly if hillsides are intensely cultivated – the dumping of soil over the edge of the road formation can have devastating results.

• **Presence of construction activities:** Temporary site works are typically characterised by borrow pits, ruts in the road created by vehicle wheels and drainage ditches which provide ideal breeding grounds for insects (particularly mosquitoes.) Construction workers may kill local fauna for the pot, while the canteen refuse normally associated with construction camps en

courages the proliferation of insects and vermin. One of the most serious diseases spread by construction crews in many SADC countries is malaria. Such impacts can generally be avoided by including appropriate remedial measures in contract documents.

- **Weak environmental institutions:** Successful remedial measures depend on the effectiveness of local environmental institutions, including those dealing with the regulation of land-use. For example, when new roads are being constructed in undeveloped areas, it should be mandatory for the project to be cleared by the local planning agency responsible for dealing with the planned and spontaneous development, that may occur in response to the project. However, such provisions will only be effective if the local environmental agency has the skills, manpower and authority to ensure that the contractor complies with the requirements. When the performance of local environmental institutions is likely to affect project implementation, such weaknesses should be evaluated and attended to before the project is approved.

### The Special Case of Borrow Pits

The extraction of substantial amounts of non-renewable natural resources for road construction in SADC countries, is in the order of over 150 million cubic metres per annum and has the potential to create significant damaging effects (negative impacts) on the local environment and its inhabitants.



Gravel stockpile for road construction – causes gradual depletion of a finite, non-renewable resource – an unsustainable activity.



Children exposed to risk of drowning and poor quality water. Ponding and poor drainage also increases the level of mosquito-borne disease.



Very often, worn out construction plant is abandoned and becomes an eyesore. The contract documents should cover removal of unwanted plant to an approved area.

#### Box 3.6 - Specific impacts of borrow pits in the SADC region:

- Material resources
  - permanent loss of natural resources
- Morphological damage
  - modification of the natural drainage
  - increased soil erosion and siltation of waterways by disturbance of soil
  - destabilisation of slopes
- Ecology
  - loss of wilderness and forest
  - displacement of species and habitats
  - loss of potential productivity of agricultural land
- Pollution
  - contamination of water and soil by fuel and oil spillage
  - generation of dust during the processing, loading and transporting of materials
  - increased dust generated by vehicles along access tracks
  - littering
- Social and health impacts
  - creation of habitats for disease
  - landscape alteration and interference with natural beauty
  - bisection of communities or farms
  - loss of land legacy
  - loss of antiquities, cultural heritage, areas of cultural concern (e.g. graves)
  - hazards to pedestrians and animals, including open or unmarked trial pits demarcation beacons, etc
  - safety risks to local population by exposure to heavy plant and traffic
  - noise of drilling, blasting, traffic and plant

## Borrow pit rehabilitation



(a) Original pit used for construction.



(b) Borrow pit rehabilitation in progress after one year.



(c) Full rehabilitation of borrow pit achieved after 3 years.

Other environmental impacts associated with the construction of roads in the SADC region include:

- hard rock quarries
- river bed gravel pits
- hill slope pits

Recent surveys carried out by the UK Transport Research Laboratory<sup>24</sup> in two countries have shown that:

- Historically, restoration of borrow pits has been the exception rather than the rule. On average, only around 15% of borrow pits are restored after extraction of materials.
- The environmental damage caused by improper extraction and rehabilitation practices can extend over a wide area and may only become apparent after project completion. Examples include soil erosion causing siltation of natural water courses. Around 50% of worked borrows had excessive land erosion.
- Environmental damage caused by pits is often most severe in areas important for subsistence farming. Only 4% of land previously used for farming was under cultivation after extraction of material.
- Contractors often leave pits open at the request of the land owner, because these are seen as a useful mini-reservoir to provide water for animals, washing and bathing. However, this practice poses severe risks to humans caused by exposure to stagnating water and mosquito borne disease.

Following on from the TRL survey, improved guidelines for borrow area management have been developed<sup>24</sup>. These guidelines consider:

- planning and access issues
- top soil and overburden removal and stockpiling
- rehabilitation procedures and disposal of soil
- safety (e.g. health and disease, warning signs and fencing, littering and fuel spillages).

The guidelines also contains advice for use in contract documents.

### 3.4.4 Environmental Impact Assessments

**R**esponsibility for applying sound environmental policies rests with the executing agencies in the SADC region, usually the roads agencies, guided and assisted by environmental units within the agency. However, increasingly, dedicated environmental Departments and Ministries are being established. In carrying out these responsibilities, staff should be guided by the over-arching objective of ensuring that projects are designed and implemented according to sound principles which minimise adverse impact and enhance benefits. A variety of procedures need to be followed at various stages of the project cycle in order to achieve these objectives. These procedures normally involve some kind of environmental impact assessment (EIA).

## The EIA Process

EIA is not an *outcome*. Rather, it is a *process* for improving the quality of the outcome and can be applied to any proposal<sup>25</sup>. The process is flexible and adaptable and can be tailored to suit the circumstances of any road project. In essence, an EIA evaluates foreseeable impacts, both beneficial and adverse, and helps to reveal mitigating measures and alternatives as well as to optimise positive impacts while reducing or limiting negative impacts.

The main components of the EIA include:

- establishing the need for the project
- identifying and quantifying the full range of potential impacts on the natural and social environments
- formulating remedial procedures for avoiding, mitigating and compensating for these impacts
- reflecting remedial measures in the project documents
- ensuring that remedial measures are complied with during the project implementation

The EIA process is usually integrated into the project cycle as a means of improving the quality of the outcome. Community involvement in this process is important and necessary as it seeks to solicit information, views and concerns that only the affected community can provide. It can take many forms and fit into the process at any or all stages depending on the type of project. It can involve a broad range of interest groups and individuals or it may only require limited involvement. The process is set out in outline in Table 3.10.

**Table 3.10 – A framework for EIA**

Phase of project cycle	Activity	Objective
Project identification	Initial screening	- register “danger signals” - avoid unnecessary investigation where impacts are likely to be minimal
Feasibility	Environmental appraisal	- predict main impacts - assess importance of effects - indicate key mitigating actions required - present implications to decision makers
Design	Environmental impact assessment	- predict in detail likely impacts, including cost implications - identify specific measures necessary to avoid, mitigate or compensate for damage - present predictions and options to decision makers
Commitment & negotiation	Environmental enforcement	- ensure environmental mitigation measures are included in the contract documents
Implementation	Environmental monitoring	- ensure environmental mitigation measures are being complied with during construction
Operations and maintenance	Environmental audit	- assess the extent of implementation of a project against the requirements derived from the EIA. - ensure lessons learned are incorporated in future projects

The output of the EIA is often formalised into an *environmental impact statement* (EIS) which, in some SADC countries, is mandatory for many road projects. Such a report would typically cover the following:

- brief description of project
- brief description of existing environment
- likely impact of project



Road upgrading requires careful planning to minimise adverse impacts on the natural environment.

- mitigation and protection measures
- consideration of “no change” alternative
- summary and conclusions

The EIS should provide a better understanding of the linkages between society, the natural environment and the sustainable use of inherited resources.

An important component of the EIA is the *environmental audit* which seeks, in essence, to assess the implementation of a project against requirements derived from the EIA. The audit can be viewed as a “snapshot” of the environmental situation at a given site and at a given time. It does not attempt to predict the potential impacts of planned investments but, rather, to serve as a source of baseline information which may complement or substitute for normal EIAs, depending on the type of project.

Box 3.7 provides an example of a checklist of issues that would typically be considered in an EIA for a LVSR.

**Box 3.7 – Typical check-list of issues to be considered in an environmental impact assessment for LVSRs<sup>7</sup>**

**Consequential developments:** Will the project stimulate land clearance for agriculture, the development of industry or mineral extraction? What steps can be taken to mitigate long-term adverse effects?

**Social factors:** Has adequate provision been made for vehicle, pedestrian and NMT safety. Are the geometric standards adopted likely to require additional safety countermeasures (e.g. signing, education programmes)?

**Geotechnical damage:** Has the project been designed to minimise the possibility of landslides and other geotechnical problems? Have long-term maintenance consequences been taken into account?

**Materials resources:** Will the project result in the unacceptable depletion of material resources that may be needed for subsequent maintenance or other construction projects? Will borrow pits be restored and can their effect on the landscape be minimised?

**Drainage:** Will the project result in increased risks from flooding or landslides as a result of disturbing natural drainage patterns? Will later development of agricultural land and other settlements affect hydrological conditions so that drainage works and bridges must be modified? Will any water impoundments create health hazards?

**Ecology:** Have the effects on animals and plants been considered? Has an ecological reconnaissance been carried out to assess effects?



*Eroded subsoils on borrow floor bed – susceptibility to erosion leads to siltation in water courses.*

**Value of the EIA**

Effective use of scarce resources is becoming increasingly important in a climate of decreasing funding and increased community demand for the improved efficiency and performance of SADC’s new generation of more autonomous roads agencies. In this regard, the EIA process offers the following benefits:

- alternative projects are systematically considered
- the decision-making process is more transparent
- environmentally significant issues are identified at an early stage

- a bridge is provided between the roads agency and the public it serves
- the community are reassured that their needs are being considered
- the roads agency is forced to consider the broader issues of its work
- local information provided through involvement of the community can improve the accuracy and relevance of the information collected for the project
- the risk of aborting a project at an advanced stage due to public dissatisfaction with the project is reduced
- interaction between technical, economic and environmental factors leads to optimum design and improved technical and economic efficiency

### Legislative Aspects

The effectiveness and success of an Environmental Impact Assessment (EIA) depends on the extent to which it is actively used and incorporated into different stages of a normal project planning process. In most SADC countries, an EIA has become a formal legal or administrative requirement. However, there is a need in each SADC country to institutionalise the entire process of environmental management by setting up a duly constituted organisation with the necessary authority and legal backing to enforce government environmental policy.

### 3.4.5 Assessing Environmental Impacts

Assessing the likely effect of a road project on the environment can be accomplished through an EIA as described above. However, quantifying these impacts is more difficult. Unlike monetary impacts, non-monetary impacts cannot be calculated, assessed or compared with each other in a standardised manner. Nonetheless, non-monetary impacts should be considered in a transparent and accountable manner. An impact assessment procedure to evaluate each of the non-monetised impacts has been developed so that these can be considered together with or compared to monetised impacts<sup>26</sup>. The procedure is based on the following three factors:

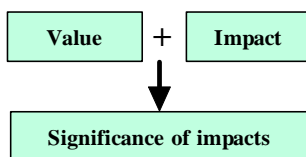
- value
- magnitude
- significance

When evaluating each of the non-monetised impacts the following steps apply:

- (1) Assess the value of areas influenced by the project and characterised with respect to the most important impacts.
- (2) Determine the nature and magnitude of impacts through qualitative descriptors
- (3) Assess the overall significance of the impacts on the project

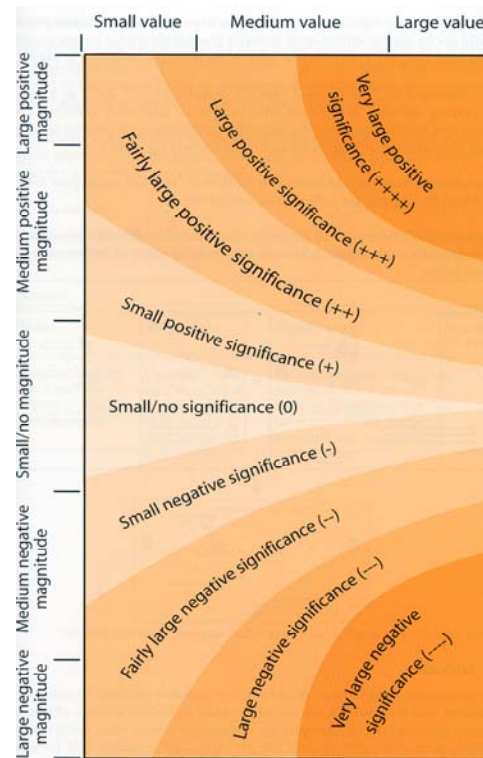
The significance of the various impacts can be assessed by combining the value and magnitude of the impact. The general principle is that the larger the value and vulnerability of the project, the more significant is the impact, whether positive or negative.

*Impact assessment is a systematic evaluation of the relevant advantages (benefits) and disadvantages (costs) that a new road plan or improvement of existing roads will generate regardless of the unit of measurement, i.e. whether measurable in monetary units or not.*



*General principle of assessing non-monetary impacts.*

A general scale for assessing the significance of the impacts is shown below, ranging from very negative (- - - -) to very positive (+ + + +) and is illustrated in Figure 3.9.

