Islamic Republic of Afghanistan

Ministry of Rural Rehabilitation and Development

Low Volume Rural Roads
Guideline and Standards

Volume 2
Geometric Design and Road Safety

July 2020

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Foreword

This Geometric Design and Road Safety Guideline for Low Volume Rural Roads (LVRR) applies to Tertiary Roads and minor Secondary Roads. The effective management of this important component of the classified road network in Afghanistan depends to a great extent on the adoption of appropriate and cost-effective standards and road safety measures that meet the needs of road users at minimum life-cycle costs.

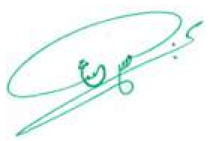
The main purpose of the Guideline is to provide all practitioners with comprehensive guidance on the wide range of factors that need to be addressed in a holistic and environmentally sustainable manner when undertaking the geometric design of rural roads, including the provision of road safety measures. The Guideline takes account of best practice developments in low volume roads technology that have evolved both regionally and internationally in the past few decades. In so doing, it retains those aspects of the existing MRRD documents that are relevant to LVRRs and addresses the gaps that have been identified from their evaluation to produce a new self-standing Guideline that will replace the current guidelines.

The Ministry of Rural Rehabilitation and Development (MRRD) expects all practitioners in the roads sector to adhere to the standards set out in the Guideline. This will ensure that a consistent, harmonized approach is followed in the design of low volume roads in the country.

The development of the Guideline was overseen by a Technical Steering Committee comprising representatives from MRRD. By its very nature, the Guideline will require periodic updating to take account of the dynamic developments in low volume roads technology. MRRD would, therefore, welcome comments and suggestions from any stakeholders as feedback on all aspects of the Guideline during its implementation. All feedback will be carefully considered by professionals and experts in future updates of the Guideline.

On behalf of the Road Development Agency, I would like to thank UK Aid through the United Kingdom Department for International Development (DFID) for its support of the development of the Guideline. I would also like to thank the Project Management Unit (PMU) of the Research for Community Access Partnership (ReCAP) and Infra Africa Development Consultants for their role in managing the project. In addition, I would commend all the road sector stakeholders who contributed their time, knowledge and effort during the development of the Guideline.

It is my sincere hope that this Guideline will herald a new era in the more efficient and cost-effective provision of low volume roads in Afghanistan. In so doing, it will make a substantial contribution to the improved infrastructure of our country and, in the process, enhance socio-economic growth and development, particularly in the rural areas of the country.



Assistant Professor, Mujeeb Rahman Karimi
Minister, Ministry of Rural Rehabilitation and Development (MRRD)

Acknowledgments

The Ministry of Rural Rehabilitation and Development (MRRD) wishes to acknowledge the support that was provided by the United Kingdom Department for International Development (DfID) for the preparation of the Geometric Design and Road Safety Guideline for Low Volume Rural Roads. The project was carried out under the aegis of the Research for Community Access Partnership (ReCAP) – a DFID-funded research program that promotes safe and sustainable access for rural communities in Africa and Asia.

The development of the Guideline was guided by a Technical Steering Committee comprising the following representatives from the MRRD:

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The project was managed by Cardno Emerging Markets, UK, and was carried out under the general guidance of the AsCAP Asia Technical Manager, Maysam Abedin. From the MRRD side, the project was coordinated by the Director, Regional Programmes, Baryalai Helali.

The Guideline was developed by the following team of consultants led by Infra Africa (Pty) Ltd, Botswana.

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Director, Regional Program
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List of Abbreviations, Acronyms and Initialisms

AADT	Average Annual Daily Traffic
ADT	Average Daily Traffic
ARRB	Australian Road Research Board
BVC	Beginning Vertical Curve
CE	Car Equivalent
CEF	Car Equivalency Factor
CSD	Context-Sensitive Design
CSIR	Council for Scientific and Industrial Research
DFID	Department for International Development
DSD	Decision Sight Distance
EDD	Extended Design Domain
EF	Equivalence Factor
EVC	End Vertical Curve
GDP	Gross Domestic Product
GoIRA	Government of the Islamic Republic of Afghanistan
GPS	Global Positioning System
HGV	Heavy Goods Vehicle
HVR	High Volume Roads
iRAP	International Road Assessment Programme
ITE	Institute of Transportation Engineers
LBM	Labor-based Methods
LED	Light-emitting diode
LCC	Life-cycle Cost
LGV	Light Goods Vehicle
LVRR	Low Volume Rural Road
LVSR	Low Volume Sealed Road
MAP	Mean Annual Precipitation
MESA	Million Equivalent Standard Axles
MGV	Medium Goods Vehicle
MRRD	Ministry of Rural Rehabilitation and Development
NDD	Normal Design Domain
NMT	Non-motorized Traffic
NPV	Net Present Value
O-D	Origin - Destination
ORN	Overseas Road Note
PCU	Passenger Car Units (CE units)
PSD	Passing Sight Distance
PVI	Point of Vertical Intercept/Inflection

RSA	Road Safety Audit
RSI	Road Safety Inspection
SE	Superelevation
SSD	Stopping Sight Distance
SU	Single Unit Truck
TIA	Traffic Impact Assessment
TLC	Traffic Load Class
TRL	Transport Research Laboratory
TSC	Technical Steering Committee
UK	United Kingdom
UKAID	UK Department for International Development
USA	United States of America
VEF	Vehicle Equivalence Factor
VHGV	Very Heavy Goods Vehicle
VOC	Vehicle Operating Costs
VPI	Vertical Point of Intercept/Inflection

Terminology

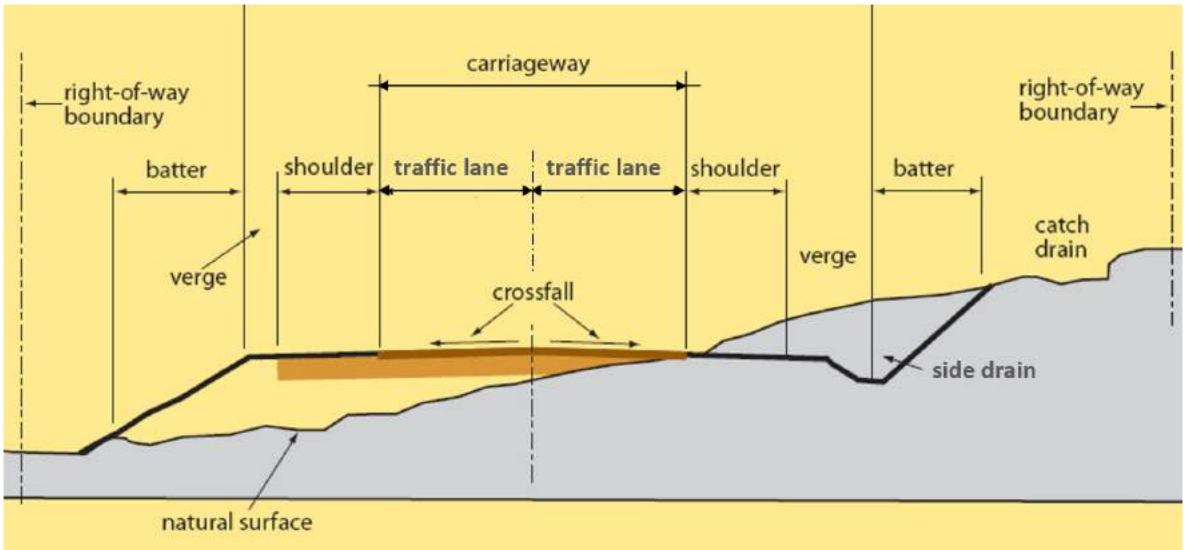

Figure 1: Road Cross Section

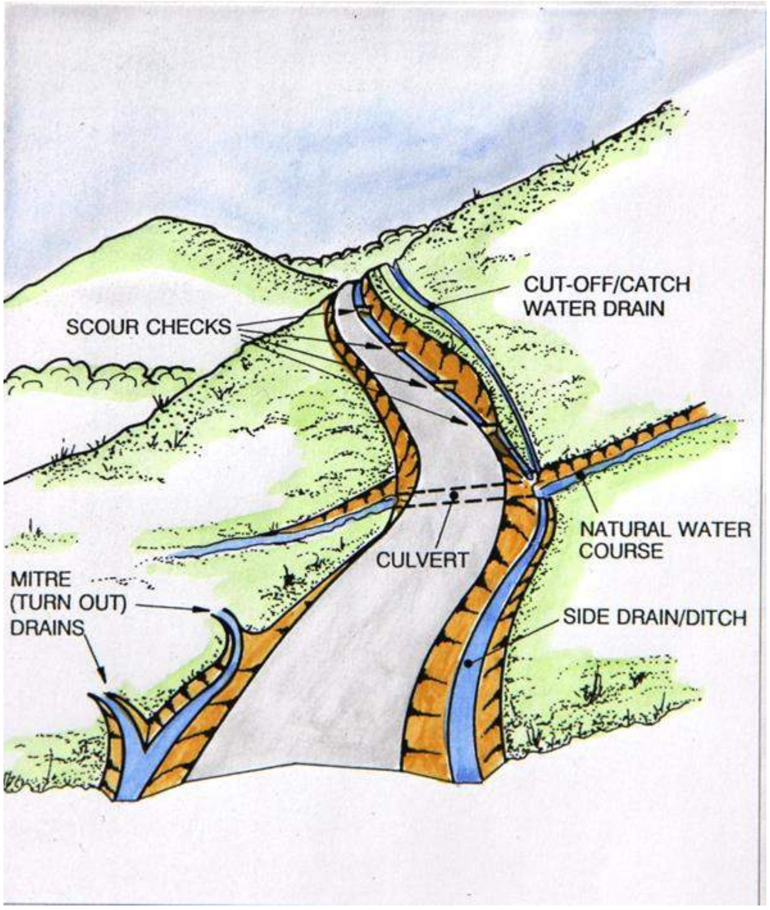

Figure 2: Main drainage elements

Part A

Geometric Design

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Low Volume Rural Roads Guideline and Standards
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1.1 Background

As a landlocked mountainous country, Afghanistan depends mainly on road transport, which serves as the backbone of the development of the country. In this context, the Government of the Islamic Republic of Afghanistan faces a massive challenge in fulfilling one of its key developmental goals – reducing poverty in the rural areas of the country by facilitating improved access to economic and social services for rural communities.

Low volume rural roads (LVRRs) compromise a substantial proportion of Afghanistan's classified road network, approximately 85%, and are viewed by the Government as a key driver for improving rural well-being, economic development and food security for the majority of Afghans (> 70%) who live in the rural areas of the country. The attainment of this goal depends critically on the existence of sound rural road infrastructure. It is therefore important that the Ministry of Rural Rehabilitation and Development (MRRD) adopts appropriate, economical design standards and practices that are tailored to the diverse physical environment of the country.

There are currently a number of technical manuals used for the planning and design of LVRRs in Afghanistan. However, in a number of aspects, they do not reflect the latest developments in LVRR technology. This has led to a need to develop new Guidelines and Standards for LVRRs that are tailored to the needs of the country and take account of the many advances in LVRR technology that have taken place in recent times in the Asian region and internationally.

1.2 Purpose

The main purpose of the Guideline is to provide practitioners with the necessary guidance for undertaking a holistic, rational, appropriate, affordable and sustainable approach to the provision of both unpaved and paved LVRRs in Afghanistan.

The focus of the Guideline is on the provision of low-cost solutions for the design of LVRRs. Such roads typically have traffic levels below 400 vpd vehicles per day and include all those classified as Tertiary Roads and some of those classified as Secondary Roads.

Figure 1-1: Typical LVRR in Afghanistan

The design of the LVRRs is aimed at minimizing the life-cycle costs of their provision by taking account of the many locally prevailing road environment factors that impact on the design process. In so doing, the developmental goal is to:

- enhance socio-economic growth, development and poverty alleviation in rural areas;
- improve connectivity of all villages to each other and to main roads and urban centers;
- improve access to basic services, such as markets, health care and education centers;
- provide reliable, lower-cost movement of people and goods from rural to urban areas;
- reduce the depletion of finite materials resources.

The Guideline draws on the outputs of a number of research and investigation projects that have been carried out in the region and internationally since the 1990s. The corroborative findings of this research provide a wealth of performance-based information that has advanced previous knowledge on various aspects of LVRR technology. This has allowed state-of-the-art guidance to be provided in the Guideline, which is expected to serve as a nationally recognized document, the application of which will harmonize approaches to the provision of LVRRs in Afghanistan. The Guideline is intended for use by all road agencies and organizations in the country's roads sector.

1.3 Scope

The Guideline highlights the approach to the geometric design of low volume rural access roads in terms of a number of factors that differ significantly from higher volume mobility roads. The fundamental design parameters that influence the development of an appropriate design solution are then addressed as a basis for selecting appropriate design standards in terms of cross section and horizontal and vertical alignment considerations as well as road safety. The thrust of the approach has been to develop a design methodology that emphasizes the economic aspects of geometric design for LVRRs.

1.4 Development

The development of the Guideline was overseen by a Technical Steering Committee (TSC) comprising seven members of the MRRD, covering a range of disciplines within the organization.

As a result of the high level of local participation in the development of the Guideline, it has been possible to capture and incorporate a significant amount of local knowledge in the document.

1.5 Structure

Part A of the Guideline is divided into two sections, as shown in Table 1-1.

Table 1-1: Structure

Section	Chapter
1. Introduction	1. Overview 2. Approach to Design
2. Design	3. Route Selection and Design Considerations 4. Traffic 5. Cross Section 6. Alignment 7. Design Standards

1.6 Benefits of Using the Guideline

There are several benefits to be derived from adopting the approaches advocated in the Guideline. These include providing LVRRs that:

- Are less expensive, in economic terms, to build and to maintain through the adoption of more appropriate LVRR technology including geometric design standards that are better suited to local conditions.
- Incorporate road safety measures to minimize road accidents.
- Take a better account of the needs of all stakeholders, particularly the local communities served by such roads.
- Ultimately, facilitate the longer-term goal of socio-economic growth, development and poverty alleviation in Afghanistan.

1.7 Sources of Information

In addition to providing general information and guidance, the Guideline also serves as a valuable source document because of its comprehensive lists of references from which readers can obtain more detailed information to meet their particular needs. A bibliography can be found at the end of each chapter of the Guideline. Where the sources of any tables or figures are not specifically indicated, they are attributed to the authors.

1.8 Updating of the Guideline

As LVRR technology is continually being researched and improved, it will be necessary to update the Guideline periodically to reflect improvements in practice. All suggestions to improve the Guideline should be in accordance with the following procedures:

- Any proposed amendments should be sent to the Regional Director, MRRD, motivating the need for the change and indicating the proposed amendment.
- Any agreed changes to the Guideline will be approved by the Regional Director, MRRD, after which all stakeholders will be advised accordingly.

1.9 Departure from Standards

There may be situations where the designer will be compelled to deviate from the standards presented in this Guideline. Where the designer departs from a standard, he/she must obtain written approval and authorization from the MRRD. The designer shall submit the following information to the Regional Director, MRRD:

- The aspect of design for which a Departure from Standards is desired.
- A description of the standard, including the normal value, and the value of the Departure from Standards.
- The reason for the Departure from Standards.
- Any mitigation to be applied in the interests of reducing the risk of road accidents.

The designer must submit all major and minor Departures from the Standards and his/her proposal for approval. If the proposed Departures from the Standards are acceptable, such departures will be given approval by the Regional Director, MRRD.

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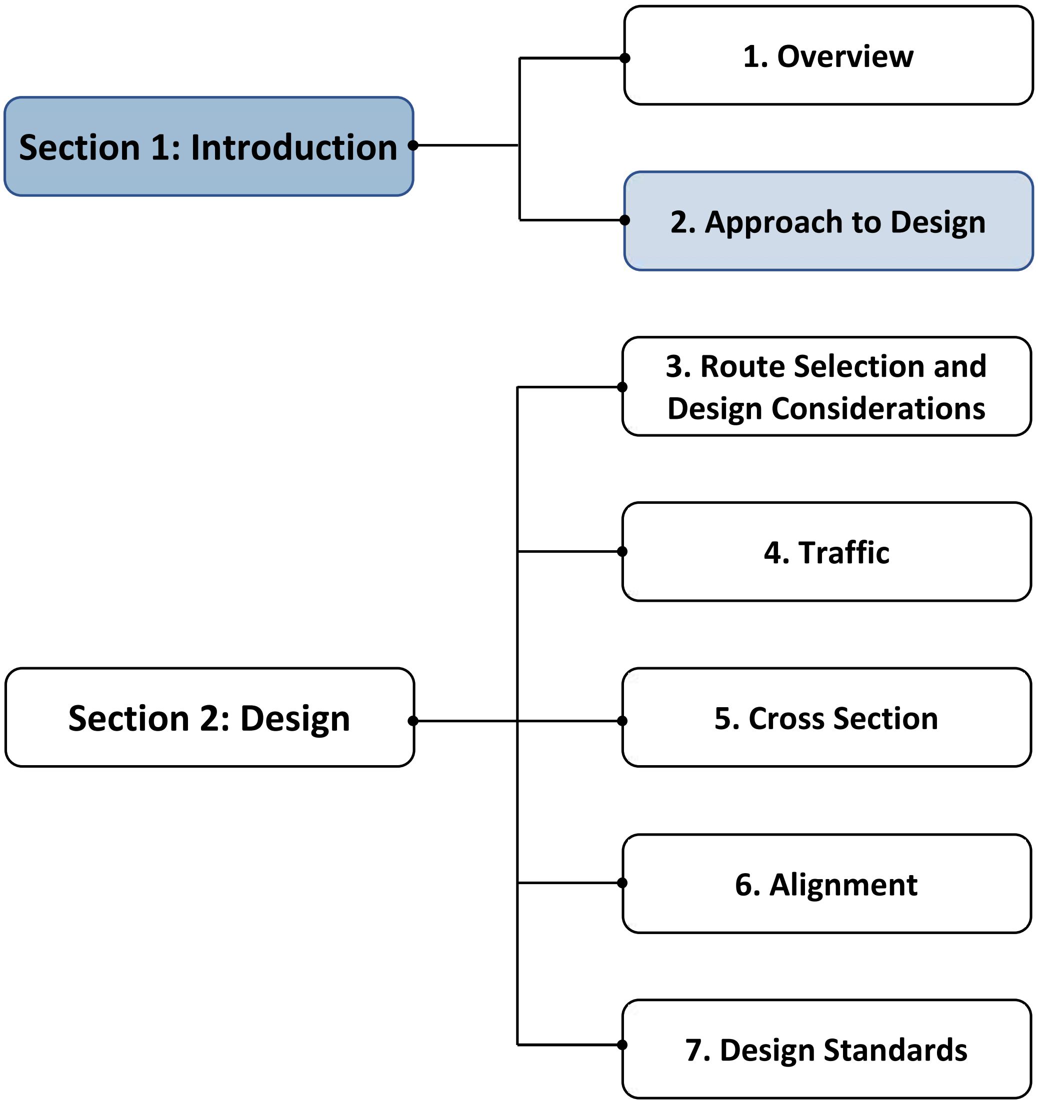
Low Volume Rural Roads Guideline and Standards
Volume 2: Part A – Geometric Design



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2.1 Introduction

2.1.1 Background

Conventional highway geometric design relates to increasing standards to increasing speed, the volume of traffic, and user comfort and convenience, which has led to relatively high-cost solutions. The application of these standards on Low Volume Rural Roads (LVRRs) cannot be justified since the costs would far exceed the commensurate benefits. Thus, a more holistic approach needs to be taken in which the over-riding criterion of acceptability is the achievement of an appropriate level of all-year access to communities at "least cost" (in terms of total life-cycle costs), while at the same time ensuring the LVRRs are "fit for purpose" in terms of user requirements and road safety.

2.1.2 Purpose and Scope

The main purpose of this chapter is to outline the approach for the design of LVRRs in a manner that is context-sensitive, and that emphasizes the economic aspects of geometric design whilst taking due account of the road safety aspects. Flexibility in the application of the guidance given in this chapter is encouraged so that independent designs tailored to particular situations can be developed.

The chapter firstly presents the definition and classification system used in the Guideline. This is then followed by an overview of the Context Sensitive Design (CSD) concept and the application of this concept in terms of a number of design considerations that influence the geometric design process. Finally, an elaboration of the CSD concept is presented in Appendix A whilst a generic Table of Contents for a design report is presented in Appendix B.

2.2 Definition of a Low Volume Rural Road

For pavement design purposes LVRRs are defined as those roads that have a base year average daily traffic (ADT) of up to about 300 motorized, 4-wheeled vehicles, including about 20-25% commercial vehicles, and a related cumulative traffic loading of up to about one million Equivalent Standard Axles (MESA) per lane over a design life of typically 10 – 15 years. Therefore, depending on the number and mass of the commercial vehicles in the traffic stream, the base year traffic for pavement design purposes could be somewhat more or less than 300 vpd for the same traffic loading. For geometric design purposes, however, the traffic at mid-life is required and this could exceed 300 motor vehicles per day.

However, none of these figures provide a complete picture of the unique characteristics of LVRRs in that there are many other aspects that need to be considered in their design as discussed below.

2.3 Road Classification System

2.3.1 General

Afghanistan's road network comprises various types of rural and urban roads, each of which fulfills a particular function in facilitating vehicular travel between points of origin and destination as well as providing access to property. The classification of the network is essential for a variety of purposes, including policy and planning activities, and entails an orderly grouping of roads into a set of sub-systems according to the type of service they are intended to provide to the public.

2.3.2 Road Classes and Functions

A schematic diagram of the various road classifications is illustrated in Figure 2-1. The diagram illustrates the relative function of the road classifications in terms of primary, secondary and tertiary roads. This is a generic diagram and, in practice, there will be many overlaps of function and clear distinctions may not always be apparent in functional terms alone. This hierarchy should not be confused with the division of administrative responsibilities which may be based on other criteria.

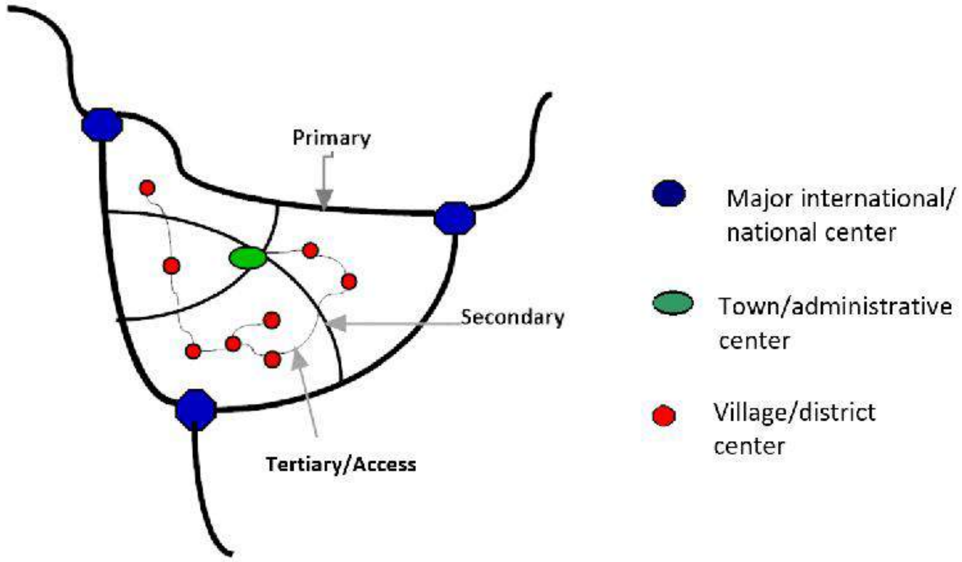

Figure 2-1: Road Classes and Functions

The key objective of a well-conceived classification system is to facilitate road user accessibility to all parts of the road network, thereby improving transport efficiency and, in turn, improving, sustaining and supporting social and economic growth and development. In this regard, Afghanistan's roads have been classified on the basis of their function, i.e., the purpose or the character of the service that they are intended to provide in terms of connecting different centers of population and economic activity. The following classes of roads have been defined in relation to whether they serve a primarily *mobility* or *access* function, as shown in Table 2-1.

Table 2-1: Road Classification System

Basic Function	Road Class		Road Definition	Level of Service
Mobility	Primary	National highways (trunk roads)	Main highways linking all Provincial Capitals of the country	*Very.high:* Provides the highest level of service at high speed for the longest uninterrupted distance, with a minimal degree of access control. To be designed to the highest standards.
		State/Regional highways (main roads)	Highways linking the major cities or regions of the country.	
		Provincial roads	Roads which connect provinces to each other or provinces to National State highways	*High:* Provides a high level of service at relatively high speed for intermediate and long distances
Mobility / Access	Secondary	Rural	Roads that link: - Provincial capital to District capital - District capital to National or State Highways - District capital to District capital	*High/Moderate:* Provides a less highly developed level of service at relatively high speed for shorter distances.
Access	Tertiary		Roads that link: - Village to Provincial capital - Village to the Primary road network - Village to District headquarters - Village to village	*Moderate:.*Provides a moderate level of service at moderate/varying speed

The term "level of service" referred to in Table 2-1 does not indicate the capacity Levels of Service (LoS). Rather, it refers to the quality/standard of road provided, in that a high order road, such as a Primary International road, has a relatively high level of service meaning wider road reserve, wider lanes, maximum road signs, rest areas, landscaping, and so forth.

2.3.3 LVRR Classes and Functions

In terms of the type of the LVRRs being catered for in this Guideline, they will all be expected primarily to fulfill an access function. LVRRs include the following classes of roads.

1. **Secondary roads:** Only those secondary roads that comply with the definition of a LVRR as defined above and include:
   - Roads that link:
     - Provincial capital to District capital
     - District capital to National or State Highways
     - District capital to District capital
2. **Tertiary roads:** All roads that are classified as Tertiary roads and include:
   - Roads that link:
     - Village to Provincial capital
     - Village to the Primary road network
     - Village to District headquarters
     - Village to village

In view of the above, the relationship between road class and road function is presented in Figure 2-2.

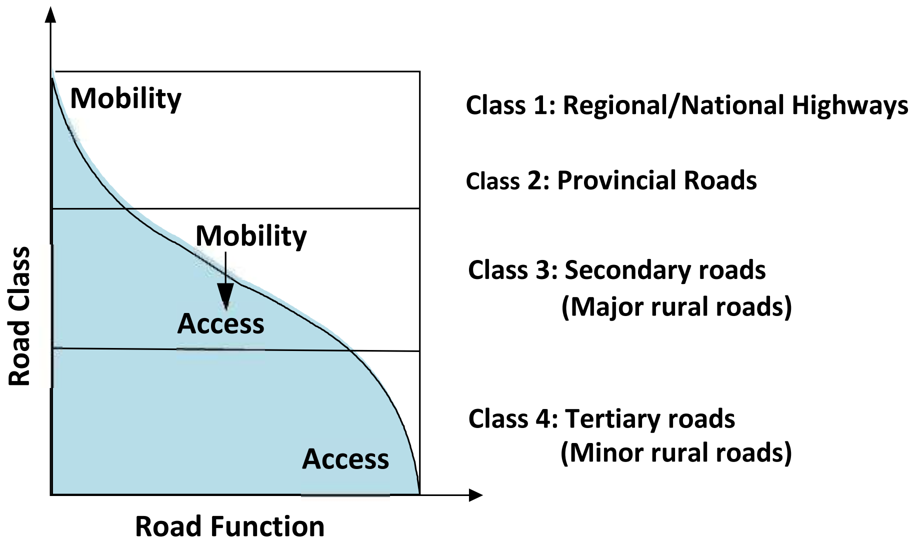

Figure 2-2: Relationship between Road Class and Road Function

Mobility roads

These relatively high-trafficked roads are designed to move traffic over relatively long distances quickly, effectively and efficiently. They are therefore higher speed through-routes on which movement is dominant, and access and pedestrian crossings are limited to defined and clearly demarcated positions at widely spaced intervals.

Access Roads

These are relatively low volume roads designed to provide access to the various properties and land served by the roads. The provision of access allows both vehicles and pedestrians entry to and from adjacent land. As such, care must be taken to keep speeds low for the safety of slow-moving pedestrians and turning traffic.

The majority of the Tertiary roads are essentially, but not necessarily, LVRRs. However, the functional class associated with different mixes of traffic can sometimes alter these generalizations (e.g., a LVRR serving a military function or merely a road serving a quarry that uses particularly large vehicles), but this is not common. Based on the functional classification system used in Afghanistan, Table 2-2 shows those classes of roads which, for geometric design purposes, may be defined as LVRRs.

Table 2-2: Classification of LVRRs - Road Design Classes

Road Design Class	AADT at Mid Design Life	Functional Class
LVRR 5	>350	Some Secondary Roads All Tertiary roads
LVRR 4	250 – 350	
LVRR 3	150 – 250	
LVRR 2	50 – 150	
LVRR 1	< 50	

This Guideline deals with the design of low volume, access-type roads only, for which the standards are quite different from those for mobility roads that generally attract more traditional design standards, which may be found, for example, in the AASHTO “Green Book” (2018).

For geometric design purposes, the mid-life ADT rather than the base year or end of life ADT, is used. This is to strike an economic balance between ensuring that the road is not significantly over-designed at the beginning of its life (by adopting an end design life traffic ADT), or under-designed at the end of its design life (by adopting a base year ADT). Thus, an LVRR with a base year ADT < 300 (in accordance with the LVRR definition) may have a mid-life ADT > 400 depending on the forecasted traffic growth, and be classified on that basis as LVRR 5. Similarly, an LVRR with base year ADT = 40 may have a mid-life ADT of 50 – 100 and be classified on that basis as LVRR 2.

2.4 Characteristics of Low Volume Rural Roads

The particular characteristics of LVRRs affecting their geometric design include the following:

- LVRRs often need to cater to high proportions of NMT, including pedestrians, bicycles and animal-drawn carts as well as motorcycle traffic, a traffic mode that has grown tremendously during the last few years in many parts of Afghanistan and often constitute the main means of public transport.
- The majority of LVRRs are relatively short in length and travel time, and therefore, speed is not a deciding factor for the required service level and associated geometric standard.
- Existing land use and adjacent properties often limit the effective cross-sectional width that can be constructed without causing major disturbances for the local population and associated costs for land acquisition and compensations.
- Most road users are familiar with the terrain and alignment of the road and will, therefore, take necessary precautions to avoid conflicts and accidents.
- LVRRs are often constructed by labor-based methods, which limits the volume of earthworks that can be constructed within reasonable costs.

In light of the above LVRR characteristics, the main concerns of the engineer are:

- To design a road that is “fit for purpose” by fitting the road into the physical environment at least cost allowing the existing alignment to fix the travel speed and variable cross section width to accommodate the prevailing traffic.
- To address potential “black spots” with properly engineered solutions such as appropriate traffic calming or road widening and lane segregation at blind crest curves.