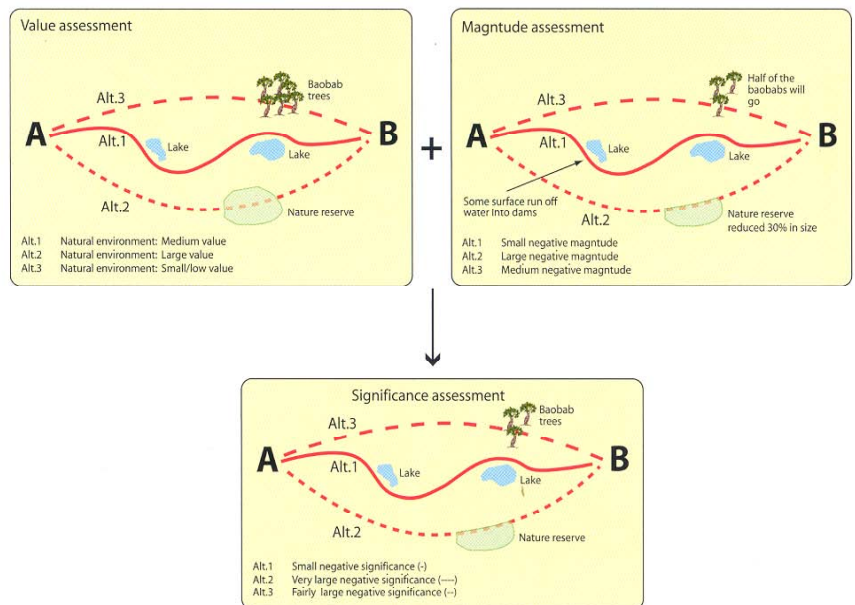


- ++++ Very large positive significance
- +++ Large positive significance
- ++ Fairly large positive significance
- + Small positive significance
- 0 No significance
- Small negative significance
- Fairly large negative significance
- Large negative influence
- Very large negative significance

The horizontal axis measures value of impact while the vertical axis shows the magnitude of the impact. For example, an impact whose value is found to lie in the region “large value” and whose magnitude lies in the region “large positive”, will have a significance factor described as very large positive significance. This implies that the road alternative will be positive with respect to the impact.

**Figure 3.9 - A framework for assessing the significance of impacts on LVSR projects<sup>26</sup>**

An example of the process of assessing the value of the natural environment, the magnitude of the impacts, as well as the significance of the impacts is shown in Figure 3.10.



**Figure 3.10 – Example of assessing value, magnitude and significance of impacts on LVSRs<sup>27</sup>**

### 3.5 Summary

The key points arising in this chapter are:

1. Planning and appraisal procedures should consider a wide range of external factors, many of them of a non-technical nature, that affect the planning process if long-term sustainability of the investment is to be achieved.
2. Stakeholder consultations are critical in the planning process for which there are a number of techniques which should be undertaken as appropriate and as transparently as possible.
3. The traditional methods of investment appraisal are generally not adequate for capturing the full range of benefits – often of a social rather than economic nature - arising from the provision of LVSRs. More recently developed models, such as the World Bank's Roads Economic Decision (RED) model, are better suited for appraising such roads.
4. The implications of adopting cost-reducing measures, such as the use of more appropriate pavement and geometric design methods and wider use of natural gravels rather than crushed stone, in combination with the use of appraisal models, such as RED, is to reduce the traffic threshold level for sealing an earth/gravel road from the previous figure of over 200 vpd to less than 100 vpd.
5. Environmental issues are assuming greater importance in the region than hitherto. Environmental impact assessments (EIA) should become an integral aspect of all LVSR projects. The effectiveness of the EIA will depend on the extent to which it is actively used and incorporated into different stages of the project planning process.

The important processes of planning and appraisal have been covered in this chapter together with environmental issues. Decisions made during the initial planning phase are particularly influential and have a high impact on the subsequent stages of LVSR provision, including those of geometric design and the associated road safety issues covered in Chapter 4.

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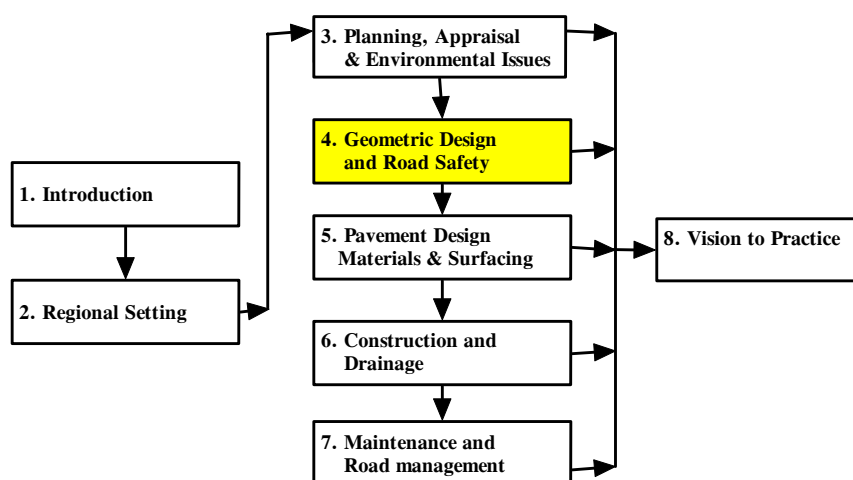
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# Chapter 4



# **Geometric Design and Road Safety**



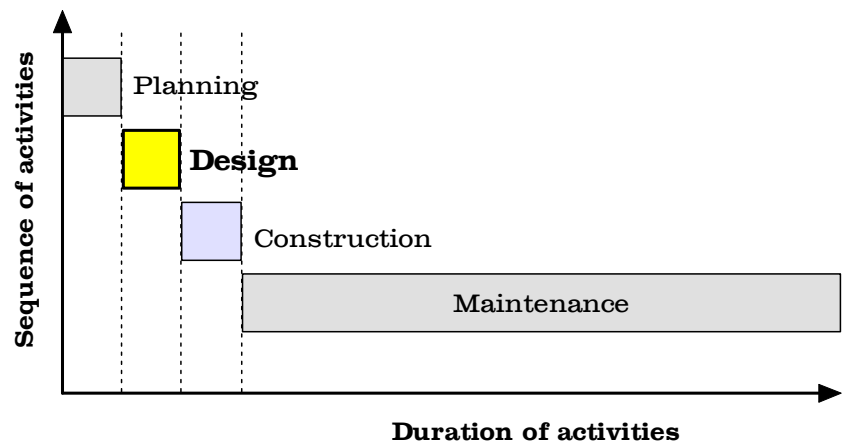
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# Geometric Design and Road Safety

## 4

### 4.1 Introduction

#### 4.1.1 Background



**G**eometric design is one of the first stages of the LVSR design process that is normally carried out after the planning and appraisal stages. The outcome determines the construction requirements and influences the maintenance requirements. In the design process, the layout of the road in the terrain is designed to meet the specific needs of road users. This involves the selection of suitable road widths and horizontal and vertical alignments in accordance with appropriately prescribed standards which provide the following:

- minimum levels of safety and comfort for drivers
- a framework for economic design
- consistency of alignment

The design standards should take into account the road environment, road conditions, traffic characteristics and driver behaviour. In so doing, the design aims to provide a road with an alignment and cross-section that is not only the best compromise between operational efficiency, safety and economy but also minimises any adverse environmental and social/cultural impacts. This requires a thorough knowledge of the local road environment which affects every aspect of the design process.

*It was only in 2001 that, AASHTO produced their "Guidelines for Geometric Design of Very Low-volume Local Roads (ADT  $\leq$  400)". This was in recognition of the fact that "...very low traffic volumes make designs normally applied on higher volume roads less cost effective." Prior to this, their "Policy on Geometric Design of Rural Highways – 1965 edition", which did not cater specifically for low-volume roads, was the de facto standard adopted in most SADC countries!*



*Accident rates in the SADC region are of the order of 30 – 50 times higher than in Europe or the USA.*



*Severe erosion of side slopes that can lead to siltation of streams and rivers.*

### Geometric Design

The geometric design of LVSRs presents a unique challenge because the relatively low traffic levels make designs normally applied on higher volume roads less cost effective. Unfortunately, design standards for LVSRs have never been specifically developed for the SADC region. In the absence of such standards, there has been a tendency to use national standards that are based on those developed in industrialised countries, such as the traditionally used AASHTO *Policy on Geometric Design of Rural Highways*<sup>1</sup>.

Imported standards tend to cater for relatively high levels of traffic and embody relatively high levels of service, as a result of which, they are often inappropriate for application to LVSRs. Moreover, they give little, if any, consideration to the use of labour-based methods of construction which can influence the design process (ref. Box 1.) This results in LVSRs often being designed in a manner that does not take account of the socio-economic and other characteristics of the local road environment.

### Road Safety

Many aspects of the geometric design process are affected by the road environment which, in turn, can influence the level of road safety provided to road users. Experience has shown that simply adopting "international" design standards from developed countries will not necessarily result in levels of safety that are achieved in those countries as these are generally accompanied by effective enforcement, driver training and publicity - influences that are often not operating as efficiently in the SADC region.

Road traffic operations also tend to be complex and often involve a mixture of motor vehicles, bicycles, animal drawn vehicles and pedestrians. A large proportion of the traffic composition is dominated by relatively old, over-loaded and slow-moving vehicles and there are often low levels of driver training and control of road users. In such an environment, traffic safety assumes paramount importance, an aspect of geometric design which is often inadequately addressed at the various stages of planning, designing and constructing LVSRs.

### Environmental Issues

Many aspects of the geometric design process also have a potential impact on the physical and social/cultural environments, especially where the alignment traverses built-up areas and where there is a high potential for severe erosion. Unfortunately, various practical measures that can be undertaken during the geometric planning process to minimise environmental impacts are often not adequately understood and addressed.

From the above, it is apparent that existing design standards and practice are generally not appropriate for application in the SADC region. A need therefore exists to adapt these standards in order to provide acceptable levels of service, safety and uniformity consistent with the types of traffic generally experienced on LVSRs. Such adaptation needs to be based on local knowledge, experience, socio-economic conditions and established criteria within a design process that needs to be flexible and multi-faceted, from feasibility to the end-of-life cycle.

### 4.1.2 Basic Terminology

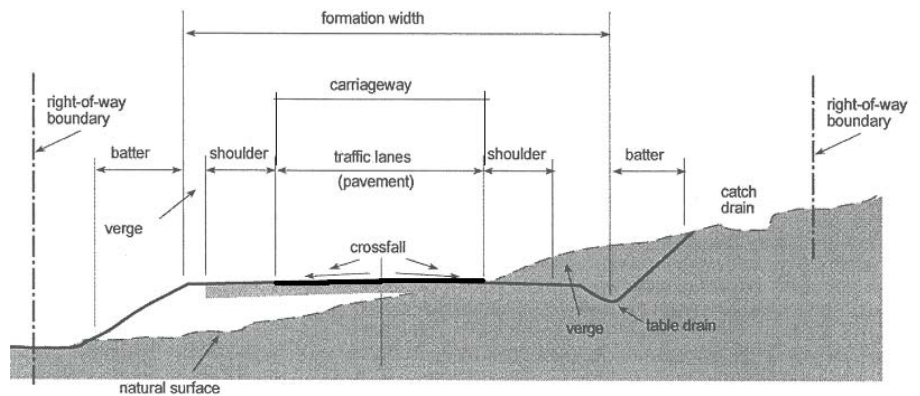


Figure 4.1 – Typical road cross section elements (After Austroads<sup>2</sup>)

### 4.1.3 Purpose and Scope of Chapter

The main purpose of this chapter is to raise awareness of the widely differing recommendations made by various design guides or manuals pertaining to LVSRs. It highlights the many shortcomings that are inherent in those traditional approaches to geometric design that have been imported and used without appropriate adaptation to the specific characteristics of the LVSR environment. Particular emphasis is placed on the need to incorporate appropriate road safety features in the design process.

The approach adopted is not prescriptive; neither is it intended to be a detailed design manual that could supersede the need for application of sound principles by the knowledgeable design professional. Rather, it emphasises the need to consider the basis on which various design parameters are chosen in relation to the specifics of the SADC region's road environment.

## 4.2 Design Philosophy, Standards and Approach

### 4.2.1 Philosophy

The philosophy embodied in the geometric design of a road is linked to such factors as a country's economic prosperity, the state of development of the road network and the unique characteristics of the road environment within which the road functions. It would normally evolve from analytical evaluation and experience of local conditions and often reflect the physical and economic environment of the road project itself. Thus, geometric design philosophy would be expected to vary between industrialised and developing countries.

The functionality and characteristics of the road network in the SADC region are quite different from those in industrialised countries. Not only are traffic levels relatively low, but the traffic mix is complex, consisting of a mixture of motorised and non-motorised traffic. The proportion of commercial vehicles and levels of pedestrianisation near peri-urban areas are also relatively high. This clearly dictates a need to develop a design philosophy and related standards that are suited to the socio-economic environment of the region. Such a philosophy would be expected to be quite different from that embodied in geometric design manuals developed in industrialised countries that often form the basis of geometric design in the region. Such manuals generally cater to higher traffic volumes, greater need for all-weather accessibility and provide for operational efficiency of the traffic using the network - requirements that are clearly less appropriate for the region.

### 4.2.2 Standards

Geometric design standards provide the link between the cost of building and subsequently maintaining the road and the cost of its use by road users. Usually, the higher the geometric standard, the higher the construction cost and the lower the road user costs. The aim is to select design standards that minimise total transport costs. Thus, the relatively low traffic characteristics of LVSRs means that road improvements should be planned at the lowest practicable standards (without unduly impairing safety requirements) if costs are to be justified by the benefits obtained.

Unfortunately, there are no existing standards in any SADC country that are based on in-country research into economic and safety factors. Those standards that do exist vary tremendously, reflecting either the practice of the developed countries with which SADC countries have had previous ties or the preferences of international consultants who have worked in these countries. Many of them are a direct translation from overseas practice, sometimes with some modification to compensate for local operational differences and deficiencies, often without full evaluation of the consequences.

In view of the above, until standards for LVSRs are developed, the challenge is to apply existing designs and standards in a flexible manner to fit the parameters pertaining to the local environment and to achieve safe economic design.



*Flat terrain with little constraint on geometric standards.*



*Hilly terrain with constraints on geometric standards.*

*LVSRs, more than any others, call for a detailed examination of design options on the basis of sufficient data to allow an appropriate choice of geometric standards and should not be designed according to rigid guidelines and standards established a priori, often in environments very different from those prevailing in the SADC region.*

### **Choice of Standards**

The choice of geometric design standards is related to the function of a road. In a developing region, such as SADC, three stages of road network development usually occur, as follows:

- Stage 1 - provision of access
- Stage 2 - improvement in existing capacity
- Stage 3 - increase in operational efficiency

LVSRs generally fulfil a function within road networks at Stages 1 or 2 of the above sequence. Thus, the road design philosophy and standards should reflect the particular requirements of such roads and their particular characteristics. In this regard, a case may be made for a “relaxation” of traditional standards as, when sensibly applied, they can result in substantial construction cost savings, with little additional risk of increased accidents. Such relaxations, or local reductions in standards, can be undertaken in the context of the “Design Domain”, a relatively new concept in geometric design which is described further in Section 4.3.2.

### **4.2.3 Approach**

**I**nvestment in road infrastructure represents a large part of investment in national development programmes. It is therefore even more important to ensure that scarce funds are deployed to best advantage. There is a tendency for the construction cost per kilometre to increase as each road design criterion is considered. As a matter of policy, therefore, it is necessary to ensure that an approach to geometric design is adopted which is appropriate to the prevailing socio-economic conditions. This may mean considering design approaches that favour labour exclusive rather than plant exclusive construction technology.

#### **Box 4.1 – Labour-based methods and geometric design<sup>3</sup>**

In a labour-abundant economy, it is often beneficial to employ labour-based rather than equipment-based methods of road construction. In such a situation, the choice of technology can be a major constraint or facilitator affecting design. Where labour-based technology is being contemplated at the geometric planning stage, it could have the following implications:

- the geometric standards that are achievable will be seriously affected, especially in rolling, hilly or mountainous terrain
- economic haul distances will be limited to those achievable using wheel barrows
- mass balancing will need to be achieved by transverse rather than longitudinal earthwork distribution
- maximum gradients will need to follow the natural terrain gradients
- horizontal alignments will need to be less direct
- maximum cuts and fills will need to be low

The reverse of the above is true for equipment intensive technology. Thus, at the geometric planning stage, consideration must be given to the type of technology to be employed in road construction and the influence this will have on the approach to geometric design.

The following aspects of geometric design require particular consideration from a policy perspective as they have a crucial bearing on the life-cycle costs of LVSR provision:

- Design standards
  - design speed
  - cross-sectional dimensions
  - safety measures
  - maximum gradient
  - horizontal curvature

In the final analysis, the wide variety of topographic, climatic, economic and social conditions will dictate the road geometry appropriate to a specific situation. The aim should be to establish a basic network of LVSRs by spreading limited resources to cover several road projects rather than building a smaller number of roads to a higher standard. In this way, funds saved by using cost-effective design standards can be used for other projects which would bring the best economical return on the investment.

Cost effective geometric design can be achieved by identifying areas where road standards could be made more flexible and more responsive to environmental changes consonant with local knowledge, experience, socio-economic conditions and established criteria.

## 4.3 Design Framework and Process

Physical obstacles in the terrain can constrain design options.



### 4.3.1 Framework

LVSRS fulfil a variety of functions within diverse operational environments. Thus, designs need to cater for an array of different situations in which consideration must be given to all the inter-acting elements that affect the design process.

In order to help define the situations which are appropriate for a specific design application, it is useful to group them within a design framework as shown in Table 4.1.

Table 4.1 – Design Framework

Element	Range	Influence on design
Project type	<ul style="list-style-type: none"> <li>▪ New</li> <li>▪ Existing</li> </ul>	<ul style="list-style-type: none"> <li>▪ greater flexibility of choice but there are few new “greenfield” projects</li> <li>▪ focus on upgrading/reconstruction projects which places constraints on designer’s choice</li> <li>▪ designer’s choice often restricted by nature of existing developments and roadside environment</li> </ul>
Area type	<ul style="list-style-type: none"> <li>▪ Urban</li> <li>▪ Peri-urban</li> <li>▪ Rural</li> </ul>	<ul style="list-style-type: none"> <li>▪ wide range of operating characteristics, constraints and configurations which vary widely in terms of                             <ul style="list-style-type: none"> <li>- range of uses</li> <li>- traffic volumes, speeds and mix</li> <li>- pedestrian activity</li> </ul> </li> <li>▪ need for producing appropriate matching designs</li> </ul>
Functional classification	<ul style="list-style-type: none"> <li>▪ Primary</li> <li>▪ Secondary</li> <li>▪ Tertiary/access</li> </ul>	<ul style="list-style-type: none"> <li>▪ identifies relative importance of mobility and access functions for road</li> <li>▪ prescribes related minimum standards</li> </ul>
Terrain type	<ul style="list-style-type: none"> <li>▪ Flat</li> <li>▪ Rolling</li> <li>▪ Mountainous</li> </ul>	<ul style="list-style-type: none"> <li>▪ influences choice of alignment, design/operating speeds and standards</li> <li>▪ impacts on drainage and maintenance requirements and also on environment</li> </ul>
Design/operating speed	<ul style="list-style-type: none"> <li>▪ Low</li> <li>▪ Medium</li> <li>▪ High</li> </ul>	<ul style="list-style-type: none"> <li>▪ used to correlate various features of design</li> <li>▪ ultimately determines construction, maintenance and road user costs</li> </ul>
Traffic volumes, type and mix	<ul style="list-style-type: none"> <li>▪ Low</li> <li>▪ Medium</li> <li>▪ High</li> </ul>	<ul style="list-style-type: none"> <li>▪ provides fundamental basis of design</li> <li>▪ includes both motorised and non-motorised traffic</li> </ul>

LVSRS projects will be, predominantly, the upgrading of existing gravel roads to a bituminous standard. The designer’s freedom of choice will often be restricted by developments, including ribbon development, surrounding the road to be upgraded. Thus, rigid adherence to standards may not be possible and flexibility must be built into the process through the adoption of flexible design techniques.

### 4.3.2 Process

The process of geometric design contains various stages within which the final product is gradually developed. The process is iterative. A number of investigations and evaluations have to be undertaken, questions asked, and decisions taken in preparatory phases that may have to be re-evaluated later, until the process has provided satisfactory results. An outline of the design process is presented in Figure 4.2.

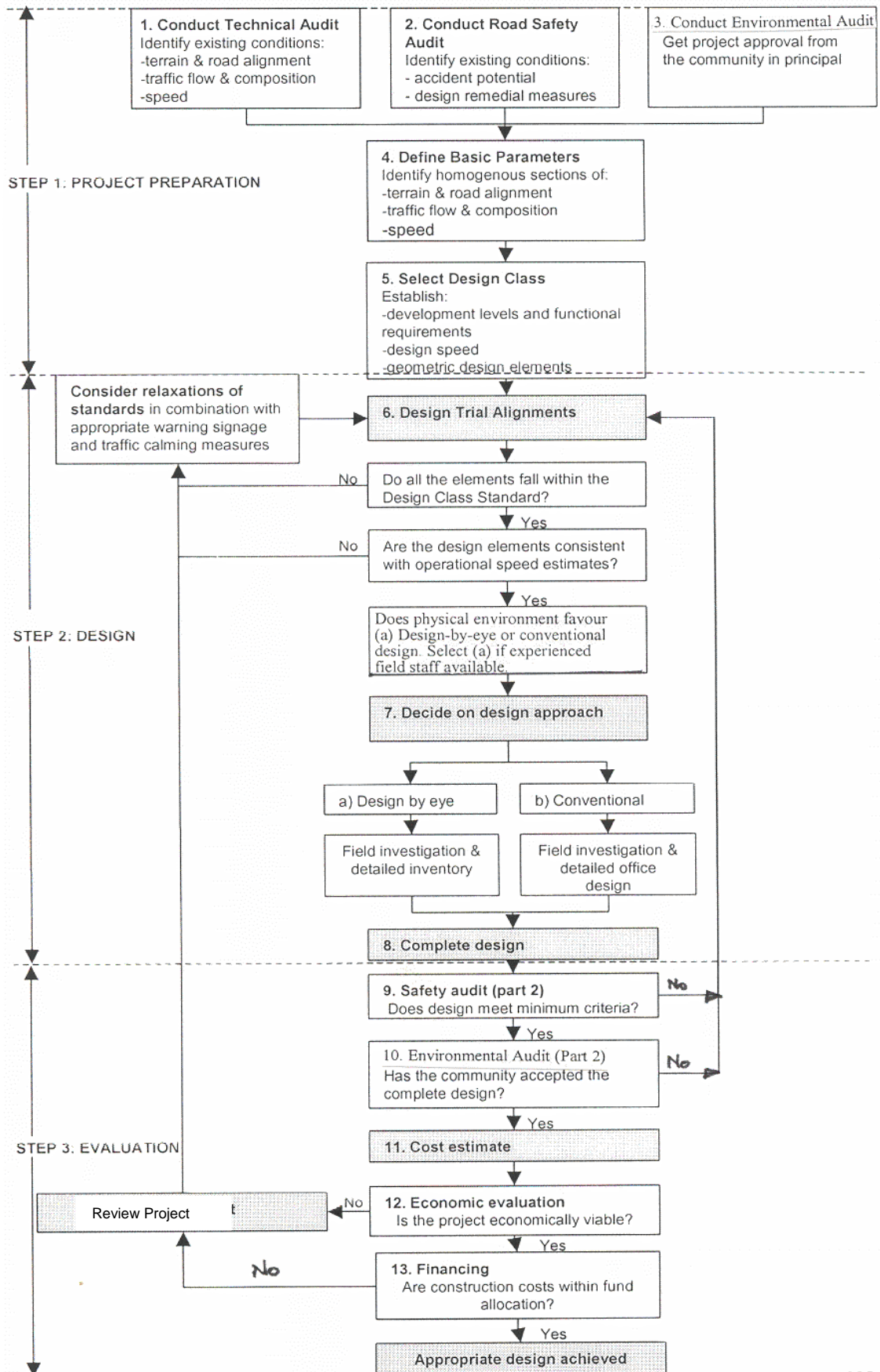


Figure 4.2 The geometric design process

The design process may be broken down into three phases as follows:

- project preparation
- design
- evaluation

### **A. Step 1 – Project Preparation**

The project preparation phase embodies a number of concepts that are not normally considered in conventional design manuals. These include a focus on the planning aspects of the geometric design process in which there is:

- a primary, over-riding focus on road safety
- continuous public involvement in all stages of the design process.