2.5 Context-Sensitive Design

2.5.1 General

Context-Sensitive Design (CSD) provides a significant change from the traditional approach of focusing almost exclusively on mobility to an approach that balances access, safety and environmental preservation with the available funding. The approach provides flexibility to encourage independent designs tailored to particular situations, i.e., the design can deviate when necessary from accepted design criteria provided acceptable standards of safety are achieved at reduced costs. The challenge is to develop a design solution that takes account of the competing alternatives and trade-offs that might be needed, as discussed further in *Appendix.A:.Design.Domain.Concept.*

CSD recognizes that, in some cases, exceptions may be required in applying standards. For example, where the provision of an engineered alignment results in excessive earthworks, it may be preferable to accept variable travel speeds in order to reduce costs and minimize social or environmental impacts whilst paying due attention to road safety through the adoption, where necessary, of appropriate countermeasures. An example of this approach is presented below in *Section.2.6.4 – Alignment.Design.*

By applying CSD, the approach to design adopted in this Guide addresses the unique requirements, and recommends appropriate geometric design standards, for LVRRs. By so doing, it affords design engineers with the flexibility to adopt appropriate standards that are less restrictive and costly than those generally applied to HVRs. However, where there is a deviation of the normal standard for one element, it is usually required that a higher than normal standard be used for other elements to compensate (e.g., the use of a wider pavement where a crest vertical curve of a low standard must be adopted). Thus, the approach discourages unnecessary improvements to the road geometry and the roadside, except where there is site-specific evidence of safety problems where such improvements are likely to provide substantial safety benefits.

The approach outlined above should also consider the potential effects of future development that may affect the function of the road within its design life in terms of changes in traffic volumes, patterns, and operating conditions. Should such changes result in a likely reclassification of the road to a higher class outside of the LVRR range, then the standards for higher volume roads should be adopted.

2.5.2 Design and Operating Speed

Design speed is traditionally used in highway design as an index which links road function, traffic flow and terrain to the design parameters of sight distance and curvature to ensure that a driver is presented with a reasonably consistent speed environment and not faced by 'surprises'. However, the uniform design speed concept should be reconsidered as a basis for the design of LVRR for two reasons:

1) Low volume access roads are distinctly different from higher volume mobility roads, for which higher design and operating speeds are justified.
2) Applying uniform design speeds to LVRR designs to obtain a consistent speed environment will inevitably lead to increased earthworks, acquisition of adjacent land and properties for adjustment or horizontal and vertical alignment, and consequently higher project costs.

Operating speed on LVRRs will, therefore, normally be variable and dictated by the terrain, existing alignment (in case of upgrading) and roadside developments, always accepting the principle of not surprising the driver. Normally LVRRs will accommodate variable operating speeds up to 80 km/h, but some access roads have long open stretches traversing easy terrain where it may be feasible and desirable to allow for higher speeds without incurring unjustifiable costs, in which case traditional highway standards may be more appropriate.

Chapter 2 – Approach to Design

2.5.3 Road Width and Traffic Safety

In addition to such factors as traffic composition and travel speed, topography/terrain and nature of the roadside development, the number of conflicts (vehicles passing in either direction) on a LVRR is a key determinant of carriageway width. Table 2-3 shows the average daily and an hourly number of interactions/km and the average time between interactions/km based on a 12-hour traveling day.

Table 2-3: Indicative Conflicts/km and Average Time between Conflicts/km on LVRRs

AADT	300		100		300	100
Speed (km/h)	Avg. Interactions/km		Avg. Interactions/km		Average time between Interactions/km	Average time between Interactions/km
	Per Day	Per Hour	Per Day	Per Hour		
40	46	3.8	5.0	0.4	16 min	2 hr 21 min
60	31	2.6	3.5	0.3	23 min	3 hr 30 min
80	23	1.9	2.5	0.2	31 min	4 hr 39 min

As indicated in Table 2-3, even on roads with 300 vpd, the number of interactions/km/hr is very low and considerable periods of time elapse between potentially hazardous meeting situations. It is also apparent from observation that on LVRRs, vehicles tend to travel toward the center of the road even with a road width of 6.0 m which, in principle, allows for segregated lane traffic. With this width, the outer wheel path is usually not clearly defined, but will typically be ≥ 1.0 m from the edge of the road.

In view of the above, it can be concluded that for most of the time and at all traffic levels, LVRRs as defined above, are effectively operating as single-lane roads and that this feature can be used to ensure satisfactory levels of service and safety for all road users without resorting to unnecessarily generous and costly standards. A consequence of this is that normal shoulders or additional width to accommodate NMT in a low-speed environment can be omitted except in particularly busy areas within villages, trading areas, etc. This would contribute to keeping the construction costs at affordable levels. On this basis, the recommended carriageway widths for five different basic geometric standards (LVRR 1 – LVRR 5) are presented in *Chapter.5 – Cross.Sections.*

The safe and comfortable accommodation of road users is closely related to the width of the carriageway and the traveling speed of motorized traffic. At high vehicle speeds, more space is needed for other road users to feel safe. Conversely, wide roads tend to encourage high speeds, thereby reducing the level of road safety, both real and perceived. Speed is universally recognized as being closely related to the risk of road accidents; hence the LVRR design must aim at keeping traveling speeds relatively low.

The typical traffic situations on a LVRR 4 road with less than 400 vpd and a low percentage of heavy traffic – typically up to about 25% – are illustrated in Figure 2-3 to Figure 2-5. With these low traffic volumes, vehicles tend to travel towards the middle of the road leaving space for pedestrians and motorcycle/cyclists on either side.

Figure 2-3: Typical Traffic Situation (LVRR 4 Standard - schematic)

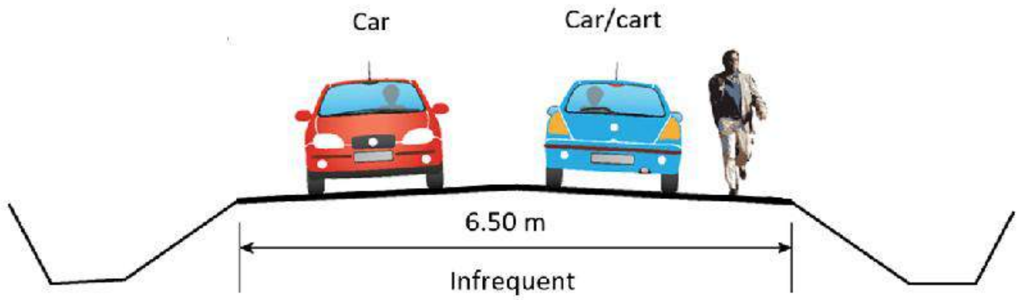

Figure 2-4: Infrequent Traffic Occurrence (LVRR 4 Standard - schematic)

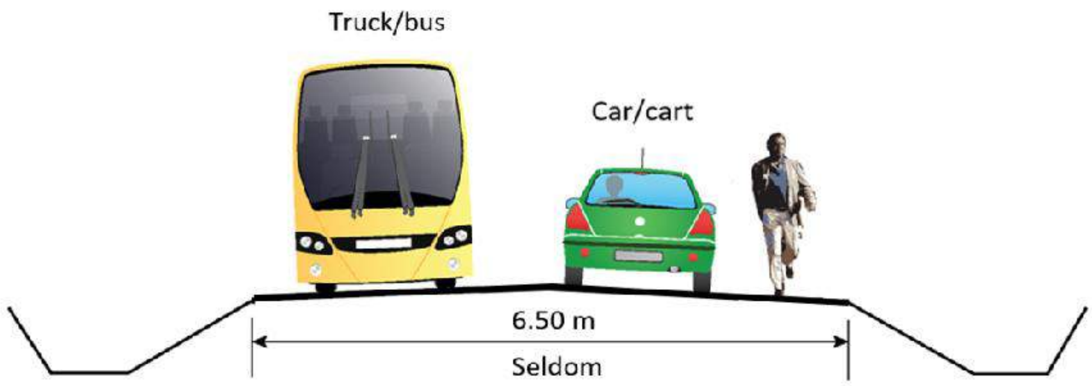

Figure 2-5: Very Infrequent Traffic Occurrence (LVRR 4 Standard - schematic)

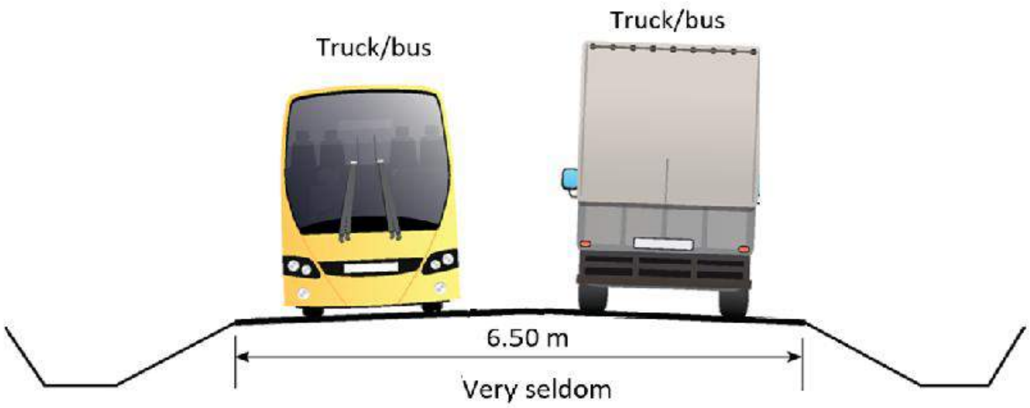

Figure 2-6: Rare Traffic Occurrence (LVRR 4 Standard - schematic)

2.5.4 Alignment Design

There are essentially two types of projects that will be faced by the geometric designer, namely:

1) **Brownfield site:** Is a project site where a road already exists and may influence the geometric design to the extent that the use of normal design approaches may not be economically justified.
2) **Greenfield site:** Is a project site where a new road or section of a road is to be constructed where none existed before.

Designing an alignment for an entirely new road where no road existed before is a considerably more complex process than merely upgrading an existing road because of the many different route alignments that are possible and the relative lack of information available at the beginning of the process. In many cases, a pre-feasibility study may be required to identify possible corridors for the road and to decide whether the project is likely to be viable.

In view of the above, a careful balance needs to be struck between the cost of improving the existing alignment, both horizontally and vertically, or widening the road, with the benefits to be derived from so doing. This requires an approach that emphasizes the economic aspects of geometric design and which needs to be applied with an appropriate understanding of economic analysis.

There are two main options that may be considered for the design of an LVRR alignment as follows:

Option A – Alignment engineered for fulfilling an access function

This option adopts most of the existing alignment except in problem areas where safety may be an issue and is applicable to most, if not all, of the Tertiary roads and those Secondary roads that comply with the definition of an LVRR.

The use of this option means that, to a large extent, "the existing alignment fixes the travel speed". It will result in variable cross section widths (because the width of most of the existing road need not be changed) and travel speeds but will not incur significant earthworks costs. This option is appropriate in situations where:

- The road is unlikely to change its function over its design life.
- The road is likely to be used mostly by local people and seldom by other users who are not familiar with the characteristics of the alignment.
- Problem areas such as very tight curves, steep grades or other potentially black spots are addressed by sound engineering solutions such as curve widening, lane widening and demarcation, and use of appropriate traffic calming measures.

In many cases, based on the least cost criterion discussed above, Option A is the most economical standard in that it will result in an alignment that is "fit for purpose" and provide an appropriate level of access at minimum costs. However, the adoption of this option will require some good engineering judgment to be exercised by a design engineer with experience in LVRR design.

The adoption of Option A is supported by research findings, which have shown that:

- In terms of geometry, drivers will choose lower speeds on roads that have rough surfaces, are narrow, winding or hilly, and where the direction of the road and the lane boundaries are not well delineated.
- The roadside environment and objects next to the road can also affect speed. Multiple objects next to the road can increase peripheral visual flow and therefore increase perceived speed, which will lead to reduced actual speed.
- Drivers will also slow down if they feel they are too close to objects on the side of the road e.g., pedestrians and cyclists, and they feel they are unable to move away.
- Drivers choose lower speeds on roads with multiple access points to prepare for the possible entry of other vehicles and in visually complex environments in order to process the higher levels of visual information.

The adoption of Option A should be coupled with the following measures:

- Installation of traffic calming measures where required, particularly in areas with a high incidence of non-motorized traffic (NMT), e.g., speed humps, rumble strips, warning and speed limit signs, etc.
- Fully engineered solutions at potentially hazardous spots that can be achieved within reasonable costs (e.g., road widening/lane separation over sharp crests, alignment improvement to straighten out blind curves).
- Adequate advance warning to drivers and speed-reducing measures where potentially hazardous situations cannot be avoided without incurring prohibitive costs.
- Varying road carriageway width dictated by the amount and mix of traffic and terrain.

Option B – Alignment engineered for fulfilling a mobility function

A fully engineered alignment is one in which the design speed, in most cases, determines the alignment. This option uses a consistent cross-section width throughout and a fixed design speed that determines many of the geometric requirements such as passing and stopping sight distances, engineered curvature, both horizontally and vertically, etc. These are the design principles and specifications contained in *Chapter.7 – Design.Standards,* which should be used when Option A is not appropriate.

Whenever an entirely new road is to be designed and constructed on a greenfield site, it is most likely to be in the higher road classes and Option B is then the natural choice, but elements of Option A could still be applied.

The same principle as applied above for the design of the horizontal alignment of an LVRR also applies to the vertical alignment, except where there is site-specific evidence of safety problems for which appropriate countermeasures can be put in place. For example, where sight distances do not comply with those specified for HVRs, mitigating countermeasures should be considered, such as road widening, center line marking and, where feasible, lane separation at the approach to the vertical curve rather than embarking on earthworks to flatten the crest curve.

2.5.5 Selection of Design Standards

A geometric standard represents a service level that is deemed appropriate for the particular road environment. Typically, this service level increases with traffic and is relatively high for major, highly trafficked roads and has a clear connection with transport efficiency and economic benefits. For LVRRs the benefits of a high service level are less tangible in economic terms and, as a result, a compromise has to be reached between service level and costs in relation to the selected standard. The approach for doing so is based on the CSD concept, as described above, and elaborated on in Appendix A.

There are essentially two types of standards considered in this Guide, as follows:

(1) Those related to an Option A alignment design that adopts lower-than-normal design standards, as applied to paved and unpaved roads with an ADT less than 400 vpd at mid-life, i.e., road design classes LVRR 1 to LVRR 4. These standards would generally be applied in cases where it is impractical to meet the normally applied standards, often because of extremely severe terrain conditions. Under such circumstances, the standards must be relaxed, but not at the expense of road safety for which compensatory countermeasures would be required, including traffic calming measures and road signage and markings.

(2) Those related to an Option B alignment design that adopts normally applied design standards as applied to paved and unpaved roads with an ADT more than 400 vpd at mid-life, i.e., road design class LVRR 5. These standards are modified for different terrain types with optional inclusion of shoulders based on either a high number of motorcycles and NMTs and/or a high proportion of heavy vehicles. Thus, the designer has a wide range of standards from which to choose, ensuring that a suitable standard is available for almost all situations (see *Chapter.7 – Design.Standards*).

Ideally, the adoption of either an Option A or an Option B alignment should be made on the basis of a life-cycle cost analysis, as presented in the *Pavement.Design Guide,.Chapter.12 – Life-Cycle Costing.* However, in practice, the data for undertaking such an analysis is seldom available and, instead, recourse will need to be made to sound engineering judgment.

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Appendix A: Design Domain Concept

The Design Domain concept has been developed internationally as a for the design of upgrading projects, particularly for LVRRs, where it will be uneconomical to conform to the normal Design Domain applied for new roads. It places emphasis on developing appropriate and cost-effective designs rather than providing a design that simply meets "standards". It recognizes that there is a range of values that 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 performance in average conditions of safety, operation and economic and environmental consequences. Figure A-1 illustrates this concept.