The main activities undertaken in the project preparation phase include:

(1) **Technical Audit:** One of the first tasks to be carried out is a technical audit of the project. This entails information gathering on such factors as terrain and road alignment, traffic flows and composition, overall speed and speed over individual sections, land use and settlements including schools and hospitals. Traffic counts and traffic forecasts also need to be conducted. The results of the technical audit provide an input into the next step - the definition of basic parameters.

(2) **Road Safety Audit (1):** The preliminary design stage of the audit entails investigation of all factors that could have an adverse impact on the safety of the design, including such factors as accident “black spots” and the accident potential related to the improvement/upgrading of the road assessed, so that the information can be included in the subsequent design.

(3) **Environmental Audit (1):** The community should be consulted and involved at an early stage of the design process. This is necessary to ensure that their views are accommodated where appropriate and their priorities taken into account in the final design.

(4) **Define Basic Parameters:** The main task is to identify and group the project into homogenous sections with similar conditions and characteristics such as terrain, alignment, traffic, speed, land use and development. The information will form the basis for selection of the design class.

(5) **Select Design Class:** The selection of design speed and geometric elements is based on the developmental potential and functional requirements of the road. The design class for each homogenous section of road, in terms of terrain, road alignment, traffic and speed, can then be determined as a basis for selecting the various design elements.

### **B. Step 2 – Design**

(6) **Design Trial Alignment:** The trial alignments will confirm if the intended standard can be introduced, for instance, if the design elements fall within the standard and are consistent with the expected operational speed. Failure to comply with set conditions will require new trials with modified inputs. Such trials may include relaxation of standards consisting of measures such as a lower design speed in combination with appropriate signage or traffic calming measures.

(7) **Decide on design approach:** The design approach will be dependent on topography, institutional arrangements, availability of suitable skilled and experienced field staff, etc. The selection of the design approach is also influenced by the type of project in terms of whether it involves rehabilitation of an existing facility or provision of a new one. The requirements for the field surveys and investigations will also depend on the type of project.

(8) **Complete Design:** The completion of the design concludes Stage 2 – Design, and is followed by the next Stage 3 – Evaluation. This stage includes the follow-up of a number of audits and evaluations related to safety, social considerations, costs, along with economics and financing which received preliminary consideration in the project preparation phase.

### **Step 3 – Evaluation**

(9) **Road Safety Audit (2):** The design features are examined from a safety point of view. Remedial measures are proposed for possible weaknesses in the design. If the design is such that simple remedial measures are not adequate to rectify the shortcomings, the design will need to be reviewed and new trial alignments be carried out. This iterative procedure will be repeated until the design is acceptable from a road safety perspective.

(10) **Environmental Audit (2):** Public participation should continue after the detailed design is completed. If necessary, modifications or adjustments to the design, as a result of community consultations, will have to be undertaken to ensure that the final project accords with local requirements.

(11) **Cost Estimate:** Cost estimates should be conducted at various steps of the design process as they may influence the scope of the project and decisions made concerning the design controls and elements. A detailed cost estimate will be required at final design stage to allow an economic evaluation of the project to be carried out.

(12) **Economic Evaluation:** Cost-benefit analyses, as described in Chapter 3, need to be undertaken to allow the viability of the project to be assessed. If the project turns out to be not viable in terms of the criteria prescribed, modifications to the project may need to be undertaken. Such modifications may include relaxations of design standards, stage construction, or other factors that reduce cost or increase benefits.

(13) **Financing:** Adequate financing for the project, in terms of both construction and future maintenance costs, needs to be secured before implementation begins, otherwise the sustainability of the project could be jeopardised. Should such funding not be available, it may be preferable to defer implementation until it can be obtained.

(14) **Appropriate Design Achieved:** If the tasks outlined in the flow chart and in the discussion above have been methodically carried out, the final result should be an appropriate geometric design.

In 1990 road traffic accidents were rated ninth in the top ten causes of death and disability in the world. By 2020 it is predicted that it will be rated third.

Harvard School of Public Health Projections.

### 4.3.3 Safety Issues

#### Importance of Safety

Studies carried out by international organisations reveal that the road safety situation throughout the African continent, including the SADC region, is one of the worst in the world<sup>4</sup>. Fatality rates, in relation to vehicle fleets, are 30 – 40 times higher than those of industrialised countries. Indeed, in several countries a motor vehicle is over one hundred times more likely to be involved in a fatal crash than in Europe or the USA.

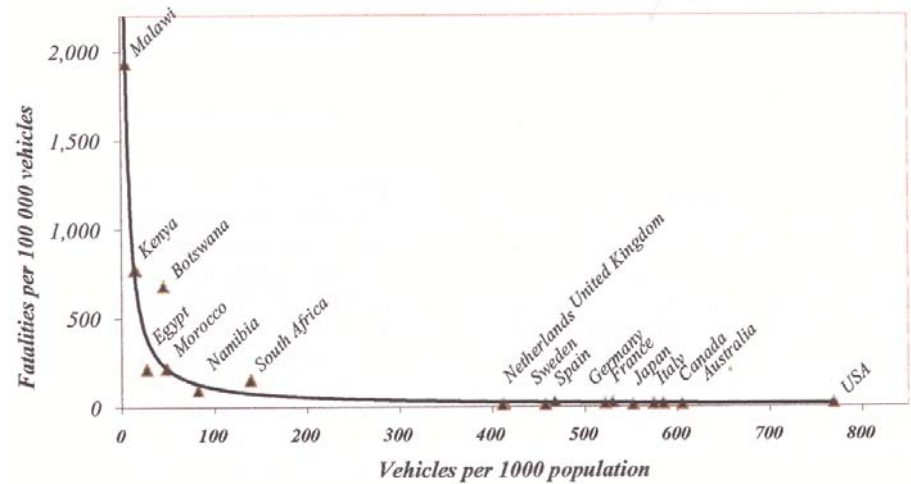


Figure 4.3 – International comparison of fatalities in selected countries<sup>4</sup>

Because of the substantial cost implications on the economies of these countries – of the order of one to two per cent of gross national product (GNP) - road safety has become of paramount importance in all aspects of road provision.

Road safety is multi-dimensional in nature and cannot be discussed in isolation to geometric design. As illustrated in Figure 4.4, both the various elements of the road system, such as geometry and pavement condition and operational conditions, such as operating speed, influence road safety.



Unconventional signs are sometimes used to warn of the dangers of speeding.



A poorly-maintained road sign can be the cause of road accidents.

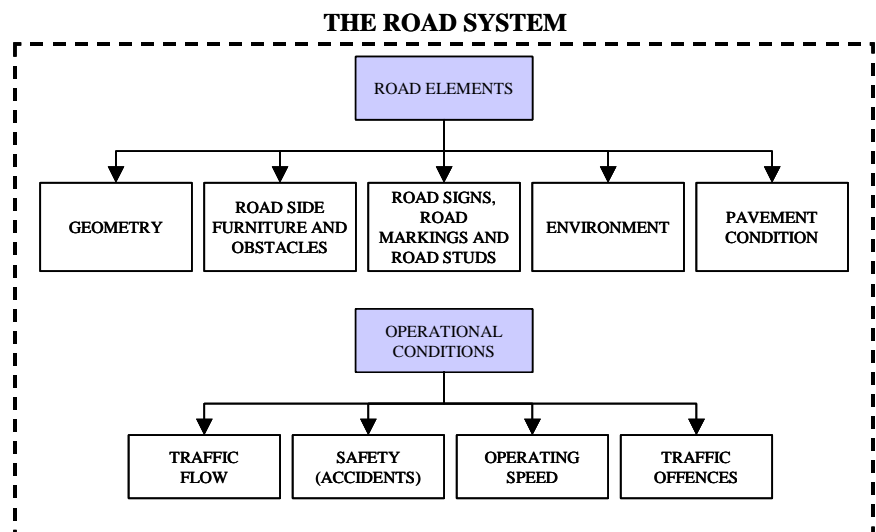


Figure 4.4 - Elements of the road systems and operational condition



Speed limit painted on the road.

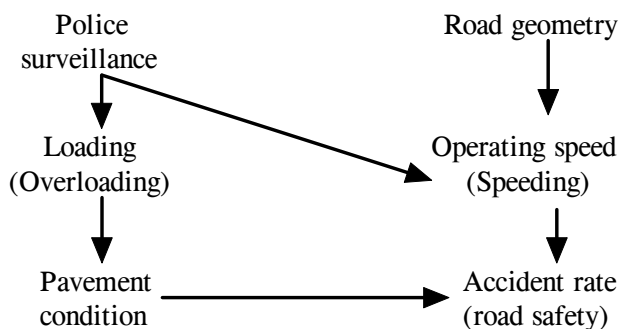


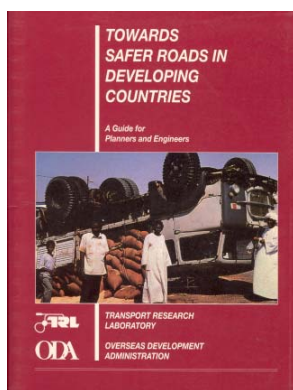
Figure 4.5 – An example of the interrelationship between road elements and operational conditions

Thus, although the importance of designing for safety is now widely recognised, the actual process of identifying key design features and resolving the conflict of safety and other considerations is complex and requires tackling in a holistic manner.

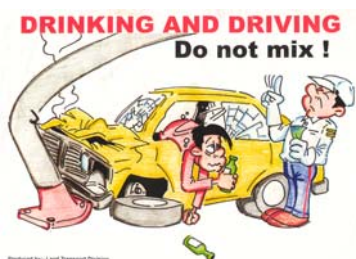
### The Nature of Accidents

Confronting the challenge of safety requires proactive strategies that treat the root causes of accidents and levels of severity before they occur. To this end, valuable guidance on accident prevention is given in a number of documents including, particularly, the TRL guide entitled *Towards Safer Roads in Developing Countries*<sup>5</sup>.

As illustrated in Figure 4.6, accidents are multi-causal in nature, involving human factors, the road environment and vehicle factors. They are more often caused by a *combination* of these factors, with human factors contributing to an estimated 95 per cent of all accidents, the road environment 28 per cent and vehicles 'only' 8 per cent. Thus, although not the dominant cause of road accidents, it is important that features are not introduced in the geometric design which could result in additional negative impacts on road safety.



The above document provides practical guidance on how to make roads safer by highlighting the key, safety-related factors which need to be incorporated when planning, designing and operating road networks.



Drinking and driving are a common cause of accidents in the SADC region.

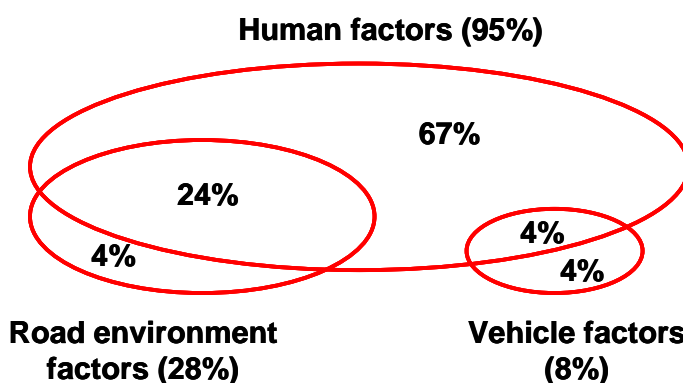


Figure 4.6 – Factors contributing to road accidents<sup>6</sup>

### The Influence of Design

Almost all geometric design elements affect road safety by:

- influencing the ability of the driver to control his/her vehicle
- influencing the opportunities that exist for conflict (and accidents) with other road users
- influencing the outcome of an out-of-control vehicle
- affecting the behaviour and attentiveness of a driver

Thus, by incorporating good design principles from the start of the design process, it is possible to avoid many problems simply by planning and designing new roads or upgrading existing ones in a safety conscious manner. *Moreover, it is often possible to improve road safety characteristics markedly at little or no extra cost, provided the road safety implications of design features are considered at the design stage. Unfortunately, road design engineers are often part of the problem and their failure to take adequate account of operational use of roads often result in increased speeds and increased deaths when such roads pass through communities straddling the road.*

There are a number of tools to assist in this process, such as Road Safety Audits, which are considered below.