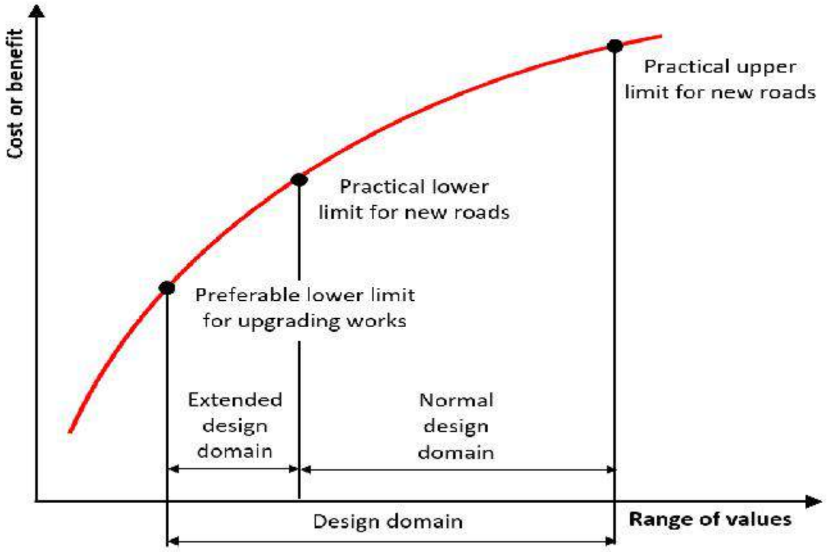


Figure A-1: The design domain concept
Source: Cox and Arndt (2006)

As illustrated in Figure A-1, the Design Domain comprises a Normal Design Domain (NDD) and an Extended Design Domain (EDD). The NDD defines the normal limits for the values of the parameters that have traditionally been selected for new roads. In this domain, the resulting designs are generally safer and more efficient in operation, but may cost more to construct. In contrast, the EDD concept uses values to a limited extent outside those in the NDD range and would generally be considered less safe or less efficient, but usually less expensive than those in the NDD. However, in the context of LVRRs, with relatively few head-on meetings per day (see Table 2-3), this approach can generally be justified and defended on engineering and economic grounds and operating experience.

The decision on the design values to adopt in the EDD should be made using objective data on the changes in cost, safety and levels of service caused by changes in the design, together with benefit-cost analysis. Such data may not always be available for LVRRs, particularly data that relates changes in the values associated with specific design elements and parameters to safety performance. In such a situation, designers should use sound engineering judgment to qualitatively assess the potential effects of changes for the various design elements involved.

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 on those which simply meet 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; and

- 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.

As a general principle, values in the upper part of the Design Domain should be selected when:

- designing new roads, particularly those in greenfield sites;
- designing roads with relatively high volumes of traffic;
- little additional cost is involved in the use of these values, and
- a significant accident history exists at a particular location.

In contrast to the above, values in the lower part of the Design Domain, i.e., in the Extended Design Domain, should be selected when:

- upgrading existing roads, particularly those on brownfield sites;
- designing roads with relatively low volumes of traffic;
- financial or physical constraints exist, and
- no significant accident history exists at a particular location.

Figure A-2 illustrates how the Design Domain concept might be applied to a single design parameter, for example, shoulder width. In practice, a value for shoulder width might be chosen that optimizes the balance between costs and safety. Selection of a value within the domain will depend on a trade-off between various costs and benefits. To a large extent, the Design Domain concept formalizes the approach adopted in this Guide to design the various elements of a LVRR where the use of fixed standards often cannot be justified on the basis of a benefit-cost analysis.

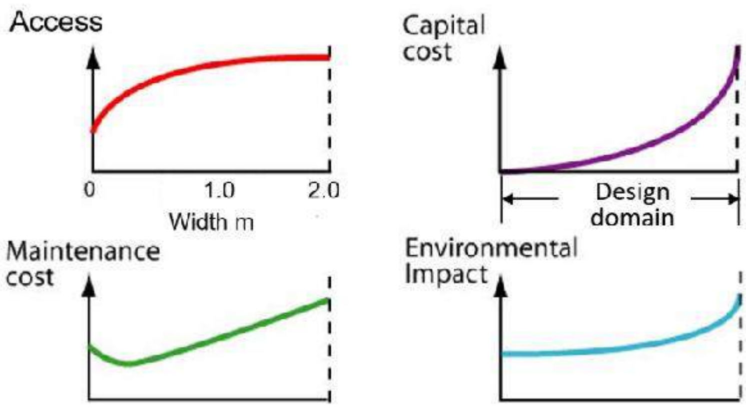


Figure A-2: Example of design domain application - shoulder width

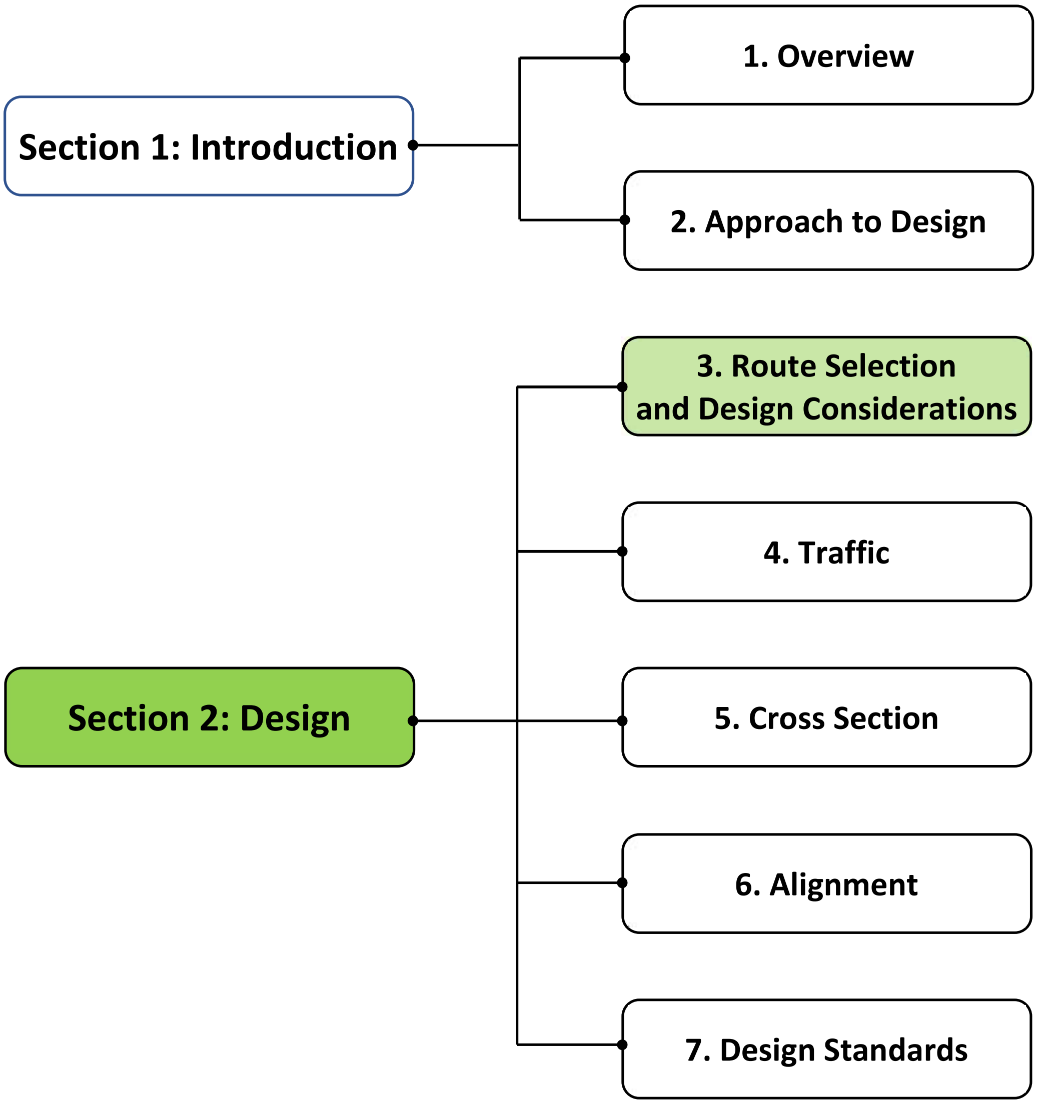
Appendix B: Generic Table of Contents for a Design Report

The design report that should be compiled after completing a design should contain the following topics:

1. Title page and Introductory Information
2. Table of Contents
3. Location Map
4. Background to the Project
5. Brief Summaries of Site Surveys (Specific Detailed Reports of Surveys should exist)
6. Specifications
   - Introduction
   - Objectives
   - Design Policy
   - Design Controls
   - Lane Requirements (if any)
   - Other Conditions
7. Summary of Environmental Issues
8. Horizontal Alignment
9. Vertical Alignment (profile)
10. Alternative Routes Considered
11. Any Co-ordination Aspects of the Horizontal and Vertical Alignment
12. Examples of Curve Designs
13. Cross Sections
14. Drainage
    - Catchment Areas
    - Plan of Ditch and Culvert Layout
15. Details of all Intersections
16. Construction Cost Estimates and Comparisons
17. Economic Analysis (if Appropriate)
18. Summary of Key Technical Issues

Section 2
Design

Low Volume Rural Roads Guideline and Standards
Volume 2: Part A – Geometric Design



Contents

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3.1 Introduction

3.1.1 Background

There are a wide variety of factors that affect, and sometimes control, the geometric design of a LVRR and impact on the outcome of the design. These factors include consideration of physical, social, financial, engineering, economic and environmental issues that all affect the development of the road. Thus, the design approach needs to be undertaken in a holistic and balanced manner that not only meets the needs of all road users but does so in a safe, convenient, cost-effective and environmentally sustainable manner. The attainment of this goal requires a careful approach to the selection of the route, within it the best alignment and, after that, a sound understanding of several fundamental design considerations.

3.1.2 Purpose and Scope

This chapter discusses all of the main factors that affect the geometric design of a LVRR so that the engineer can take due account of them in the process of undertaking this activity. The chapter initially considers the factors that govern the selection of the route corridor (carried out during the planning stage), and goes on to discuss the selection of the route for a LVRR within the corridor and the various fundamental factors that affect the design of the alignment of the LVRR on the chosen route. Although many of the factors are outside the control of the designer, the engineering required to cater to them is the responsibility of the designer. Thus, the purpose of this chapter is to outline the wide range of factors that the designer must consider in undertaking the appropriate design of a LVRR.

3.2 Route Selection

3.2.1 General

The fundamental principle of route selection and alignment improvement is to achieve the least overall transportation cost. It should be borne in mind, however, that in the case of a LVRR, its economic viability is related more to the direct social benefits that it generates rather than to the almost insignificant user benefits generated by relatively low volumes of traffic. Moreover, in the case of every LVRR, e.g., Class LVRR 1 or LVRR 2, where basic access is already provided, it is often a matter of Government policy whether the investment will be made. Thus, alternative investment options should be ranked using a Multi-Criteria Analysis, rather than seeking to determine the economic viability of specific investments.

Given the above, the route of a LVRR should be decided only after conducting proper surveys and investigations of the possible options that should then be subjected to an appropriate cost-benefit analysis based on preliminary designs.

In general, most new LVRRs in Afghanistan will follow the existing tracks and footpaths. However, there may be a need to extend the existing network, especially in the more remote areas of the country, or to undertake a realignment as part of a road improvement scheme. In such a situation, route selection can be divided broadly into two stages:

- Definition of the corridor within which route options are identified and selected; and
- Selection and design of the preferred route within the corridor.

The flow chart for corridor and route selection is presented in Figure 3-1 which summarises the processes and data sources that combine to make up the corridor and route selection stages of a new road construction project. It is assumed that the selection of the corridor is part of the strategic planning process which is beyond the scope of this chapter.

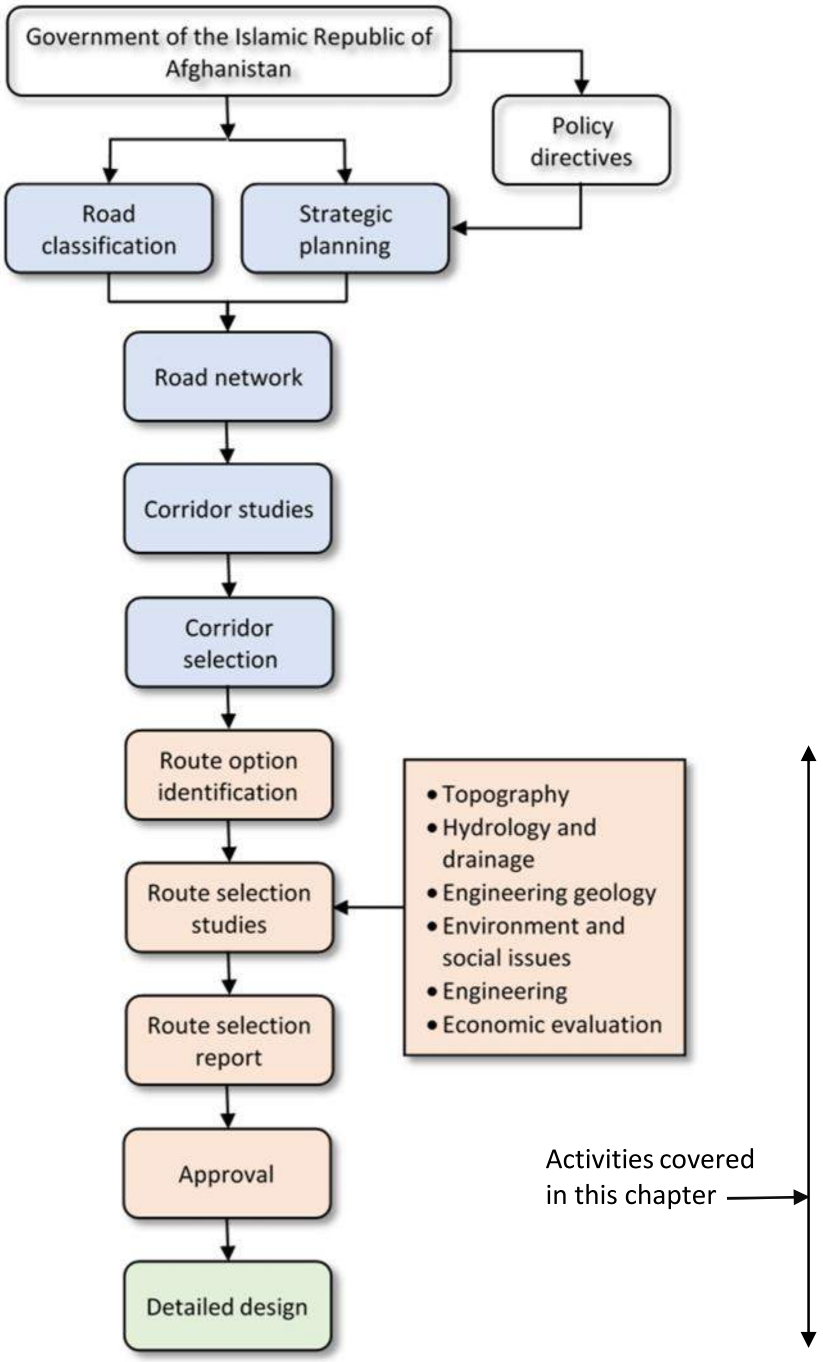

Figure 3-1: Flow chart for corridor and route selection

3.2.2 Route Corridor Identification

The selection of the route corridor is normally carried out during the planning stage.

A route corridor is defined as the length and width of an area of terrain that needs to be studied to be able to identify route options within it. There are no minimum or maximum dimensions to the width, as this is determined usually by the geographical structure of the existing road network, intended road purpose, or road category, topography, and the envisaged constraints imposed by social and environmental factors.

The data resources and activities required for identifying a route corridor are discussed in Section 3.2.7 and include:

- Existing topographic and other specialized mapping including satellite imagery
- Site reconnaissance
- Site surveys

3.2.3 Route Definition and Identification of Options

Route options are defined as approximate alignments within the route corridor that are compared in order to select the preferred route. The "footprint" of each route option should be defined sufficiently to allow its feasibility (engineering, social and environmental) and the approximate cost to be assessed, taking into account the topography and geometric constraints. At least two or three possible route options should be considered within the route corridor which:

- Connect the stated start and endpoints via any specified intermediate points;
- Maximize connectivity with the existing road network;
- Avoid environmentally sensitive areas;
- Avoid low-lying areas and minimize drainage requirements by keeping to the high ground;
- Follow the land contours as far as practicable to reduce the extent of cut and fill;
- Avoid or minimize the effects on vegetation;
- Avoid any adverse impacts on settlements and housing areas;
- Satisfy local community desires and concerns;
- Avoid areas requiring complex and expensive engineering solutions; and
- Allow the road to be designed within its required geometric standards and safety requirements.