*Reviews of road projects in many developing countries reveal a depressing catalogue of unsafe and inconsiderate road designs which though compliant with highway design standards, remain unsafe because of the particular characteristics of the traffic using the road and the "operating environment" in which the road will function<sup>4</sup>.*



*Designs need to cater for different types of road users.*

#### Box 4.2 – Key principles for designing safer roads

Adherence to various key principles of design can considerably improve the safety of LVSRs. These key principles are summarised below:

- *Designing for all road users.*
  - includes non-motorised vehicles, pedestrians, etc.
  - Has implications for almost all aspects of road design, including carriageway width, shoulder design, side slopes and side drains
- *Providing a clear and consistent message to the driver*
  - roads should be easily "read" and understood by drivers and should not present them with any sudden surprises
- *Encouraging appropriate speeds and behaviour by design.*
  - traffic speed can be influenced by altering the "look" of the road, for example by providing clear visual clues such as changing the shoulder treatment or installing prominent signing
- *Reducing conflicts*
  - cannot be avoided entirely but can be reduced by design, e.g. by staggering junctions or by using guard rails to channel pedestrians to safer crossing points
- *Creating a forgiving road environment.*
  - forgives a driver's mistakes or vehicle failure, to the extent that this is possible, without significantly increasing costs.
  - ensures that demands are not placed upon the driver which are beyond his or her ability to manage

Despite adherence to various key principles for designing safer roads, very few engineering measures, on their own, are totally self-enforcing. They normally require other measures of external control and facilitation such as enforcement and education, to be fully effective (ref. Section 4.5).

### Road Safety Audits

Safety should be given special attention at all stages of the design process. One effective means of achieving that goal is by the use of a road safety audit. This may be defined as “...a formalised examination of an existing or future road or traffic project or any project which interacts with road users, in which independent, qualified examiner reports on the project’s accident potential and safety performance”<sup>6</sup>.

The objectives of a road safety audit are essentially to:

- identify and report on the accident potential and safety problems of a road project
- ensure that road elements with an accident potential are removed or improved
- ensure that measures are implemented to reduce accident risks.

As illustrated in Figure 4.7, road safety auditing is an iterative process and should be carried out at all stages of a road project from preliminary design, through detailed design to pre-opening. They provide an opportunity, especially during the preliminary design stages of the project, to eliminate, as far as possible, road safety problems in the provision of both new roads as well as those being upgraded.



Roads safety audits help to produce designs that reduce risks to road users.

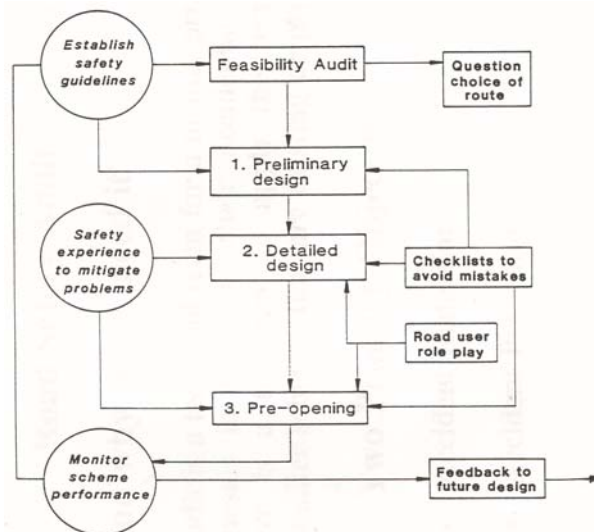


Figure 4.7 – Road safety audit flow-chart

The major benefits of such audits include:

- a reduction in the likelihood of accidents on the road network
- a reduction in the severity of accidents on the road network
- an increased awareness of safe design practices among traffic engineers and road designers
- a reduction in expenditure on remedial measures
- a reduction in the life-cycle cost of a road

The resources required for carrying out a road safety audit are usually quite small and could add about 4 per cent to the road design costs. However, the benefits can be very marked with an estimated potential benefit-cost ratio of 20:1<sup>7</sup>.

By conducting road safety audits, a road authority is showing that it has the intention to improve the safety on its road, and consequently has a stronger defence against tort liability claims.



Designs should cater for pedestrians as well as traffic.

### Box 4.3 – Road Safety Audits in SADC

Road safety audits have not yet become a formalized, mandatory aspect of the road design process in many SADC countries. At present, road safety is assumed to be addressed through adherence to geometric design standards. However, this is neither adequate nor sufficient. It has been shown that “roads designed to standards are neither necessarily safe nor unsafe and that the linkage between standards and safety is largely unpremeditated”<sup>8</sup>. As a result:

- there is a need to accelerate the rate of adoption of a more formalized road safety audit procedure appropriate to all roads in any country
- road safety audit procedures should be introduced as part of a comprehensive road safety programme in all countries
- lessons learned from safety audits should be centrally coordinated and shared amongst all countries in the region

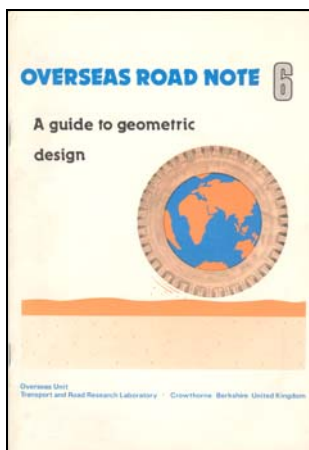
### 4.3.4 Design Guides/Manuals

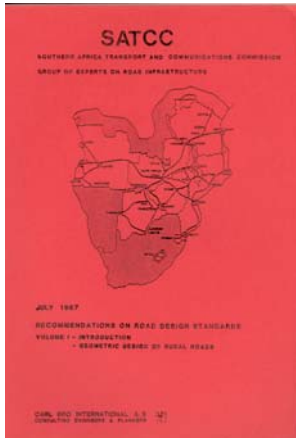
In recognition of the shortcomings of the use of guides from developed countries for LVSRs, attempts have been made to develop more appropriate guides for developed countries (e.g. TRL’s ORN 6<sup>9</sup>). Recourse has also been made to the use of more appropriate standards emanating from other countries such as Australia (e.g. NAASRA<sup>10</sup>, Austroads<sup>11</sup> and ARRB<sup>12</sup> guidelines). Most recently, guidelines have been developed in the region for use either nationally (e.g. South Africa’s G2 Manual<sup>8</sup>) or regionally (e.g. SATCC’s Geometric Design of Rural Roads<sup>13</sup>). However, neither of these guidelines apply to LVSRs.

Table 4.2 provides a listing of the various design guides and the extent of their use in the region.

Table 4.2 – Design guides/manuals used in SADC region

Design Guide/Manual	Degree of Use		
	High	Med	Low
<b>USA</b> <ul style="list-style-type: none"> <li>• AASHO:               <ul style="list-style-type: none"> <li>- A Policy on Geometric Design of Rural Highways (1965).</li> </ul> </li> <li>• AASHTO:               <ul style="list-style-type: none"> <li>- A policy on Geometric Design of Highways and Streets (1984).</li> <li>- Guidelines for Geometric Design of Very Low-volume Local Roads (ADT ≤400) (2001).</li> </ul> </li> </ul>	X		X*
<b>Australia</b> <ul style="list-style-type: none"> <li>• NAASRA:               <ul style="list-style-type: none"> <li>- Interim Guide to the geometric design of rural roads. (1980).</li> </ul> </li> <li>• Austroads:               <ul style="list-style-type: none"> <li>- Rural Road Design: Guide to the design of Rural Roads (1989).</li> </ul> </li> <li>• ARRB:               <ul style="list-style-type: none"> <li>- Road classifications, geometric designs and maintenance standards for low-volume roads (2001).</li> </ul> </li> </ul>		X	X*
<b>United Kingdom</b> <ul style="list-style-type: none"> <li>• TRL:               <ul style="list-style-type: none"> <li>- Overseas Road Note 6: A guide to geometric design (1988).</li> </ul> </li> </ul>		X	





<b>Southern Africa</b>			
<ul style="list-style-type: none"> <li>• SATCC:                             <ul style="list-style-type: none"> <li>- Recommendations on Road Design Standards: Geometric Design of Rural Roads.</li> </ul> </li> <li>• South Africa:                             <ul style="list-style-type: none"> <li>- G2 – Geometric Design Manual (South Africa, 2003).</li> </ul> </li> <li>• Member states: Country manuals based essentially on one or other of the guides listed above.</li> </ul>		X	
	X		X

\* These guidelines have very recently been developed and knowledge of their existence and use is still very limited.

All the guidelines/manuals listed above are based on different philosophies and make different assumptions or use different criteria for developing design values for the various design elements. For example, some guides give emphasis to safety considerations while others may place emphasis on service level, capacity, comfort or aesthetic values. Not surprisingly, the resulting design values recommended, and their related cost implications, all differ, sometimes quite significantly. Thus, it is essential for the designer to have a thorough understanding of the origin, background and basis of development of the design guides or manuals and related design criteria as a basis for adaptation, where necessary, and subsequent judicious application to LVSR situations.

In the next section, a comparison is made of design values obtained from the application of some of the design guides considered most appropriate for use in the SADC region.

## 4.4 Design Controls and Elements

### 4.4.1 Techniques

There are a number of techniques that have been developed in recent years which offer a considerable degree of *flexibility* to the LVSR designer in the design process as well as improve the quality of the design. These are described briefly below:

#### Context Sensitive Design

Context Sensitive Design<sup>14</sup> is responsive to, or consistent with, the road's natural characteristics and human behaviour, i.e. the design can deviate when necessary from accepted design criteria. Consideration is given to the desires and needs of the community by inviting the appropriate stakeholders to participate in identifying solutions so that they are acceptable to the community.

Context Sensitive Design recognises that exceptions may be required in some cases in applying standards. For example, where provision of an engineered alignment results in excessive earthworks, it may be preferable to lower the design speed in order to minimise social or environmental impacts.

#### Design Domain Concept

The 'design domain' concept<sup>8</sup>, shown in Figure 4.8, recognizes that there is a range of values which could be adopted for a particular design parameter within absolute upper and lower limits. Values adopted for a particular design parameter within the design domain would achieve an acceptable, though varying, level of service in average conditions in terms of safety, operational, economic and environmental consequences.

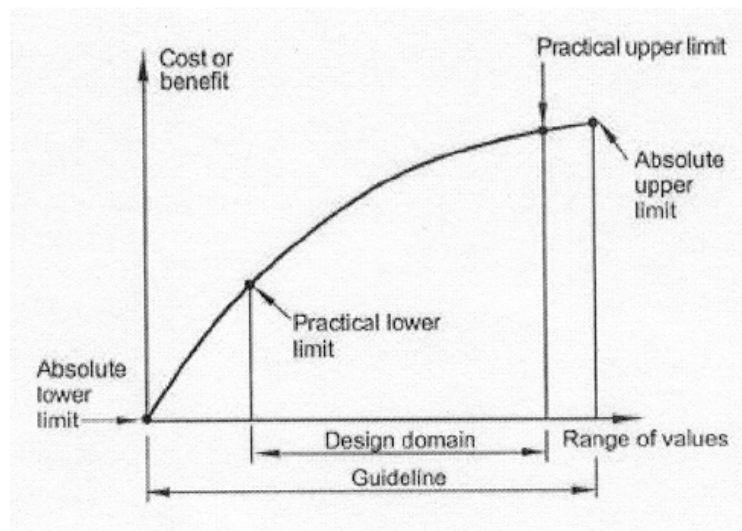


Figure 4.8 – The design domain concept

While values within the lower region of the design domain are generally less safe and less operationally efficient, they are normally less costly than those in the upper region. In the upper region of the domain, resulting designs are generally safer and more efficient in operation, but may cost more to construct. The design domain sets the limit within which parameters should be selected for consideration within the value-engineering concept.

The design domain concept provides the following benefits to the designer:

- it is directly related to the true nature of the road design function and process, since it places emphasis on developing appropriate and cost-effective designs, rather than simply meeting standards
- it directly reflects the continuous nature of the relationship between service, cost and safety and changes in design dimensions. It thus reinforces the need to consider the impacts of 'trade-offs' throughout the domain and not just when a "standards" threshold has been crossed
- it provides an implicit link to the concept of 'Factor of Safety' – a concept that is used in other civil engineering design processes where risk and safety are important.

An example of the design domain concept for shoulder width is shown in Figure 4.9.

#### The flexibility offered by the Design Domain concept

For many elements, a range of dimensions is given and the designer has the responsibility of choosing the appropriate value for a particular application. If a design involves compromise, it may be more appropriate to compromise several elements by a small amount than to compromise one element excessively. It is important that a design should be balanced.

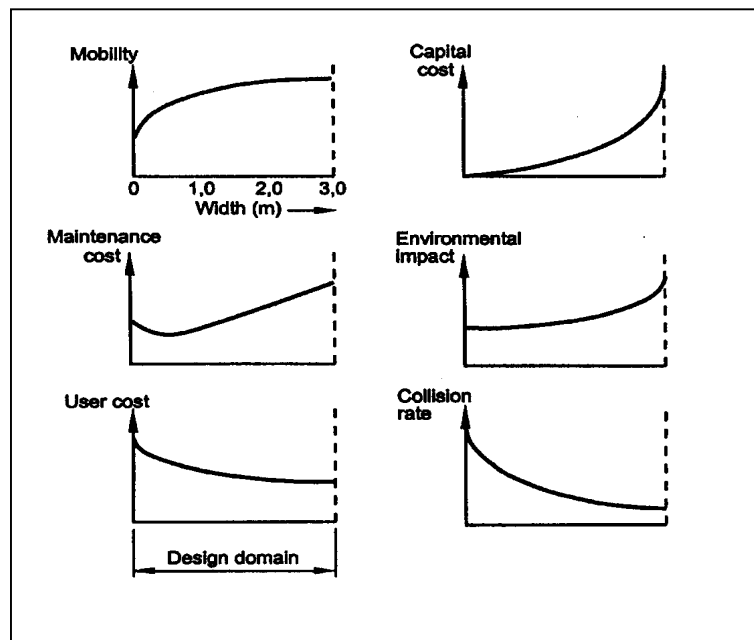


Figure 4.9 – Example of design domain application – shoulder width<sup>14</sup>

#### Design-By-Eye

Conventional approaches to design involve precise engineering surveys over the total length of the road as a basis for producing horizontal and vertical alignments and cross-sections on working drawings from which quantities are normally calculated. The cost of this approach, which is normally justified for relatively high volume/standard roads, can hardly be justified for relatively low-volume/standard roads.

*Design-by-eye* is a relatively simple approach to design which is intended primarily for the upgrading of existing LVRs where the geometry is adequate. In this approach, the route alignment is chosen “by eye” at the time of construction by experienced site staff who are aware of the economic, operational and safety consequences of geometric design.

**Box 4.4 - Advantages of the Design-by-eye approach**

- Enables the engineer to fit the alignment to the terrain so that it causes minimum disturbance to any existing facilities and the adjacent physical environment.
- Obviates the need for a conventional topographic survey of the existing road and normal plan and profile drawings do not need to be prepared.
- Allows the geometry of the road to be described on a simple road location straight-line plan showing roughly the horizontal alignment with kilometre-stationing and possible improvements indicated, such as sight distances.
- Minimises earthworks, increases speed of construction and reduces preparatory costs and, ultimately, construction costs by 10 – 20 per cent.
- Can result in a finished product of at least similar quality to the conventional approach.

The design-by-eye approach is best suited to situations where detailed documentation in terms of drawings and quantities is not required. This includes situations where construction is undertaken by a management team or by in-house construction units rather than by a contractor governed by rigidly specified contractual and payment conditions of a contract.

The degree to which the design-by-eye approach is applied in relation to conventional approaches (full horizontal and vertical survey and control) can also vary widely depending on local circumstances and can include the following options:

- no survey, but brief indications of corridor, areas to avoid, required fill/cut heights for drainage, soils, or other information
- survey of the horizontal alignment and/or vertical alignment with spot surveys of alignment options at critical locations
- survey of the horizontal alignment and vertical alignment up to e.g. sub-base level only. Base course then to be placed within thickness tolerances

**4.4.2 Controls**

**T**he need to relate the physical elements of a road with the requirements of the driver in an environmentally acceptable manner imposes a number of controls on the road designer. Many of these controls relate to the characteristics of the road environment; those that may be appropriate for one environment may well not be appropriate for another. The more important design controls include:

- driver characteristics
- design speed
- design vehicles
- design traffic
- sight distances
- environmental factors

Design parameters such as driver-eye-height and perception-reaction time vary considerably among drivers as well as vehicle type and driving conditions. Thus, in relation to the underlying assumptions made, guidance on various design parameters pertaining to driver characteristics vary quite significantly as illustrated in Table 4.3. As a result, the values derived for related design elements such as sight distance are affected. Such guidance should therefore be carefully evaluated in relation to the assumptions made and their applicability to the project situation.

Table 4.3 – Driver characteristics recommended for rural/low-volume roads

Parameter	Design Guide		
	SATCC	TRL ORN6	ARRB
Driver eye height (m)	1.00	1.05	1.15
Brake reaction time (secs)	2.5	2.0	2.5
Object height (stopping) (m)	0.10	0.20	0.20
Object height (passing)(m)	1.00	1.05	-

### Speed Kills – Kill Speed



Non-standard sign intended to shock drivers into driving carefully.

### Design Speed

The *design speed* is probably the most influential factor affecting the geometric design of a LVSR and is influenced by the following factors:

- nature of the terrain
- classification of the road
- density and character of the adjoining land use
- traffic volumes and composition expected on the road
- cross-section

Design speed is normally taken as the maximum speed that 85% of the drivers are expected to adopt over a specified section of the completed road when conditions are so favourable that the design features of the road govern the driver's choice of speed. The higher the design speed, the higher, usually, the cost of construction. In undulating country, a rough rule of thumb is that an increase of 20 km/h in the speed standard doubles the cost of earthworks.

It is noteworthy that the conventional design speed approach to specifying alignment design standards carries implicit assumptions regarding driver behaviour which have not been substantiated by empirical research<sup>15</sup>. Alternative design procedures have been developed which ensure compatibility between alignment standard and observed driver-speed behaviour, and in which emphasis is placed on consistency and driver expectancy rather than absolute minimum standards. Such an approach is believed to result in safer operations, particularly for low-standard alignments, than the conventional design speed approach<sup>16</sup>. As a result, it would appear better suited to the SADC region where driver behaviour is a critical determinant of operational, and hence, design speed.

Although speed has been viewed traditionally as the most influential factor affecting the geometric design of LVSRs, it is also suggested that life-cycle costs could be considered as the most important factor<sup>3</sup>. The rationale behind this approach is that cost will continue to be the most critical constraint on LVSR provision. This cost minimisation approach also applies to the horizontal and vertical design (4.4.3 Design elements). Speed, geometrics etc. would then emerge as the outputs from the life-cycle costs analysis.

Speed limits can be used to influence driver behaviour, but only if they are realistic. When the speed limit is set at a level that is significantly different from the 85<sup>th</sup> percentile of the free speed, this tends to produce an accident prone situation as drivers tend not to adjust their speeds to the notional classification of the road but, rather, to its physical characteristics. Attention should therefore be given to creating a road environment which tailors the operating speed to a level commensurate with the constrained alignment<sup>17</sup>.

*“The expertise required by the low-volume road designer may lie in his ability to make his intentions clear to the road user and to create a state of mind in the driver such that he will be content to travel at safe speed”. However, while the approach is sound, quantitative guidelines are still lacking.*

**Box 4.5 - Design versus operational speeds in the SADC region**

There are marked differences in the physical environments of countries in the SADC region which, as a result, have a large influence on the application of a number of geometric parameters. For example, the terrain in countries such as Botswana and Namibia is mostly flat. As a result, operational speeds tend to be much higher than the design speed and, *from a traffic safety perspective, there may be need to introduce special measures to constrain the high operational speed close to the design speed.* In contrast, in countries such as Lesotho, Seychelles and Mozambique, the terrain in parts is very mountainous. As a result, the design features of the road govern and sometimes constrain the driver's selection of speed.

*Braking distance and those factors which depend on it, such as sight distance, are approximately proportional to the square of the speed and every increase in the design speed represents a significant increase the value of these factors. However, extra construction costs are usually offset by the benefits to traffic, namely increased safety, capacity and convenience, and lower road user costs.*

Guidance on design speeds is given in a number of design manuals<sup>8,9,10,11,12,13</sup> which all purport to apply to rural/LVRs in developing countries. The design speeds recommended vary, presumably depending on the philosophy of design adopted and the environment for which they are meant to apply – examples are shown in Table 4.4. In view of the critical effect that design speed has on the values of other geometric elements and the related costs of implementing them, careful consideration should be given to the choice of this influential parameter.

**Table 4.4 – Recommended design speed values for selected design guides**

Parameter	Design Guide								
	SATCC			TRL ORN 6			ARRB		
Traffic (ADT)	-			100 – 400			> 100		
Terrain	F	R	M	F	R	M	F	R	M
Design Speed km/h	70	70	50	70	60	50	80	70	50

Note: F = flat, R = rolling, M = mountainous.

### Design Vehicle

The physical characteristics of vehicles and the proportions of the various sizes of vehicles using a road are positive controls in design and define several geometric design elements. The dimensions used to define design vehicles are typically the 85<sup>th</sup> percentile value of any given dimension but are, in fact, hypothetical vehicles selected to represent a particular vehicle class.

The dimensions of design vehicles adopted in design manuals developed overseas are, quite naturally, based on vehicle types found in those countries. However, the range of vehicle types found in the SADC region and their operating characteristics, in terms of vehicle performance, condition, usage, traffic mix and road users' attitude, vary quite significantly from those in developed countries. Thus, careful attention should be paid to design vehicle characteristics in the LVSR design process.

Vehicle size regulations in the region have undergone substantial revisions in recent years which have resulted in the emergence of relatively large, multi-vehicle combinations up to 22 metres in length. These developments also indicate the need to adopt design vehicles that are appropriate to the region.

Designs need to accommodate expected traffic over the life of the road.



Good sight distances on a well-designed LVSR. Note wide shoulder and shallow slope to drainage ditch which both reduce potential hazards.

## Design Traffic

The *design traffic* is a critical design control which has a major impact on all geometric design elements of a road. For HVR's, this factor normally applies only to motorised traffic in terms of Annual Average Daily Traffic (AADT) in the *design year*. However, for LVSRs, due account must also be taken of non-motorised traffic, animal-drawn vehicles and large pedestrian flows near urban and peri-urban areas which all affect such design elements as carriageway and shoulder widths. Unfortunately, none of the recent regional guidelines and few international guidelines, fully cater for non-motorised traffic. Measures that could be considered are wider shoulders, sealed shoulders, wider side drains or physical separation from motorised traffic, all of which will increase costs.

## Sight Distance

A critical feature of safe road geometry is provision of adequate sight distance – the distance ahead that can be seen by the driver. As an irreducible minimum, drivers must be able to see objects on the road with sufficient time to allow them to manoeuvre around them or to stop. The basic elements of sight distance which are important to LVRs include:

- stopping sight distance—the distance needed for safe stopping from travelling speed
- meeting sight distance – the distance needed for drivers of two vehicles travelling in opposite directions to bring their vehicles to a safe stop
- passing sight distance – the distance needed to see ahead for safe overtaking

The values of Stopping Sight Distance (SSD) and Passing Sight Distance (PSD) recommended in various design manuals for rural/LVRs vary quite significantly as shown in Table 4.5. For SSD, this is due to different assumptions regarding brake reaction time and braking distance, which is dependent on vehicle condition and characteristics and object size. For PSD, this is due to different assumptions about the component distances in which a passing manoeuvre can be divided, different assumed speeds for the manoeuvre and, to some extent, driver behaviour.

**Table 4.5 – Minimum stopping (SSD) and passing (PSD) sight distances**

Design Speed (km/h)	SATTC		TRL ORN6		ARRB	
	SSD	PSD	SSD	PSD	SSD	PSD
40	44	110	35	-	-	-
50	-	-	50	140	50	-
60	79	230	65	180	-	-
70	-	-	85	240	90	-
80	126	420	-	-	110	-
100	185	700	160	430	-	-



Deep V-type drainage ditches leave no room for recovery if a vehicle runs off the road.

Sight distance has an impact on road safety. Poor visibility alone may cause a collision between oncoming vehicles. No local guide is available for LVSRs. In the final analysis, therefore, the designer should be aware of the differences in sight distance recommended by various guides and should adopt values for which the underlying assumptions accord closest to project conditions.

## Environmental Issues

All road projects have an impact on the environment. However, the provision of LVSRs that result in an improvement of existing earth/gravel roads without involving major earthworks or disturbance of existing cut and fill slopes or drainage patterns have little or no environmental impact. Indeed, the introduction of a sealed road as a replacement for an earth/gravel road has an important positive effect on the environment in that there is no longer any dust from the earth/gravel road which would have had a negative impact on the environment, particularly when the road passed through built up areas.