The preferred route is usually selected using desk studies and field investigations that are undertaken to a sufficient level of detail to allow confident comparisons to be made (see *Section 3.2.7 – Desk Study and Ground Investigations).* The criteria used to select the preferred route may vary from project to project, but some typical criteria, or factors, are presented below:

- Minimum route length
- Minimum construction cost
- Minimum maintenance cost (where persistent geohazards require ongoing investment)
- Minimum cumulative rise and fall
- Minimum length of steep gradients
- Minimum length of reduced horizontal standard due to topographic and other constraints
- Minimum number and span of required bridges (though ordinarily covered in cost)
- Ease of construction and required construction technology
- Minimal environmental, social impact and cultural constraints – though most of the major constraints should have been avoided during corridor selection
- Socio-economic benefits to be accrued
- Minimal unfavorable geological conditions and slope geohazards
- Sufficient freeboard above flood levels
- Construction materials availability

It should be noted that construction cost will cover a wide range of cost drivers, including route length, subgrade suitability, bridges, earthworks (including excavations in hilly terrain and embankments in flood-prone terrain), haulage costs for borrow and spoil disposal, and the need to mitigate geohazards, including flooding, erosion and landslides. These costs can be difficult to determine without detailed investigations and, for low volume roads especially, it is advisable not to consider route options that will require expensive and complex engineering mitigation.

3.2.4 Requirements of an Ideal Route

The basic requirements of an ideal route between two points are that it should be:

- **Short:** It is desirable to have a short (or shortest) route between two terminal stations. A straight route would be the shortest, though there may be several practical considerations that would cause deviations from the shortest path.
- **Easy:** The route should be such that it is as easy as possible to construct and maintain the road.
- **Safe:** The route should be safe enough for construction and maintenance from the viewpoint of stability of natural hill slopes, embankment and cut slopes and foundation of embankments.
- **Economical:** The route should be considered economical only if the costs of road construction and maintenance are less than the road user benefits, including social benefits.
- **Environment:** Due consideration should be given to the protection/preservation of the environment, particularly in hilly areas. Disturbance to vegetation should be minimized.
- **Aesthetics:** The aesthetics of the area should be borne in mind when selecting the route, which should be integrated with the surrounding landscape as far as possible.

3.2.5 Factors Controlling the Route

The various factors that control the route include:

- Obligatory points; and
- Connectivity.

Obligatory points

These are control points governing the route selection. These control points may be divided broadly into two categories.

- Points through which the route is to pass;
- Points through which the route should not pass.

Obligatory points through which the road route has to pass may cause it to often deviate from the shortest or easiest path. The various examples of this category may be a bridge site, important towns, groups of villages and places of religious, social, political and commercial importance.

Obligatory points through which the route should not pass include religious sites such as burial grounds, areas protected for environmental reasons, areas designated for military purposes, swampy areas, and areas with problematic ground conditions.

When it is necessary to cross mountains or high ridges, the various alternatives are to cut a tunnel, or to go round the hills or to deviate until a suitable hill pass is available. The suitability of these alternatives depends on many other factors, such as the topography and site conditions.

Connectivity

In most cases, road users tend to use certain routes traditionally. These may either be due to convenience, social connection with other areas, etc. The proposed route should, therefore, keep in view this traffic flow pattern.

Other considerations

Various other factors that may govern the route selection are hydrology and drainage, political considerations and aesthetics. The alignment controls also include the limits of the specifications for the class of road being designed. These include maximum gradients, radii of horizontal curves, sight distances, etc.

3.2.6 Factors Affecting Route Selection in Mountainous Terrain and Sand Dune Areas

Mountainous Terrain

The following special considerations should be given to the selection of the route in the mountainous regions of Afghanistan, including the Hindu Kush mountains, which run from the northeast to the southwest of the country:

- When crossing mountain ranges, the road should preferably cross ridges at their lowest elevation. In certain cases, the use of tunnels may be more appropriate than negotiating high mountain ranges, especially where short sections of tunneled alignment would replace length above ground routes where large quantities of rock associated with open cut can be avoided. The decision should be made on the basis of a cost-benefit analysis. The advantages and disadvantages of tunneling or deep rock-cut sections are presented in Table 3-2 below.
- The route should be selected with the view to avoid hairpin bends and on final alignment as far as possible.
- As far as possible, the following situations should be avoided or mitigation measures put in place (see Volume 1: Pavement Design Guideline, *Chapter 3 – Geotechnical Investigations and Design, Section 5-4: Roadside Slope Stabilisation*):
    - unstable hill features;
    - areas having perennial/potential landslide, erosion or settlement problems;
    - areas subject to seepage/flow from springs.

Table 3-1: Tunneling versus Deep rock-cut options

Tunneling options		Deep rock-cut options	
Advantages	**Disadvantages**	**Advantages**	**Disadvantage**
1. Can reduce alignment length where tunnels are constructed through ridges and spurs	1. Can be costly when compared to open-cut in many-most situations	1. More consistent with conventional engineering on low volume mountain roads	1. Requires expensive excavation
2. Can be used to avoid major rock excavations in open-cut which can be costly and can trigger rock slope failures	2. Unlikely to be feasible in side-long ground, i.e., works best where the alignment is 'against' the terrain rather than 'parallel' to it	2. Likely to be cheaper than tunneling in many-most situations	2. Will generate large volumes of waste rock to be disposed of
3. Can provide protection from snow avalanches and major rock failures	3. Requires expensive ground investigation and geotechnical design		3. Blasting tends to destabilize adjacent rock masses
4. Generally, tunnels have a lower impact on the environment than open excavations	4. Will require expensive support structures in low-quality rock		4. Can trigger large rock failures if not designed and excavated properly, that pose a danger to workforce, public and traffic
	5. Can pose a hazard to traffic without sufficient lighting and ventilation		5. May require expensive land acquisition and compensation
	6. Can be hazardous to pedestrian access unless special provision is made		

Sand Dune Areas

In the sand dune areas of Afghanistan, such as those in the southwestern sandy deserts, the following special considerations should be given to the selection of the route.

- Locations where sand is loose and unstable should be avoided and the route selected along the ridges having vegetation.
- Preference should be given to areas having coarse sand than to areas having fine, wind-blown sand.
- In locating a road in an area having longitudinal sand dunes, the best location is always at the top of a ridge or in the inter-dunal space. The location along the face of longitudinal dunes should be avoided.
- The route of the road should, as far as possible, run parallel to the sand dunes, and the sand dunes should be crossed without disturbing their profile.
- The gradeline should be raised 0.2 to 0.5 m above the adjacent ground level. Higher embankments should be avoided as, otherwise, eddies at the windward slope will cause sand to drop on the road.
- An aerodynamic cross section profile will minimize sand accumulation against the side slope. This can be achieved by having slopes H:V ≥ 4:1 for embankments and H:V ≥ 6:1.

3.2.7 Procedure for Route Selection

General

The final location of the route is based on the undertaking of a desk study followed by ground verification on the basis of engineering surveys. These activities are typically completed in four sequential stages, as follows:

- Reconnaissance
- Preliminary Survey
- Determination of Final center Line
- Final location and Detailed Survey

Reconnaissance

The reconnaissance survey is typically undertaken in the following sequence:

- Desk study of topographical maps, geological maps and aerial photographs
- Preliminary aerial survey reconnaissance, where practicable.
- Ground reconnaissance.
- Final decision-making

Desk study: The desk study is a critically important exercise. It is the initial stage during which options are identified based on the project scope. During the desk study, It will be desirable to consider all the objectives listed in previous sections of this chapter to the extent that available data allows. This includes recourse to the topographical, geological and soil maps which should be consulted to define, as closely as possible at this stage, the details of the terrain and its underlying geology. In Afghanistan, 1:250,000 scale topographical maps can be found at http://pubs.usg.gov/of/2005, and there are larger-scale maps available in the country at 1:50,000 nationally, 1:10,000 locally and 1:2,000 for areas of mineral development. Geological maps are also available at 1:500,000 and locally at 1:100,000. Further information on the geology of Afghanistan can be found at the following website:

https://www.bgs.ac.uk/downloads/browse.cfm?sec=7&cat=83.

Satellite imagery generally provides an excellent source of environmental data for route selection purposes. Free-to-view 3D imagery available through Google Earth varies considerably in quality for Afghanistan but may be useful. As described in *Volume 1: Chapter 3 – Physical Environment*, the topography and geomorphology of Afghanistan are extremely varied, and much of this detail can be identified by using Google Earth interpretation. Digital elevation data, suitable for Digital Elevation Model (DEM) terrain analysis, can be downloaded from ASTER and SRTM internet sites, though such data can prove misleading in mountainous terrain. Maps, also available from the internet that claim to portray landslide susceptibility (or hazard) should be treated as indicative, at the very best.

During the desk study, the probable alignment can be located from a study of the topographical maps and aerial photographs from consideration of the following:

- An alignment that avoids valleys, lakes and low-lying, flood-susceptible, areas.
- When the road has to cross a row of hills, the possibility of crossing through mountainous passes.
- The approximate location of bridge sites for river crossings, avoiding bends of the river.
- When the road is to be connected to two specific points, the achievable gradient in hilly areas. Alternate routes may need to be considered based on the permissible gradients, say the ruling gradient and the limiting gradient.
- Areas of landslide susceptibility to be avoided. Figure 3-2, for example, is taken from an area near Fayzabad which shows the extent of landslides that affect the valley side in this particular location which exhibits both older landslide scars to the left and new/ reactivated scars to the right.

Source: Google earth

Figure 3-2: Landslide-affected terrain in northern Afghanistan

From the desk study, a rough indication may be obtained of the routes to be further surveyed in the field.

Aerial reconnaissance: If practicable, a preliminary aerial reconnaissance of the selected corridors should be undertaken upon completion of the desk study. This reconnaissance will provide an aerial perspective of the locality and will supplement and help clarify the information obtained from the desk study, thereby helping in the selection of the preferred alignment.

Ground reconnaissance*:* A reconnaissance survey should be undertaken once route options have been identified from the desk study. The reconnaissance should comprise engineering and environmental personnel and, in mountain areas especially, engineering geological and hydrological specialists. This survey team should inspect a fairly broad stretch of land along the proposed alternative routes determined from the desk study and aerial reconnaissance if carried out. The various feasible alternative routes are further verified physically in the field by ground reconnaissance to select the final route. Some of the details to be collected include:

- Valleys, lakes, marshy lands, ridges, hills, permanent structures, archeological structures and other obstructions along the route, which may not be available from the desk study.
- Gradient, length of gradient and radius of curvature of alternative alignments.
- Number and type of cross drainage structures, maximum flood levels and natural groundwater level along the possible routes.
- Soil type along the routes from field identification tests, and observations of geological features.
- Sources of construction materials, water and location of stone quarries.
- When the road passes through hilly or mountainous areas, additional data regarding the geological formation, type of rocks, the dip of strata, seepage flow, etc., may be observed so as to decide on the stable and unstable sides of the hill for the road alignment.

Consideration of the above will allow reliable construction costs and environmental impact assessments to facilitate credible route comparison and selection. Consultation with stakeholders will assist in the identification of issues that might prove significant during design, construction and operation, including land acquisition and land management concerns.

Figure 3-3: Landslide-affected terrain that would pose a serious difficulty for road alignments

Preliminary survey

The main objectives of the preliminary survey are to:

- Survey the various alternative alignments proposed after the ground reconnaissance and to collect all the necessary details of topography, drainage and soil.
- Compare the different proposals in view of the requirements of an ideal alignment (see Section 3.2.5 above).
- Estimate the quantity of earthworks, materials and other construction aspects and to work out the preliminary costs of the alternative alignments.
- Finalize the best alignment from all considerations

Final decision-making: It is often the case that, for whatever reason, one route option becomes the favored option for a number of reasons. However, it is also not uncommon to find that engineering, environmental and economic conflicts complicate decision-making. It is important that the final decision is made in the light of all available information. It is also important to ensure that decision-making is as objective as possible so that all considerations and stakeholder views are accommodated.

There may be instances where multiple factors need to be assessed, sometimes with conflicting implications for route selection. Certain factors, such as route length or environmental impact, may be judged to be more important than others, and this will vary from location to location depending on circumstances. In such a situation, Multi-Criteria Analysis (MCA) is often used to assist in the route selection process. It allows each factor to be systematically assessed in either a quantitative or semi-qualitative way and then combines scores to reach an overall preferred route. It is usual to apply a weighting factor, depending on its agreed significance. For example, a route that is 20% longer than its alternatives may be the preferred option if it minimizes the need to acquire agricultural land or encroach into a forest area.

Table 3-2: Typical MCA criteria used in comparing route options

Item	Criteria	Weight	Comment
A	Population served	30	Within 2-2.5km on either side of the road
B	Access to social centers (Number)	20	Schools, health centers and local markets
C	Access to economic opportunities, including employment (Number)	20	Major markets and towns, admin centers, mines, factories, commercial farms etc
D	Direct/indirect request from the community (Yes/No)	10	All or nothing
E	Current level of accessibility	10	Worst situation gets higher score
F	Traffic volume (PCU or ADT)	10	AADT in PCUs or ADT
	Total Maximum Score	100	

Table 3-3 lists some of the criteria that might typically be assessed in an MCA for route selection. Through consultation, it is important to engage with all potentially affected stakeholders in order to ensure that the list of criteria is fully-inclusive of all concerns.

Table 3-3: Common criteria for consideration in MCA and route selection

Primary Criteria	Secondary Criteria	Basis of Assessment
Engineering	Road length	km/mile
	Terrain – elevation, steepness and complexity of topography	Height, relief, slope angle (°)
	Earthworks – need for major or continuous cuts and fills	Volume
	Drainage – number and spans of river crossings	Number and spans
	Materials – subgrade conditions and availability of construction materials	Good, moderate, poor
	Geo-hazards – potential exposure to flooding, landslides	High, moderate, low
	Cost – outline cost estimate associated with each option	$ or local currency
Social	Community access – for example, changes to rural accessibility to public transport, education, employment, markets and health facilities	Good, moderate, low
	Resettlement – need to rehouse families as a result of construction	Numbers affected and demographics
	Severance – are communities split into sub-areas by the route option or are they separated from farmland for example	Numbers affected
	Cultural heritage – are sites of cultural and religious importance affected by the route?	Numbers affected
	Road safety – are pedestrians and road users at risk from traffic accidents?	Yes, no, numbers
	Pollution – could road runoff or fuel and oil spillages affect	Yes, no, number of

Primary Criteria	Secondary Criteria	Basis of Assessment
	habitats and could air pollution and noise affect public health?	locations, ecological and public health severity
Environmental	Ecology - are there any areas of important bio-diversity (gazetted or otherwise) impacted or at potential risk?	Yes, no, number and areas, ecological severity
	Water – are there any water bodies at potential risk of pollution and are there any potable water supplies that could be affected?	Yes, no, number and importance, population potentially affected
	Agricultural Land – are there areas of prime agricultural land that will be removed?	Yes, no, area
	Landscape – are there areas of high landscape value at potential risk, including in areas of tourism?	Yes, no, number, area
	Erosion – are there any soils along the route option that are particularly prone to erosion	Length
Economic	Viability	Qualitative, NPV, EIRR, Cost-Benefit Analysis
Planning	Sustainability - Does the route satisfy regional and local sustainable development goals?	Yes, no, not applicable

From the outcome of the MCA, a preferred alignment(s) within the corridor may be chosen for the preliminary survey, as discussed below.