When there is a new road alignment or when spot improvements include excavations in existing slopes, the environmental impacts of the works should be evaluated and suitable remedial measures introduced. Where slope instability or erodible soils present a problem, various remedial measures need to be considered, including bio-engineering methods, sometimes in combination with engineering structures. Such measures can also be used to improve surface drainage, particularly in rolling and hilly terrain with steep gradients.



*Bio-engineering offers the engineer a new set of tools, but does not normally replace the use of civil engineering structures. The materials and skills are all available in rural areas, however remote.*

Because of the low levels of traffic on LVSRs, environmental pollution from these roads is also low. However, there may be some slight increase in air pollution from increased emissions if steeper grades and super-elevations result from a design-by-eye approach. The disturbance due to noise is also increased in hilly areas where the strain on the engines due to steep gradients and heavy loads is extensive. Because of the low traffic volumes on LVSRs, the environmental impacts from emissions and noise are rather limited, but an environmental impact assessment should always be carried out.

In order to minimise the adverse impacts of LVSR provision, it is important to carry out an environmental audit at the commencement of the design process. Such an activity aims to:

- design road corridors to minimise environmental and social/cultural impacts and maximise user safety
- integrate the results of the geometric planning process into the design process
- identify appropriate design options to minimise impacts of the proposal and be compliant with the design brief
- provide an Environmental Design Report that sets out various criteria for minimising environmental impacts
- consider the objectives of all road users, and the natural and cultural values of the community through consultation
- minimise disturbance to the natural vegetation and landscapes
- ensure road drainage systems use natural drainage lines and maintain catchment integrity at all times.

### 4.4.3 Elements

The road design process includes the selection, sizing and linking of the following elements which, to a large extent, is influenced by the chosen design speed:

- cross-section
- bridges and culverts
- horizontal alignment
- vertical alignment

All of the above elements affect road safety by influencing the ability of the driver to maintain vehicle control and identify hazards. It is therefore essential that particular attention should be given to safety as a prime design criterion.

#### Cross-Section

The following elements of the road cross-section for various classes of LVSRs need to be considered:

- width of carriageway
- width of shoulders
- cross-fall
- width of road reserve

Of particular importance to LVSRs is the issue of catering simultaneously for the requirements of motorised as well as non-motorised traffic and pedestrians. In such circumstances, it will be necessary to consider cost-effective ways of segregating these various types of road users within an appropriately designed cross-section in which carriageway and shoulder widths play a crucial role.

Relatively wide shoulders (typically 1.5 to 2 metres) are particularly important in mixed traffic situations and serve the following important functions:

- movement of pedestrians and non-motorised traffic with minimum encroachment on the carriageway
- provision of additional manoeuvring space for vehicles and on which a driver may regain control of his vehicle if it goes out of control
- provision of space for the use of vehicles which are broken down
- provision of additional width to the cross section thereby improving sight distances

Examples and comments on appropriate values for the cross section elements for various classes of LVSRs are given in Table 4.6.



*Lay-bys provide a safe haven where vehicles can pull off the road.*



*A segregated footpath can be a cost-effective means of catering for high volumes of pedestrian traffic.*



*Where a segregated footpath is not possible, the use of relatively wide, sealed shoulders provides an acceptable surface for walking or cycling.*

Table 4.6 – Examples of typical cross-sectional widths<sup>9</sup>

Road Function	Indicative Traffic Flow	Carriageway		Shoulder	
		Width (m)	Comments	Width (m)	Comments
Primary	> 400	5.5 to 6.0	Two commercial vehicles will pass completely within the carriageway; some movement towards the edge may occur.	1.0	Represents the minimum width recommended. Need to provide edge markings on shoulder. Widths may need to be increased to cater for pedestrians or non-motorised traffic.
Secondary	100 – 400	5.5 to 6.0	Need to maintain a minimum width of 5.5 m to avoid severe edge break even at low traffic levels.	1.0	For traffic safety reasons, sealing of shoulders is recommended. This is also advantageous for structural and maintenance reasons.
Tertiary/ Access	20 – 100	3.0	Single lane. Two commercial vehicles will pass completely within the total width of 6.0 m utilising the shoulders	1.5	

Note: In case of a high percentage of heavy vehicles, say over 40%, it is advisable to increase the carriageway to 5.5, 6.0 or 6.5 metres.



Severe edge break on a 5 m carriageway even at relatively low traffic levels (< 100 vpd).

Higher standards will put a higher demand on the construction and maintenance budget and this needs to be considered at the design stage. For instance, increased road width produces a greater area to be maintained, thus increasing costs. However, increased width also spreads the traffic loading over a greater area, thereby to some extent reducing pavement deterioration. Thus, as described in Chapter 3, a life cycle cost analysis of the various options should be undertaken to provide guidance on the optimum solution.

**Camber and cross-fall:** A commonly recommended value of all design manuals for the minimum normal cross fall on a paved road is 3%, including shoulders where they have the same surface as the carriageway. The preferable maximum value of super-elevation is normally set at 6-7% and with an absolute maximum of 10%. As indicated in Table 4.7, the use of a higher value of super-elevation makes it possible to introduce a smaller horizontal curve based on the same design speed.

Table 4.7 Design radii for different super-elevations

Design speed (km/h)	Horizontal radius (m) (Supe-relevation 6 %)	Horizontal radius (m) (Super-elevation 10%)
60	100	85



A segregated footway on a narrow bridge provides protection for pedestrians.

### Bridges and Culverts

The cross-section on bridges needs additional consideration, particularly where they have been built with a restricted carriageway width. In such situations, there may be insufficient clearance for a truck to safely pass a pedestrian. This engenders a need to provide a segregated footpath and, where not possible, to employ traffic calming measures in combination with warning signs.

### Horizontal Alignment

The following horizontal alignment elements need to be considered for various classes of LVSRs:

- minimum radius of curvature
- minimum stopping sight distance
- minimum passing sight distance
- super-elevation
- widening of curves



Good combination of curves and adequate horizontal curvature provide for a safe road environment. However, a lack of road markings constitutes a serious safety hazard.

In general, the horizontal alignment should conform to the landscape. On new alignments, long straights should be avoided as they have an adverse impact on the motorist. Measures are required to reduce headlight or sun glare in appropriate circumstances, as well as to reduce boredom and fatigue.

On existing alignments, as far as possible, upgrading should be undertaken without changing the existing curve geometry and cross-section. Curve improvements should focus on low-cost measures designed to control speeds, enhance curve tracking or mitigate roadside encroachment severity.

Minimum horizontal curvature is governed by maximum acceptable levels of lateral and vertical acceleration, minimum sight distances required for safe stopping and passing manoeuvres and values of side friction assumed for the road surface type. These design parameters are, in turn, related to the vehicle speeds assumed in the design. Curvature standards are thus explicitly or implicitly dependent on a number of assumptions which, as illustrated in Table 4.8, result in quite different values of minimum horizontal radii. The choice of minimum radius of horizontal curves has a significant impact on earthworks and costs and therefore needs additional consideration in LVSR design.

**Table 4.8 Comparison of minimum radii of horizontal curvature**

Design Speed (km/h)	Minimum radius of horizontal curvatures							
	SATTC			TRL ORN6			ARRB	
	Side f	e=10	e= 6	Side f	e = 10	E = 6	Side f	e=7-10
40	-	-	-	0.30	30	35	-	-
50	-	-	-	0.25	60	65	0.35	45
60	-	110	140	0.23	85	100	-	-
70	-	-	-	0.20	130	150	0.31	100
80	-	210	250	0.19	175	200	0.26	160
100	-	350	420	0.15	320	375	-	-

F = side friction, e = super-elevation

## Vertical Alignment

The main components of the vertical alignment include:

- maximum gradient
- minimum stopping or passing sight distances on crest curves
- minimum radius of sag curves



Poor visibility due to hidden sag curve – a potential cause of accidents.

Vertical alignment has a direct effect on construction costs and depends on terrain. Cost can be reduced by reducing earthworks through careful route selection. Greater maximum grades should be considered for lower standard roads than for those with a higher classification. The benefits gained from reducing vehicle operating costs and time costs are unlikely to offset the additional construction costs of implementing minimal grades.

Table 4.9 shows the values for vertical crest and sag curves recommended by different design manuals for rural/LVRs in developing countries. As indicated in the Table, there is a considerable difference between the values recommended for both vertical crest and vertical sag curves, largely because of the different assumptions made in their derivation. The values recommended in the SATTC guide for trunk roads are based on headlight illumination criteria while the values by TRL ORN6 and ARRB are based on driver comfort criteria. In the SADC region, LVSRs serve a number of different functions and in very different terrains. In the absence of a local guide for LVSRs, the designer will need to determine which of the recommended values are most suited to the local terrain and road function (primary, secondary or tertiary).

Table 4.9 - Comparison of minimum radii of vertical curvature

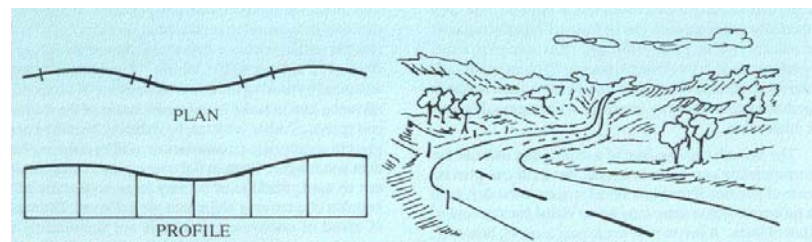
Design speed (km/h)	SATTC		TRL ORN6		ARRB	
	Crest curves <sup>1</sup>	Sag curves <sup>2</sup>	Crest curves <sup>1</sup>	Sag curves <sup>3</sup>	Crest curves <sup>1</sup>	Sag curves <sup>3</sup>
40	6	8	3	1.3	-	-
50	11	12	5	2.2	5	4
60	16	16	10	3.5	-	-
70	23	20	16	4.8	14	8
80	33	25	-	-	23	10
85	-	-	30	8.1	-	-
90	46	31	-	-	-	-
100	60	36	60	13.1	-	-

Notes:

1-Based on stopping sight distance. 2-Based on headlight illumination criteria. 3-Based on comfort criteria

### Phasing of Horizontal and Vertical Alignments

Certain combinations of horizontal and vertical curves can result in drivers seeing an apparent distortion in the alignment or grade or both, even though the horizontal and vertical curves comply with design rules. Other combinations can hide a change in horizontal alignment for the driver. Thus, proper sequencing of horizontal and vertical curvature is important for accident prevention. However, such sequencing is usually attained at the cost of extra earthworks and a careful balance must be struck between the costs and benefits of such an undertaking. Examples of good and poor alignment designs are shown in Figure 4.10.



Example of good alignment design – a smooth-flowing appearance results when vertical and horizontal curves coincide



Example of a poor alignment design – uncoordinated horizontal and vertical curves

**Figure 4.10 – Examples of good and poor combinations of horizontal and vertical alignments<sup>11</sup>**

## 4.5 Roadside Safety, Education and Enforcement

### 4.5.1 Roadside Safety

The roadside environment and its design play an important role in road safety. Elements of this environment include:

- roadside furniture and obstacles
- road signs, markings and studs
- parking facilities, lay-bys and passing lanes
- traffic calming measures and lighting

*Roadside furniture includes:*

- Road signs
- Street lighting
- Guardrails, etc

*Roadside obstacles include:*

- Trees
- Shrubs
- Illegally positioned advertising signs within road reserve
- Power lines or other utility poles within road reserve
- Building structures
- Deep side drains



An unforgiving roadside is one which is not free of obstacles that may cause serious injuries to occupants of heavy vehicles



Non-standard cattle warning sign.

### Roadside Furniture and Obstacles

Whilst fulfilling important safety roles, both roadside furniture and obstacles can have negative safety implications as well which include:

- obstructing the view of other road users and line of sight of drivers and pedestrians
- causing a risk of vehicles colliding into them

The ideal situation is to provide for a clear zone, which is kept free of hazards, including roadside furniture and obstacles. However, in cases where the provision of clear zones is too expensive or impractical due to topographical, environmental or other constraints, options should be considered to reduce the seriousness of the consequences. Figure 4.11 provides guidance on dealing with roadside hazards in order to provide a “forgiving roadside”.