3.2.8 Detailed Route Selection Report

The information and data collected during desk studies, engineering surveys and investigations, together with the cost estimates of the route options and, finally, the recommended route, should be compiled into a Route Selection Report which would typically be presented in the following format:

1. Introduction
2. Desk Studies, Reconnaissance Surveys and stakeholder Consultations
3. Project Area
   a. Socio-economic
   b. Environment
   c. Physical Characteristics
4. Route Options
   a. Socio-economic
   b. Environment
   c. Engineering
   d. Cost Estimates
   e. Economic Evaluation
5. Preferred Route Option.

3.3 Design Considerations

3.3.1 General

Based on the selection of the preferred route as discussed above, it then becomes necessary to consider those factors that affect the design of the alignment of the LVRR, including:

- Road functional considerations
- Cost and level of service
- Roadside population
- Terrain
- Land use
- Environmental considerations

- Drainage
- Climate
- Pavement type
- Road safety
- Construction technology
- Design controls
  - Traffic volume and composition
  - Design speed
  - Design vehicle
  - Pavement type

The above factors are discussed below.

3.3.2 Factors Affecting Design

Since these factors differ for every road, the geometric design of every road could, in principle, be different. It is normal practice to identify the main factors and to adopt geometric standards that comply with the requirements of these key factors.

Road functional considerations

Once the functional classification of the LVRR has been defined, major controls affecting its design must be specified in order to guide the design process. In this regard, this Guideline is concerned only with roads that primarily fulfill an access function, i.e., Tertiary roads and minor Secondary roads that fall within the definition of LVRR. These roads are the lowest levels in the network hierarchy. Thus, geometric standards may be relatively low and need only be sufficient to provide appropriate access to the rural communities as well as agricultural, commercial and population centers that they serve.

Cost and Level of Service

The basic purpose of any road is to provide or enhance connectivity and economic activity. The cost and level of service to be provided by such a road will depend on its functional classification. Once this is decided, safety, convenience, and comfort of users are factors which enter into the decisions on the standards to be adopted but are not ends in themselves. The road is merely an element to be integrated into the physical infrastructure which, taken together with the economic and social order, will facilitate development.

In the case of a LVRR, the requirement is to provide reliable, all-season passability for the prevailing means of transport. Generally, because the number of vehicles per day are low, the absolute level of road user costs on LVRRs is low and potential savings, being a relatively small fraction of total user costs, is even lower. Thus, to reduce total costs, capital costs must be kept low. In turn, this requires the adoption of design standards that match the relatively low level of service provided by a LVRR. The chosen service level is directly associated with traffic volume and function and, hence, is not treated as a separate variable. The standards for service level simply increase from the lowest road class to the highest, remaining relatively constant within each class.

Roadside development

When a road passes through a village, town or other populated or market area, safety must be a primary consideration. Pedestrian footpaths are required on both sides of the road and should preferably not be the road shoulder. Extra width may also be required in each direction for parking and for passenger pick-up, but such a wide section of road encourages drivers to increase speed; therefore, speed reduction or containment methods should be employed (refer to *Part B – Road Safety*).

In built-up areas, the problem is one of deciding the safety measures that are justified based on the size of the area or length of road that is affected. The following data is useful for making such decisions, but no precise guidelines have been developed hence engineering judgment and consultation with the local community is required:

- How many shops/traders are there?
- How many people use the area on market days?
- What development and increases are likely to happen in the next ten years?

In practice, a basic standard is specified, as indicated above, combined with some elements of traffic calming as described in *Part B – Road Safety*. These standards are not justified for the lower traffic levels of LVRR 1 and LVRR 2, unless the road passes through a particularly well-populated area. In such circumstances, the shoulders should be widened as appropriate for the extent of the populated area.

Terrain

The terrain has the greatest effect on the cost of roads; therefore, it is not economical to apply the same standards in all terrains. Drivers using LVRRs are normally familiar with this and lower standards are expected in hilly and mountainous terrain. It should be noted that the definition of terrain is exactly that, it is not a description of the eventual alignment of the road. For example, in mountainous terrain, the road alignment may be relatively flat by following contours but it could be more direct and contain very steep grades.

Three categories have been defined as shown in Table 3-4.

Table 3-4: Terrain classes

Description	5m contours per km	Characteristics	Approximate cross slopes
Level/flat	0 - 5	Largely unrestricted horizontal and vertical alignment. The natural ground slopes perpendicular to the ground contours are generally below 3%. Minimum values of alignment will rarely be necessary. Roads will, for the most part, follow the ground contours and amounts of cut and fill will be very small.	0-10 percent
Rolling	6 - 25	Low hills introducing moderate levels of rise and fall with some restrictions on vertical alignment. The natural ground slopes perpendicular to the ground contours are generally between 3 and 25%. Whilst low standard roads will be able to follow the ground contours with small amounts of cut and fill, the higher standards will require more substantial amounts.	10-15 percent
Mountainous	> 25	Rugged, hilly and mountainous with substantial restrictions in both horizontal and vertical alignment. The natural ground slopes perpendicular to the ground contours are generally above 25%Higher standard roads will generally require large amounts of cut and fill.	25-60 percent
Escarpments		Not generally dealt with as an LVR issue	Greater than 60 percent

The cross slopes are closely related to the contour crossings, as indicated in Table 3-3. However, it is a very broad classification that does not necessarily indicate difficult conditions or steep alignments. For example, a road in mountainous terrain may follow contour lines closely or be constructed in a river valley. In neither case is it inevitable that the alignment will be unduly difficult and the road relatively expensive, but the probability is higher in mountainous terrain.

An important aspect of geometric design concerns the ability of vehicles to ascend steep hills. Roads that need to be designed for very heavy vehicles or for animal-drawn carts require specific standards to address this, for example, by adopting special climbing lanes. Fortunately, the technology of trucks has improved greatly over the years and, provided they are not grossly overloaded (which is a separate problem) or poorly maintained, they do not usually require special treatment. On the other hand, animal-drawn carts are unable to ascend relatively low gradients, and catering for them in hilly and mountainous terrain is rarely possible. Climbing lanes cannot be justified on LVRRs, nor can the provision of very low maximum gradients. The maximum gradients allowable for different road classes are shown in *Chapter 7 – Design Standards.*

In mountainous areas, the geometric standard for LVRRs takes account of the constraints imposed by the difficulty and stability of the terrain, but this design standard may need to be reduced locally to cope with exceptionally difficult terrain conditions. Every effort should be made to design the road so that the maximum gradient does not exceed the advisable maximum standards shown in *Chapter 7 – Design Standards*, but where higher gradients cannot be avoided, they should be restricted in length. Gradients exceeding the absolute maxima should not be longer than 200 m, and relief gradients ≤ 6% over a minimum length of 200 m, are required to allow heavy vehicles to regain speed. Horizontal curve radii of less than the minimum specified of 15 m may sometimes be unavoidable, and warning signs will need to be provided sufficiently early to allow vehicles to divert if necessary.

A fourth terrain category is sometimes defined, namely an "*Escarpment"* category, but this is such an extreme terrain that uniform standards for it cannot be easily defined and each road in such terrain needs to be designed on its own merits.

Land use

Land use influences the design of the drainage features of a road and access to the road. Dealing with water runoff and potential erosion, for example, forms an important aspect of design, much of which is geometric in nature. These aspects are dealt with in *Chapter 6 – Alignment*.

Environmental considerations

Road construction affects the environment in many ways that can be detrimental but can also be positive. It is, therefore, important to fully consider the impact of these effects at the design stage of the project. Mitigation measures for addressing a range of environmental and social impact issues are addressed in the Pavement Design Guideline, *Chapter 14 – Practical Considerations*.

Drainage

Consideration of issues associated with drainage of the road and surrounding land can significantly affect the geometry and cross section of the road whilst the choice of the drainage system can affect the cross section or formation width. Thus, a cohesive design requires that drainage issues are considered at the earliest stage of the design process to ensure that geometric design decisions are informed by, and supportive of drainage design. The main elements of drainage design are addressed in the Pavement Design Guideline, *Chapter 8 – Drainage and Erosion Control.*

Climate

Varying standards of geometric design do not exist to cater specifically to climate. However, it is important that climate change is taken into account in the design of the drainage features which affect the road cross-section and, thus, the geometric design.

Engineering adaptations to climate change are addressed in *Volume 1, Chapter 14 – Practical Considerations.*

Pavement type

The friction factors for paved and unpaved roads are significantly different, and this affects the distance required to stop safely and the safe speed for negotiating curves. Thus, the geometric standards differ according to the type of surface (paved or unpaved), as discussed in *Chapter 7 – Design Standards*.

Road safety

The mix of rural traffic in Afghanistan often includes relatively old, slow-moving and overloaded vehicles, a large number of pedestrians, animal-drawn carts and, possibly, bicycle and motorcycle-based forms of transport of goods and people. Poor driver behavior and poor enforcement of regulations mean that methods to improve safety through engineering design assume paramount importance. These are dealt with at appropriate places throughout the Guideline and in *Part B, Chapter 2 – Road Safety*.

Construction technology

In a labor-abundant economy, it is usually beneficial to maximize the use of labor rather than rely predominantly on equipment-based methods of road construction. In such a situation, the choice of technology affects the geometric standards that can be achieved, especially in hilly and mountainous areas, because:

1. Maximum cuts and fills must be small.
2. Economic haul distances are limited to those achievable using wheel-barrows.
3. Mass balancing is achieved by transverse rather than longitudinal earth movements.
4. Maximum gradients follow the natural terrain gradients.
5. Horizontal alignments may be less direct.

The standards in hilly and mountainous terrain are always lower than in flat terrain, but this reduction in standards may need to be greater where labor-based methods are used. However, this need not always be so. For instance, following the contour lines more closely will make the road longer, but the gradients and earthworks can be less severe. Every effort should be made to preserve the same standards in the particular terrain encountered irrespective of the construction method.

Design controls

At a minimum, the following design controls must be specified that comply with the above key factors:

- Traffic volume and composition
- Design vehicle
- Design speed

Traffic volume and composition: The AADT of motorized vehicles with two or more axles provides the basic method of defining the different geometric road standards, but these are sometimes modified based on traffic composition. Five standards are defined as summarised in *Chapter 5 – Cross Section,* Table 5-1.

However, as indicated earlier, traffic volume is not the only aspect to be considered in deciding design standards, and the functional classification of the road generally plays a dominant role. It is, nevertheless, important that the designation of a road by functional type should not give rise to overdesign for the levels of traffic actually encountered. The road should be designed based on the task it has to provide, primarily the traffic that it has to carry. Details for counting and predicting traffic are provided in *Chapter 4 – Traffic*.

Design Vehicle: The physical and operating characteristics of vehicles using a LVRR control specific elements in the geometric design, e.g., tracking of large vehicles on small radius horizontal curves. In principle, the road alignment should permit easy passage of as many vehicle types as possible. However, by virtue of the function of low volume rural roads, primarily provision of access to local communities, there are various types of large vehicles that are not expected to travel on such roads. Thus, the extra expense of catering for such vehicles is not warranted.

The design vehicle is a vehicle with representative weight, physical dimensions, and operating characteristics used to establish design controls for accommodating vehicles in the designated class.

The three general classes of design vehicles applicable for LVRRs have the characteristics shown in Table 3-5.

Table 3-5: LVRR Design vehicle characteristics

Design vehicle	Code	Height (m)	Width (m)	Length (m)	Front overhang (m)	Rear overhang (m)	Wheel-base (m)	Minimum turning radius (m)
Passenger car	DV1	1.2	1.8	5.0	0.7	1.0	3.1	6.8
Single unit truck	DV3	4.3	2.6	9.1	1.2	1.8	6.1	12.8
Single unit bus	DV4	4.3	2.6	12.3	2.1	2.6	7.6	12.8

Turning templates are essential in ensuring that the kerb lines at intersections accommodate the path that the design vehicle will follow in negotiating left turns and, in the presence of median islands, the right turn. They also have applications in designing the layouts of parking areas and modal transfer stations.

Turning templates for various design vehicles, including specialized vehicles, can be plotted using commercially available computer-aided draughting programs or can be constructed from the information contained in Table 3-6 if required.

Table 3-6: Minimum turning circle radii at crawl speed (m)

Vehicle	Minimum Turning Radius Outer Wheel Path	Minimum Turning Radius Inner Wheel Path
Passenger car (P)	6.2 m	4.4 m
Single unit truck (SU)	12.8 m	8.64 m
Single unit bus (BUS)	13.1 m	7.8 m
Note: Allow an additional 0.5 m front overhang for P and SU vehicles and 1.0 m for BUS over the outer wheel path when determining clear space required for turning. Refer to Figure 3-4 below for an illustration of such a turning template.		

Should larger vehicles comprise more than 10 % of the traffic mix, which is unlikely in the case of residential and collector streets, it will become necessary to use them as design vehicles for maneuverability, in which case reference will have to be made to other appropriate design manuals.

Some typical turning templates are illustrated in Figures 3-4 and Figure 3-5.

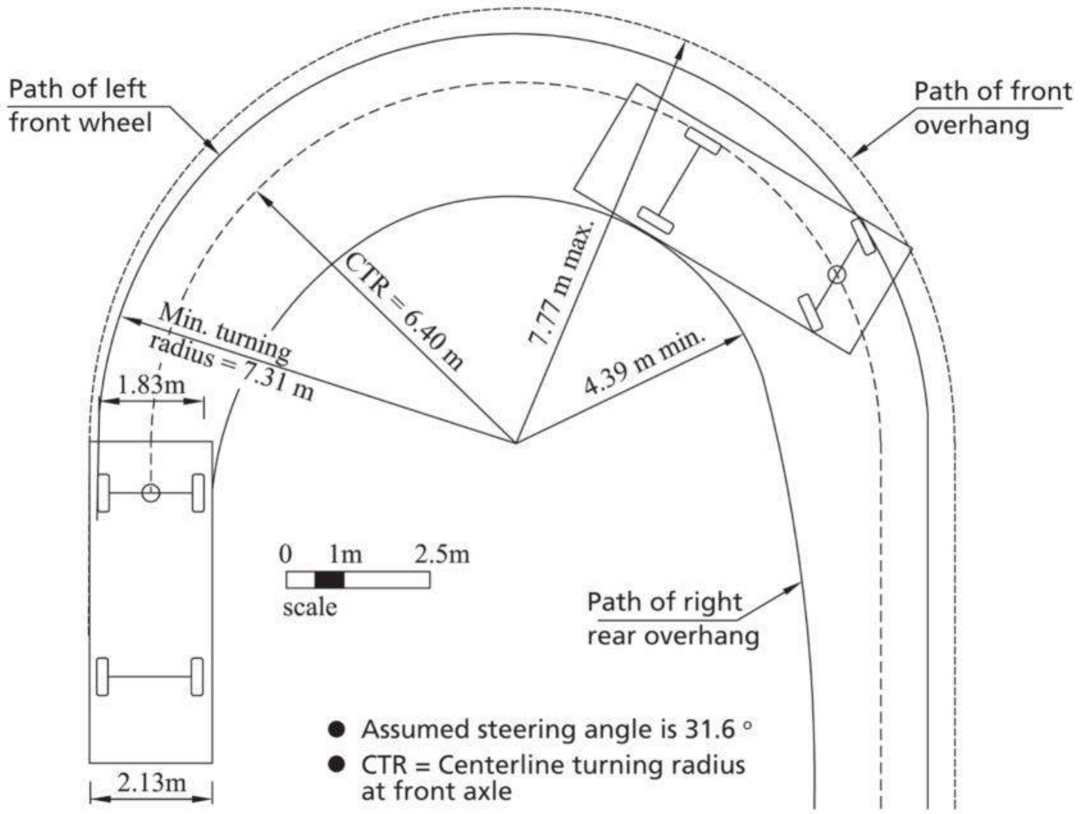

Figure 3-4: Turning template for Passenger Car

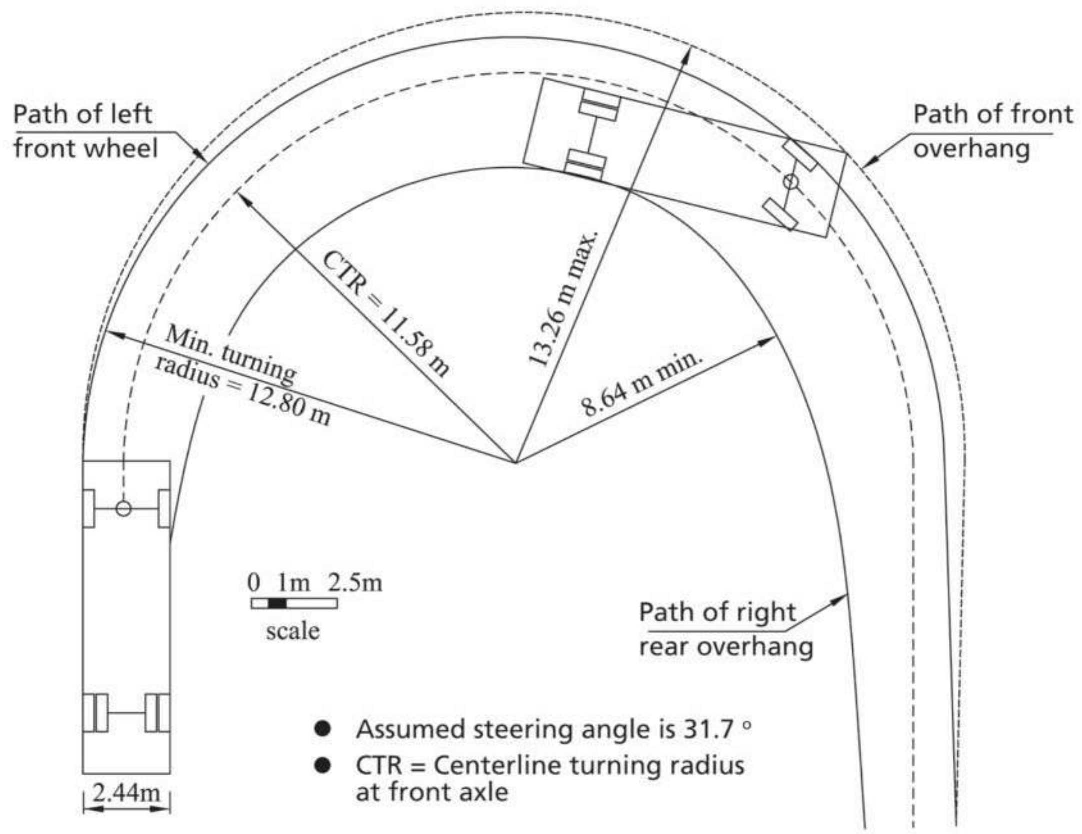

Figure 3-5: Turning template for Single Unit Truck (SU)

Design speed: Minimum horizontal and vertical curvatures are governed by the maximum acceptable levels of lateral and vertical acceleration and minimum sight distances required for safe stopping and passing maneuvers. These design parameters are, in turn, related to the vehicle speeds assumed in the design. Curvature standards are thus dependent on an assumed design speed.

Within this Guideline, the adopted design speeds are explicitly stated and, as shown in *Chapter 7 – Design Standards,* vary with both terrain and level of traffic flow. However, it must be emphasized that these speeds are intended to provide an appropriate consistency between geometric elements rather than as indicators of actual vehicle speeds at any particular location on the road section.

The use of lower design speeds in the more difficult terrain is intended to incorporate an element of reduced driver expectation and performance, as well as the need to keep construction costs to acceptable levels. As flows increase, the level of benefits from reduced road length also increases and generally supports higher standards with more direct and shorter routes.

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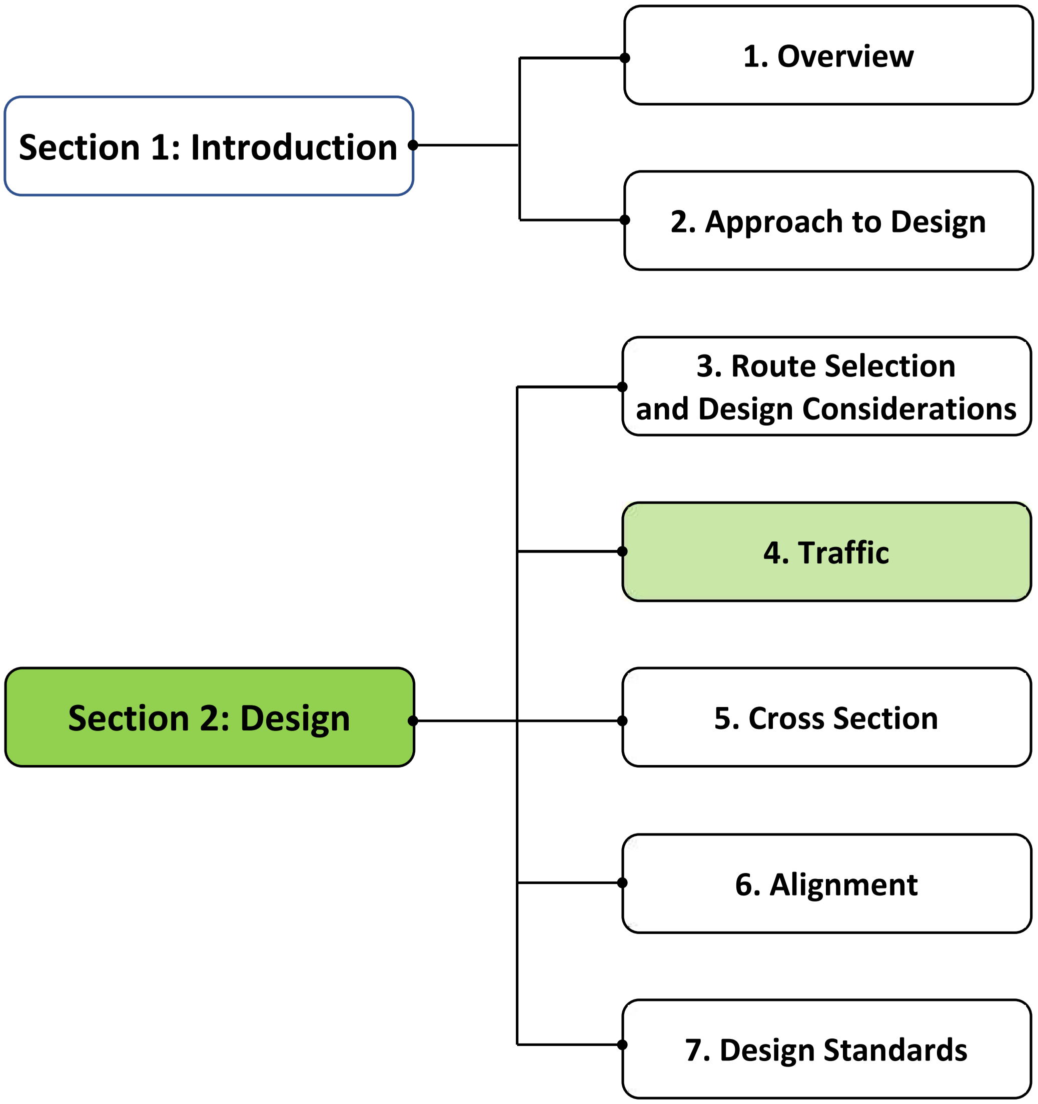

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4.1 Introduction

4.1.1 Background

Roads should be designed based on the function that they have to fulfill which is primarily to carry the estimated traffic volumes over their design lives safely, comfortably and efficiently. Thus, reliable data on traffic volumes and characteristics are essential for geometric design as well as for pavement structural design and for assisting in the planning of road safety measures, as summarised below:

- **Geometric design**: The volume and composition of traffic, both motorized and non-motorized, influence the design of the cross-section (carriageway and shoulders). The geometric design standards (refer to *Chapter 7 – Design Standards*) must cater adequately for the traffic volumes expected on LVRRs. These standards need to be modified based on the characteristics of the traffic using the road, such as different traffic mixes, including large numbers of NMTs, motorcycles, large vehicles, and pedestrians.
- **Pavement design**: The deterioration of the pavement is influenced by both the magnitude and frequency of individual axle loads. For the structural design of LVRRs, a range of Traffic Load Classes (TLC) are defined based on the traffic loading calculated in terms of cumulative equivalent standard axles carried in the specified design life. Thus, each TLC is applicable over a range of traffic levels.
- **Road safety**: The volume, type and characteristics of the traffic using the road all influence the type of road safety measures required to ensure a safe road environment.

In view of the above, reliable estimates of the existing (baseline) and future traffic volumes are required.

4.1.2 Purpose and Scope

The purpose of this chapter is to provide procedures for counting baseline traffic and predicting future traffic for determining the traffic volume as a basis for designing the geometric components of the road. The procedures are essentially very similar to those required for pavement structural design, as described in *Volume 1 – Pavement Design*, except that information about axle loads, is not required. Information about the volumes of light traffic, motorcycles and NMTs (cyclists, pedestrians and animal-drawn carts) that have no influence on the structural design are all required for geometric design and for road safety considerations.

The chapter considers types of surveys that provide the inputs for determining the design traffic. This requires the data to be sufficiently accurate to attain a reliable forecast of the future traffic volumes. The chapter considers various ways that such forecasts can be achieved, bearing in mind that all methods of forecasting traffic are subject to errors of estimation. Thus, several methods should be used, and a sensitivity analysis should be carried out to select the most likely result based on "engineering judgment".

4.2 Design Life

The design life of paved LVRRs is usually set at 10 or 15 years. The traffic for which a road is designed should be such that it is not significantly under-designed at the end of its design life or overdesigned at the beginning. Thus, the traffic at mid-life is used for geometric design. This requires a prediction of traffic growth, as described in Section 4.4 below. However, the most important property for geometric design is usually the capacity of a road, but this is not a major issue for LVRRs because the traffic level is generally too low for congestion to be a problem (ref. *Chapter 2 – Approach to Design, Section 2.5.3*).

Reliable traffic estimation is required to determine the appropriate geometric design standards and also the road safety measures for the various classes of road. The higher standards of road are based on relatively higher design speeds which relate to wider carriageways, larger radii of minimum curvature and possibly lower maximum gradients, as shown in the various design tables in *Chapter 7 – Design Standards*. Although the boundaries between one road class and another in terms of AADT are based on the best evidence available, they should be treated as approximate in the light of the uncertainties inherent in traffic estimation.

4.3 Traffic Surveys

4.3.1 General

Traffic surveys are required for geometric design as well as for planning purposes in terms of evaluating economic benefits derived from the construction of LVRRs. For these purposes, it is necessary to ascertain the volume and composition of current and future traffic in terms of all vehicle classes, motorcycles, and, importantly, NMT.

The following types of traffic surveys are typically carried out in the road project area:

- Classified Traffic Surveys
- Origin-Destination Surveys

4.3.2 Survey Methods

The most common types of surveys for counting and classifying the traffic in each class are:

- Manual and Automatic Traffic Survey
- Moving Observer Methods

Although the methods of traffic counting may vary, the objective of each method remains the same, essentially to obtain an estimate of the Annual Average Daily Traffic (AADT) using the road, disaggregated by vehicle type. Establishing reliable traffic data is notoriously difficult, especially where the roads serve a predominantly developmental or social function, and when the traffic level is low. Thus, although an AADT is more accurate as it requires a continuous count for at least 365 days, for LVRRs it sufficient to rely on a less accurate Average Daily Traffic (ADT) obtained from seasonal, classified traffic counts, as discussed below.

4.3.3 Reducing Errors in Estimating Traffic for LVRRs

Increasing the count duration

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.

Figure 4-1 shows the possible errors in AADT estimates for traffic counts of varying duration. The figure illustrates two important points; 1) that short duration traffic counts in low traffic situations can lead to large errors in traffic estimation, and 2) that there is little scope for improving accuracy by counting for more than 7 days. Thus, the duration of traffic surveys should be given careful consideration in terms of striking a balance between cost and accuracy.

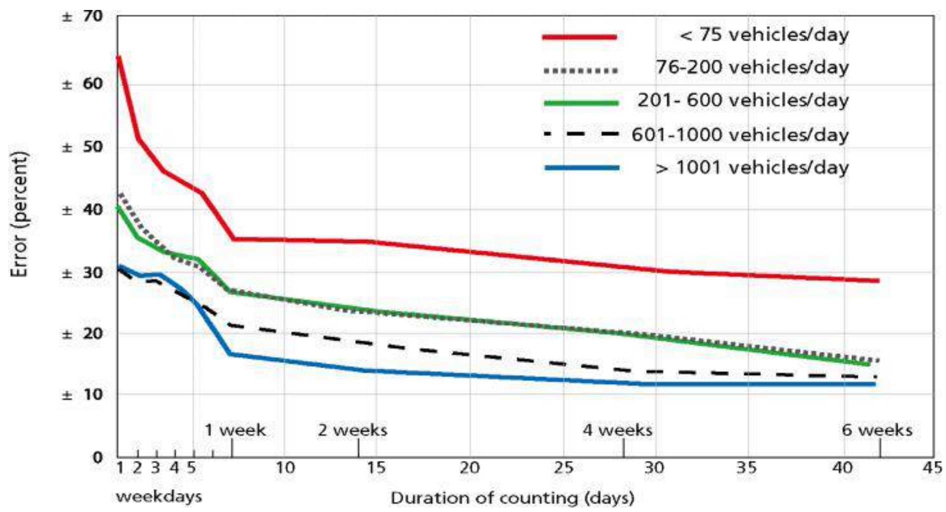

Figure 4-1: Possible errors in ADT estimates from random counts of varying duration

(Source: Howe 1972)

Errors in estimating traffic can be reduced by carrying out a **Classified Traffic Count** as follows:

- Counting for seven consecutive days.
- On some days counting for a full 24 hours, preferably with one 24-hour count on a weekday and one during a weekend; on other days, 16-hour counts (typically 06.00 – 22.00 hours) should be made and expanded to 24-hour counts using a previously established 16:24 hour conversion ratio.
- Avoiding counting at times when road travel activity increases abnormally; for example, just after the payment of wages and salaries, or at harvest time, public holidays or any other occasion when traffic is abnormally high or low. However, if the harvest season is during the wet season (often the case, for instance, in the timber industry), it is important to obtain an estimate of the additional traffic typically carried by the road during these periods.

Adjustments for season

Usually, motorized traffic volumes will decrease in the wet season to, typically, 80% of their dry season level. However, on poor quality roads, this difference can be even more marked, and the wet season traffic can decrease to as much as 35% of dry season traffic levels, as shown in Figure 4-22. For the purposes of this Guideline, it can be assumed that roads have trafficability problems when wet season traffic levels fall below about 60% of dry season levels. It is also possible that dry season traffic may be lower than wet season traffic, e.g., in areas where sands tend to become loose and less traversable in the absence of ground moisture.

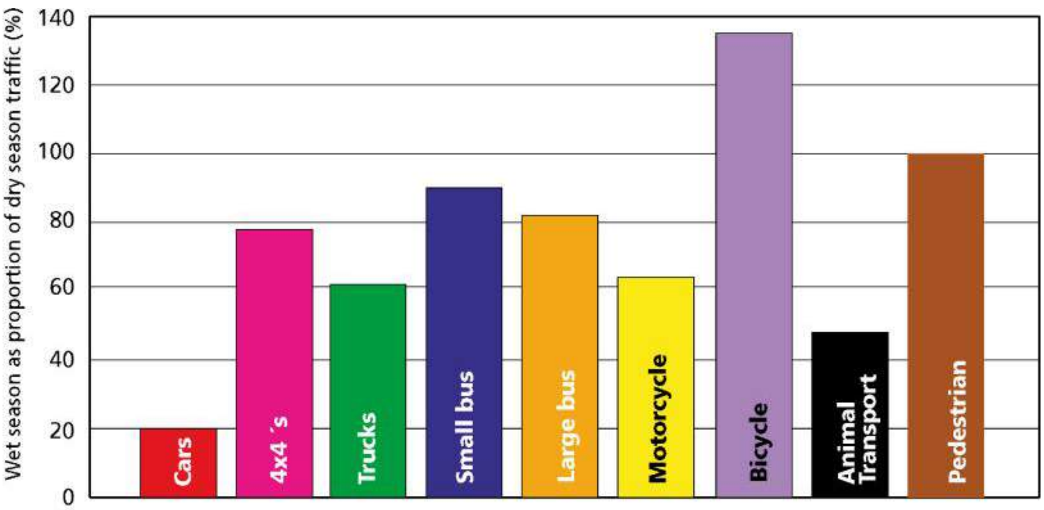

Figure 4-2: Difference in wet season and dry season traffic levels on poor quality roads
(Source: Parsley and Ellis, 2003)

An appropriate, weighted average adjustment will need to be made according to the season in which the traffic count was undertaken and the length of the wet and dry seasons, as illustrated in Figure 4-3. The Classified Traffic Count may, therefore, have to be repeated at least twice throughout the year.