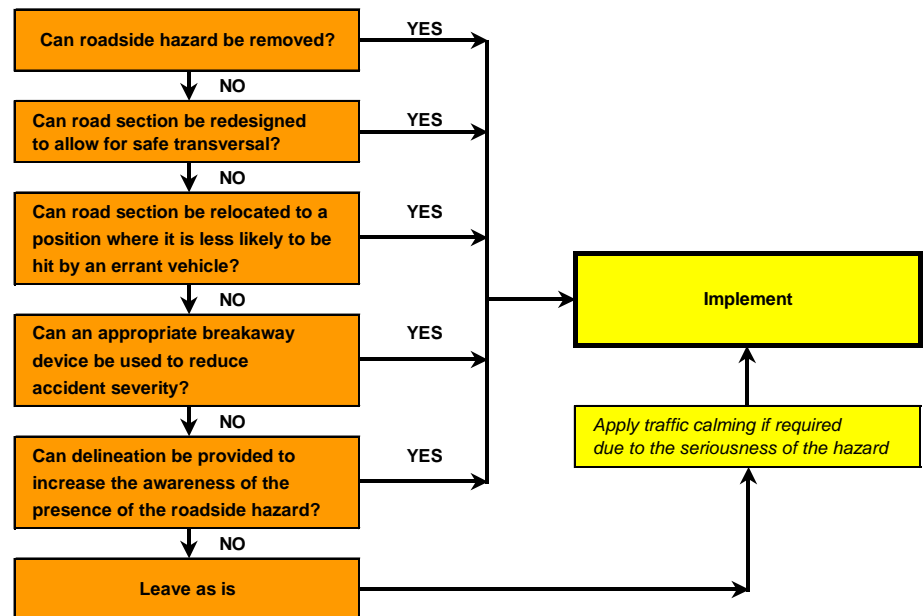
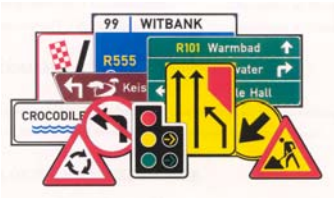


Figure 4.11 - Selection process to ensure a forgiving roadside



Various SADC traffic signs as contained in the SATCC Traffic Signs Manual.



Additional signage should be provided on dangerous curve.

## Road Signs, Markings and Studs

Road safety is greatly facilitated by the provision of road signs, markings and reflective studs, which provide drivers with information about routes, road geometry, etc.

Road signs help to regulate traffic by assigning right of way and indicating regulations in force, warning road users of hazards and guiding the road user through navigational information. Road markings play a complimentary role to road signs by conveying additional information to the driver, particularly in terms of delineating various road elements, such as the width of the lane or edge of the carriageway. Road studs, sometimes colour-coded, may be used to supplement road markings where these are subject to conditions of poor or limited visibility. The SATCC Road Traffic Signs Manual<sup>18</sup> should be used as far as possible to maintain consistency throughout the region.

Road signs generally need to be located within close proximity of the roadway (i.e. within the clear zone) and therefore need to afford some protection to errant vehicles. This can be achieved through the use of a simple breakaway device, using a notched wooden support.

Signs, particularly regulatory and warning signs, must be maintained in a sound order (i.e. its reflectivity, cleanliness, visibility) as they play a crucial role in terms of road safety in giving information on rules and hazards further ahead (e.g. sharp curves, steep down grades, areas of high pedestrian activity, etc).

Regular maintenance (trimming) of grass verges and shrubs is particularly important at bends, around road signs, and where pedestrians and animals cross regularly. Poles for services and trees in the road reserve are hazardous for vehicles accidentally leaving the road, and they may also hinder sight distance. Large trees may need to be removed from the immediate roadside. The use of high standard guard-rails is safety efficient, but is very costly. Simpler types of guard-rails or delineators made of painted wooden poles may be used instead of the normal types of guard-rails.

In case of financial constraints, first priority in the placement and maintenance of signage should be given to regulatory and warning signs. Reflectivity of road signs must be adequate for the purpose, with higher reflectivity for warning signs and little (or no) reflectivity for guidance signs. Ideally, signs should be reflectorised, but ordinary paint is better than no sign at all. Road studs should only be considered on road sections where mist is prevalent. They can usually be discontinued on shoulders and be replaced by edge lines as they suffer significant wear and tear.

## Channelisation of Traffic

Warning signs and reduced speed limits are particularly important near localised areas of high activity, such as stretches of road with ribbon development, where there is inadequate sight distance for normal overtaking manoeuvres and the crest of hills. Speed calming devices can also be used as self-enforcing measures where compliance to warning signs and speed limits are low.



*Simple, innovative measures may help to separate traffic and improve the road safety situation for non-motorized traffic in built-up areas.*



*Dedicated crossings provide increased safety for pedestrians if correctly positioned and marked.*

The easiest, and cheapest, way of segregating pedestrian and vehicular traffic is through the use of road markings (i.e. demarcation of shoulders.) These can be in white paint; although the use of another colour (e.g. yellow) helps to identify the particular function of the marking. However, kerbs and even guard-rails can be used to physically separate pedestrians and vehicles. They can also be used to give added protection to pedestrians over bridge and other structures. If there is sufficient room in areas of high pedestrian movement, a footpath (perhaps raised with a kerb to dissuade vehicles from using them) can be provided, either alongside the road itself; or preferably separated by a grass or earth verge of some kind.

Even on low-volume roads there will be areas where pedestrian movements and traffic flow are sufficiently high that pedestrians should be provided with assistance to allow them to cross the road safely. This is especially important near schools and shops. This might involve providing clearly signed zebra crossings with or without a central refuge. As well as offering pedestrians protection, crossings and refuges promote traffic calming and also encourage pedestrians to cross where it is safer to do so.

### **Parking Facilities, Lay-bys and Passing Lanes**

If the road topography permits provision should be made for stopping and parking vehicles. Thus the road design should take account of the need for bus stops, the location of (official or unofficial) street vendors and market stalls, shops and schools. Off-road parking areas should also be provided for rickshaws and taxis and so on.

When there are steep gradients, provision can be made for faster vehicles to pass slow moving lorries and buses safely. This can be provided by having an additional 'crawler' lane, or occasional lay-bys for slow moving vehicles to pull in to let traffic queues pass. However, for LVSRs, the cost-benefit aspects of such measures need to be carefully considered.

At the end of steep descents, 'emergency' provision should also be made for out-of-control vehicles with brake-failures or those travelling too quickly. For example, beds of gravel can be provided to stop vehicles that are out of control and hazardous objects should be protected or removed.

### **Traffic Calming Measures**

Although traffic-calming measures are generally aimed at reducing speeds and diverting traffic (decreasing traffic volumes) in urban areas there are a number of measures that are appropriate for LVSRs. They are normally used on sections of road where there are a high proportion of unprotected/vulnerable road users (pedestrians, cyclists and animal drawn carts, etc), or where there is a localised (unexpected) change in the design speed. Speed calming measures can basically be categorized according to the extent to which they may have an effect, namely:

- localised traffic calming measures, which include warning signs and markings, speed humps, rumble strips, jiggle-bars, pinch-points, roundabouts together with road surface texture and colour
- continuous traffic calming measures, such as speed humps, along a stretch of road



Well-designed speed humps are an effective means of slowing down traffic.



Stray cattle are a traffic safety menace in some countries.



Road safety education for school children - an important awareness raising tool.

Speed humps are one of the most effective localised traffic calming measures, but require precision in design and construction to achieve a comfortable ride when traversed at the desired speeds but uncomfortable to drivers exceeding this speed.

Rumble strips in combination with traffic signs and/or speed humps, as appropriate, are traffic calming devices used to gradually reduce high speed before a dangerous spot. Community acceptance is very important for successful implementation of traffic calming devices.

The use of physical roadway design to enforce speed limits, such as narrowed lane width, can also be employed. This, however, has to be balanced by the need for passing opportunities, which is generally determined by the traffic mix. Visual narrowing of the roadway can have the same effect on speed as physical narrowing and can be achieved by using edge lines or omitting centre lines.

### Animals

Many rural communities graze farm animals such as cows and goats on road-side vegetation. Ideally such animals should be tethered or supervised. This can be encouraged by providing community education programmes.

Domestic pets and wild animals can also pose a hazard for road users. In some SADC countries, fencing is used and can be effective if well maintained but the high cost means that it is seldom used along LVSRs. Often when fences *are* erected, gates are left open and gaps appear due to theft and vandalism, which rapidly reduces their effectiveness.

### Street Lighting

This can help visibility and safety but is expensive and generally unaffordable in the context of LVSR. There might, however, be situations where street lighting of the road can be considered, for instance, when passing built-up areas, schools, hospitals and busy intersections.

## 4.5.2 Education and Enforcement

### Education

Road safety education (RSE) is an important tool to raise awareness of problems and behaviours related to traffic and road safety. It involves teaching children, and often adults, to be safer road users. It does so by developing:

- knowledge and understanding of road traffic
- behavioural skills necessary to survive in the presence of road traffic
- an understanding of their own responsibilities for keeping themselves safe
- knowledge of the causes and consequences of road accidents
- a responsible attitude to their own safety and to the safety of others

RSE should be provided during formal schooling by trained teachers who are provided with suitable resource materials. However, it should also be recognised that not all children attend school and that many adults have never received any proper road safety education. This can be overcome by providing community road safety education programmes in addition to formal teaching in schools. Where literacy rates are low, special teaching methods can be used (e.g. drama, singing and dance) while road safety education can be incorporated into other curriculum topics (such as science and geography). RSE needs to be relevant, practical (participatory) and regular and aimed at the child's level of education and social development. In some situations the children themselves can be used to educate either their parents or other children.

Road safety publicity campaigns can also raise the awareness of problems and behaviour in addition to improving knowledge, shaping attitudes and behaviours, as well as stimulating discussion and debate. These publicity campaigns can include local drama performances in which tribal languages are used in order to reach illiterate persons. Community workshops, radio, television and cinema can also be successfully used.



*Road safety awareness campaign in progress.*

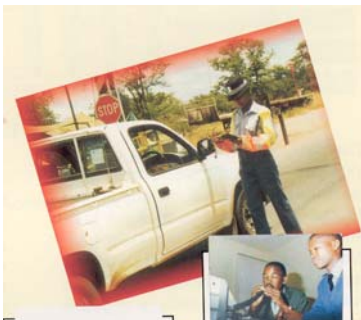
#### Box 4.6 – Examples of innovative road safety initiatives

In Swaziland community involvement has been used to solve road safety problems. A project was recently launched whereby children were employed to control stray animals on rural roads during critical times of the year (e.g. during the Easter holidays.) The community was also mobilised to erect roadside fences. The road authorities provided the materials for construction. Once erected, the community became involved in the maintenance of the fences on an on-going basis which provided a valuable source of employment for them.

### Enforcement

Traffic law enforcement is meant to achieve the safe and efficient movement of all road users including non-motorised traffic and pedestrians. In this regard, enforcement of traffic rules (such as speed limits, stop signs and rules at pedestrian crossing facilities) can be used to significantly improve road user behaviour and safety.

Unfortunately, because of a severe shortage of trained traffic police, traffic law enforcement is inadequate. As a result, drivers tend to disregard regulations and a general disregard for traffic law often gradually becomes the norm. This situation highlights the need to promote traffic law enforcement more vigorously, including the use of well mounted campaigns which, ideally, should be accompanied by education and publicity. The objective should be to improve the behaviour (and safety) of the majority of road users, rather than to simply 'catch' (and punish) a few. Moreover, such strategies should not be used as a simple means of raising money - but to improve safety.



*Enforcement is an essential component for improving road safety.*

## 4.6 Summary

The key points raised in this chapter are:

1. The functionality and characteristics of the LVSR network in the SADC region are quite different from those in industrialised countries. Traffic operations tend to be complex, comprising a mixture of both motorised and non-motorised traffic and there is often a relatively high proportion of commercial vehicles.
2. There are no geometric design standards for LVSRs in any SADC country based on in-country research into economic and safety factors. National standards are generally based on adaptations of those developed in industrialised countries and often do not cater for the characteristics of the road environment.
3. No single design guide or manual can be recommended for use as they are based on different philosophies and make different assumptions or use different criteria for developing design values for the various geometric design elements.
4. It is essential for the designer to have a thorough understanding of the underlying criteria and assumptions that have influenced the development of existing design guides or manuals as a basis for adapting them, where necessary, to suit the local road environment.
5. Road safety is a major problem with accident rates being some of the highest in the world. There is an overriding need to incorporate road safety measures in the geometric design process. Road safety audits should be introduced as part of the road design process in all countries.
6. Road safety education and enforcement are key factors which can have a major influence on road safety and should be given high priority in order to promote a road safety “culture” for all ages of road users.

This chapter has reviewed established and more recent approaches to geometric design, particularly in the context of road safety. The need for adopting appropriate standards has been stressed and the scope for improving the appalling road safety situation highlighted. Design standards will have an impact on pavement design and road surfacing - subjects that are covered in Chapter 5.

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