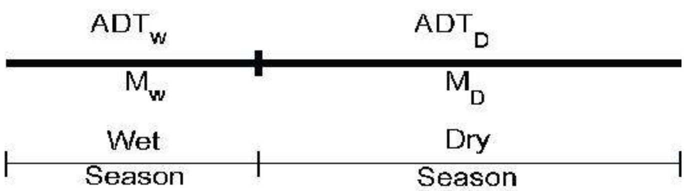

Figure 4-3: Basis for traffic count adjustment in relation to seasonal characteristics

The weighted average of the traffic count in relation to the seasonal characteristics of the region in which the counts were undertaken is obtained, as shown below.

$$Weighted\ Average\ ADT = \frac{ADT_w \times M_w}{12} + \frac{ADT_D \times M_D}{12}$$

Where: ADT_W = Average daily traffic count in wet season

ADT_D = Average daily traffic count in dry season

M_W = Number of months comprising the wet season

M_D = Number of months comprising the dry season

Example: For a wet season ADT of 240 vpd over 4 months and a dry season ADT of 360 vpd over 8 months:

Weighted Average ADT= (240 * 4)/12 + (360 * 8)/12 = 80 + 240 = 320

Location of census points

Care should be exercised in selecting 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. Thus, locations such as within villages or market places should be avoided.

If any major junctions occur along the road length, counts should also be conducted before and after the junctions.

Origin-Destination surveys

While the Classified Traffic Counts will provide information on the current traffic using the road, Origin-Destination (O-D) surveys may be required to facilitate the estimation of diverted traffic from alternative routes once the road has been improved or upgraded. Such diversion may occur due to drivers wishing to travel on a quicker or cheaper route, although this may not be the shortest. When combined with other estimates of traffic growth following a road improvement, it allows the total traffic flow to be estimated as illustrated in Figure 4-5 (page 4-8).

Origin-Destination (O-D) surveys can be undertaken using a variety of survey techniques, but are generally quite costly and may require the assistance of Traffic Police. Thus, for individual LVRR projects, it may not be feasible to undertake an O-D survey.

4.4 Traffic Growth

To determine the future traffic in each traffic class and in each direction, a forecast of future traffic must be made based on the current traffic. For many LVRRs a simple estimate based on local precedent or recent experience should be sufficient but each situation should be reviewed because traffic growth can be high, and more comprehensive analysis may be warranted. Such an analysis will require an estimate of the initial traffic when the road is completed, which will include the normal, generated and diverted traffic. For geometric design purposes, it is necessary to count non-motorized and intermediate means of transport, including pedestrians, bicycles, motorcycles, tractors and trailers and, possibly, animal transport. Growth rates for each traffic class may differ, with motorcycles growing faster than other vehicles.

1) **Normal traffic.** Traffic that would pass along the existing road or track even if no new geometry was provided. This increases naturally by virtue of normal social and economic growth.

2) **Diverted traffic.** Traffic that changes from another route (or mode of transport) to the project road because of the improved pavement, but still travels between the same origin and destination. Diverted traffic should be considered when a totally new road is to be provided or when an existing road is to be improved. To estimate the volume of diverted traffic origin-destination surveys of all junctions that adjoin to the project road are usually required, but this is usually unnecessary for LVRRs. A pragmatic approach is simply to assume that traffic will take the quickest route if the standard of the road is acceptable and not a route that provides a rough ride even if it is shorter.

3) **Generated traffic.** Additional traffic which occurs in response to the provision or improvement of the road. This is traffic generated by any additional economic growth resulting from the road. It is likely to be greater than the increase expected from normal regional economic growth. The initial volume of generated traffic can be obtained by conducting interviews with the existing road users. The interviews must focus on understanding whether upgrading the road would lead to an increased number of trips immediately. Other planning factors must also be considered. For example, if a farm is likely to increase its crop outputs as a result of improved road conditions, the extra trips generated as a result should be considered in determining the generated traffic.

There are several methods for estimating the traffic growth and each has its advantages and disadvantages, as summarised in Table 4-1. However, most are based on national statistics and a general growth figure is usually provided by the central government. The problem is that overall trends may not reflect what is likely to happen on specific LVRRs; hence the methods will not all give robust and reliable figures and some degree of judgment about the quality of the data will be required to obtain the best estimate. Local recent historical knowledge should always be used if available.

Table 4-1: Methods of estimating traffic growth

Method	Details
Local historic precedent	In some cases, annual traffic data for nearby roads, collected for a number of years might be available. The traffic data can be used to compute the traffic growth rate. The growth rate on the project road will likely be very similar to that of the adjacent or nearby roads.
Vehicle registry	The central or regional government maintains a registry of the number of vehicles registered annually; therefore, the annual traffic growth rate can be estimated from these data. However, regional or zonal data is more relevant to the project since nationwide data may not be representative of the specific project.
Weighbridges	The annual number of trucks weighed at weighbridges offers a method to estimate the growth rate related to various truck categories.
Fuel consumption trends	The government's customs department maintains records of fuel imports. Fuel imports are related to the demand, which is, in turn, related to the traffic growth rate.
Economic growth estimation	Traffic growth is closely related to the growth of the economy measured in terms of Gross Domestic Product (GDP). Economic growth rates can be obtained from government plans, and the government estimated growth figures. The growth rate of traffic should preferably be based on regional growth estimates because there can be large regional differences.
Population trends	Local population trends can also provide useful information about possible traffic growth.

4.5 Traffic Categories

4.5.1 Vehicle Classification

Table 4-2 shows an internationally-based vehicle classification system that can be used for compiling the results of the traffic survey described above.

Table 4-2: Vehicle classification system

Class	Type	Axles	Description	Use
A	Car	2	Passenger cars and taxis	Capacity analysis for geometric design
B	Pick-up/4-wheel drive	2	Pick-up, minibus, Land Rovers, Land Cruisers	
C	Small bus	2	≤ 25 seats	Capacity and axle load analysis for pavement design
D	Large bus/coach	2	> 25 seats	
E	Light Goods Vehicle	2	≤ 3.5 tonnes empty weight	
F	Medium Goods Vehicle (MGV)	2	>3.5 tonnes empty weight	
G	Heavy Goods Vehicle (HGV)	3/4	>3.5 tonnes empty weight	
H	Very Heavy Goods Vehicle VHGV)	≥4	>3.5 tonnes empty weight	
I	2-axled trailer	2	Trailers towed by MGVs HGVs or VHGVs.	
J	3-axled trailer	3		
K	4-axled trailer	4		
L	Tractor	2		
M	Motorcycles, motorcycle taxis			Capacity analysis for geometric design
N	Bicycles			
O	Other NMT			
P	Pedestrians			

The geometric design standards are modified based on the proportion of heavy vehicles in the traffic stream. The modifications depend on the road class and are described in the notes to the Tables of Standards in *Chapter 7 – Design Standards.*

4.5.2 NMT and Motorcycles

Non-motorized traffic (NMT) includes pedestrians, bicyclists and animal-drawn carts. The combined number of NMTs and motorcycles is assessed in terms of the effective road space that they occupy, as measured in terms of the Car Equivalent (CE) values presented in Table 4 3. It is important to note that, in the context of LVRRs, the use of this concept is not concerned with traffic congestion effects as such problems do not occur on LVRRs. Rather it is concerned with deciding whether the volume of these traffic categories warrants widening the carriageway or shoulders for safety reasons.

The CE concept is similar to, but not the same as, the Passenger Car Unit (PCU), which is normally used to obtain a measure of the congestion effects of NMT and motorcycles in urban/peri-urban environments.

A typical situation is an approach to a village or any other area that attracts people, for example, a village market. A dedicated pedestrian footpath is an ideal solution for improving road safety. However, the ever-growing numbers of motorcycles can present a safety problem when NMTs and motorcycles are mixed with 4-wheeled motorized traffic. The daily volumes of NMTs and motorcycles are measured using the total daily CE value. If this exceeds 300 (approximately 1200 motorcycles or 2000 pedestrians), it is recommended that consideration be given to including or widening the shoulders to improve road safety (see *Chapter 7 – Design Standards*).

Table 4-3: Car Equivalent (CE) values for mixed traffic

Vehicle	Car Equivalent Factor[1]
Pedestrian	0.15
Bicycle	0.20
Motorcycle	0.25
Bicycle with trailer	0.35
Motorcycle taxi	0.40
Motorcycle with trailer	0.45
Small animal-drawn cart	0.70
Bullock cart	2.0
All based on a passenger car = 1.0	

4.6 Determination of Design Traffic

4.6.1 General

The procedure for determining the traffic for geometric and pavement design purposes is essentially the same as summarized in and explained below. The traffic analysis for pavement design cannot be separated from the analysis for geometric design since the geometric design requirements and, ultimately, the selection of a road class and cross-section width will influence the traffic load lane distribution. The analysis for geometric and pavement design purposes should, therefore, always be carried out together.

4.6.2 Procedure

The procedure for determining the mid-life traffic and selection of road class is confined to Steps 1 to 4, as illustrated in Figure 4-5 and described below.

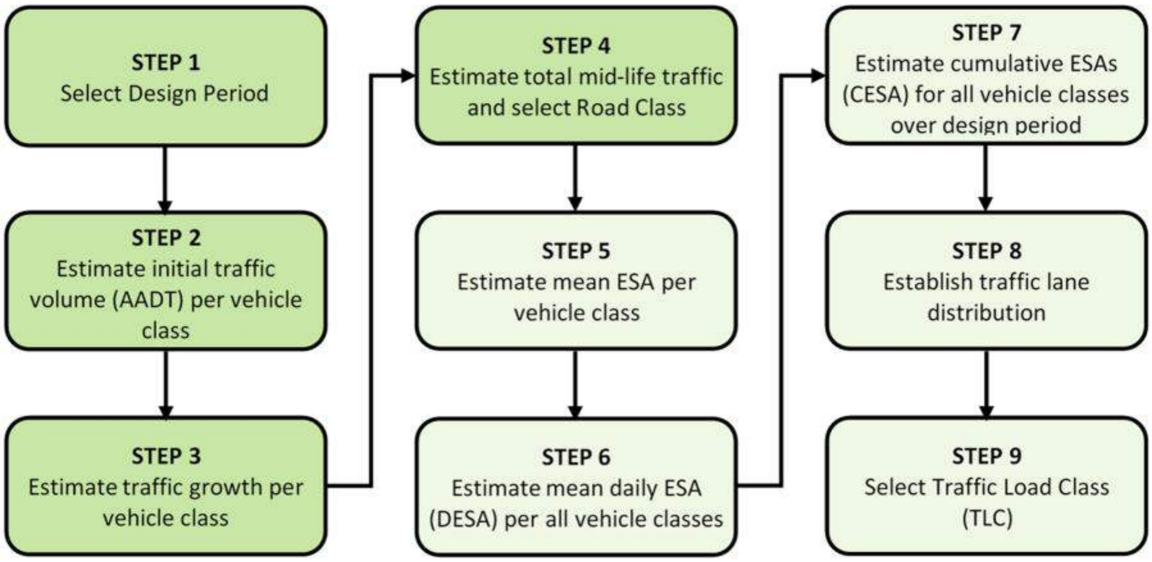

Figure 4-4: Procedure for selection of road class

Step 1: Select Design Period

The design period of the LVRR provides the basis for estimating the mid-life traffic volume for geometric design purposes.

Step 2: Estimate Initial Traffic Volume per Vehicle Class

Based on the traffic surveys described in Section 4-3, the initial traffic volume for each vehicle class can be determined. For structural design purposes, it is only the commercial vehicles in classes D to K inclusive (refer to Table 4.2) that will make any significant contribution to the total number of equivalent standard axles. However, in contrast, for geometric design purposes, it is necessary to count all traffic, including motorcycles, tractors and trailers etc. as well as and non-motorized traffic including bicycles, animal-drawn carts, and pedestrians.

Step 3: Estimate Traffic Growth per Vehicle Class

Following the establishment of the baseline traffic, further analysis is required to establish the total design traffic based on a forecast of traffic growth in each vehicle class. To forecast such growth, it is first necessary to sort traffic in terms of the following categories as described previously in Section 4.4:

- Normal traffic
- Diverted traffic
- Generated traffic

Estimating traffic growth over the design period is very sensitive to economic conditions and prone to error. It is, therefore, prudent to assume low, medium and high traffic growth rates as an input to a traffic sensitivity analysis for geometric design purposes as described below.

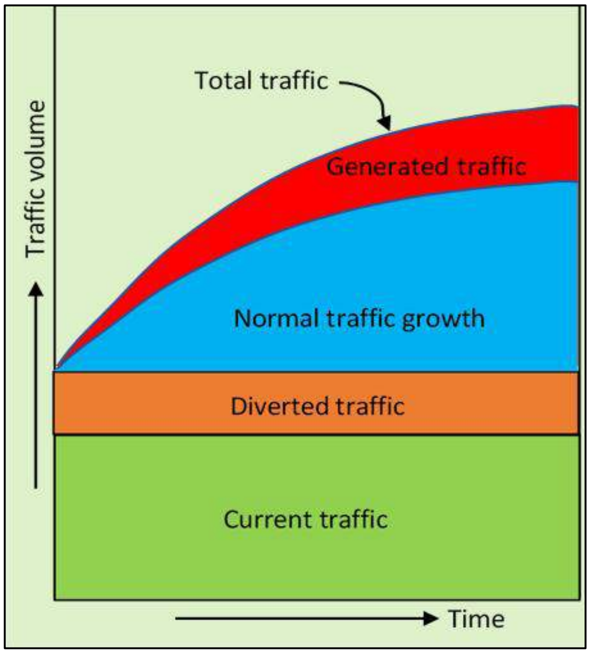

Figure 4-5: Traffic development on an improved road

The growth rate of each vehicle class may differ considerably. Traffic by Light Goods Vehicles, for example, are usually growing at a faster rate than that of Heavy Goods Vehicles, and this should be taken into account when estimating the traffic loading.

There are several methods for estimating traffic growth, as presented in Table 4-1.

It should be born in mind that both geometric design classes and structural design classes are quite wide in terms of traffic range, typically a range of 100% or more, hence the precision required of traffic estimation is not high. A common method of choosing the design traffic is simply to estimate the initial traffic, including diverted and generated traffic, and to accommodate traffic growth by choosing the next higher road class for both geometric and structural design. It can be seen from the traffic ranges in Table 2-2 in *Chapter 2 – Approach to Design*, that this is equivalent to increasing the traffic by a factor of about two or a traffic growth rate of about 8%.

Step 4: Estimate total mid-life traffic and select Road Class

The AADT in both directions in the first year of analysis consists of the current traffic plus an estimate of the generated and diverted traffic. Thus, if the total traffic is denoted by AADT and the general growth rate is **r** per cent per annum, then the traffic in any subsequent year, **x**, is given by the following equation:

$$AADT_X = AADT_0 \times \left(1 + \frac{r}{100}\right)^X$$

This is illustrated in Figure 4-6, which shows the multiplier for the AADT in the first year of analysis to obtain the AADT in any other year.

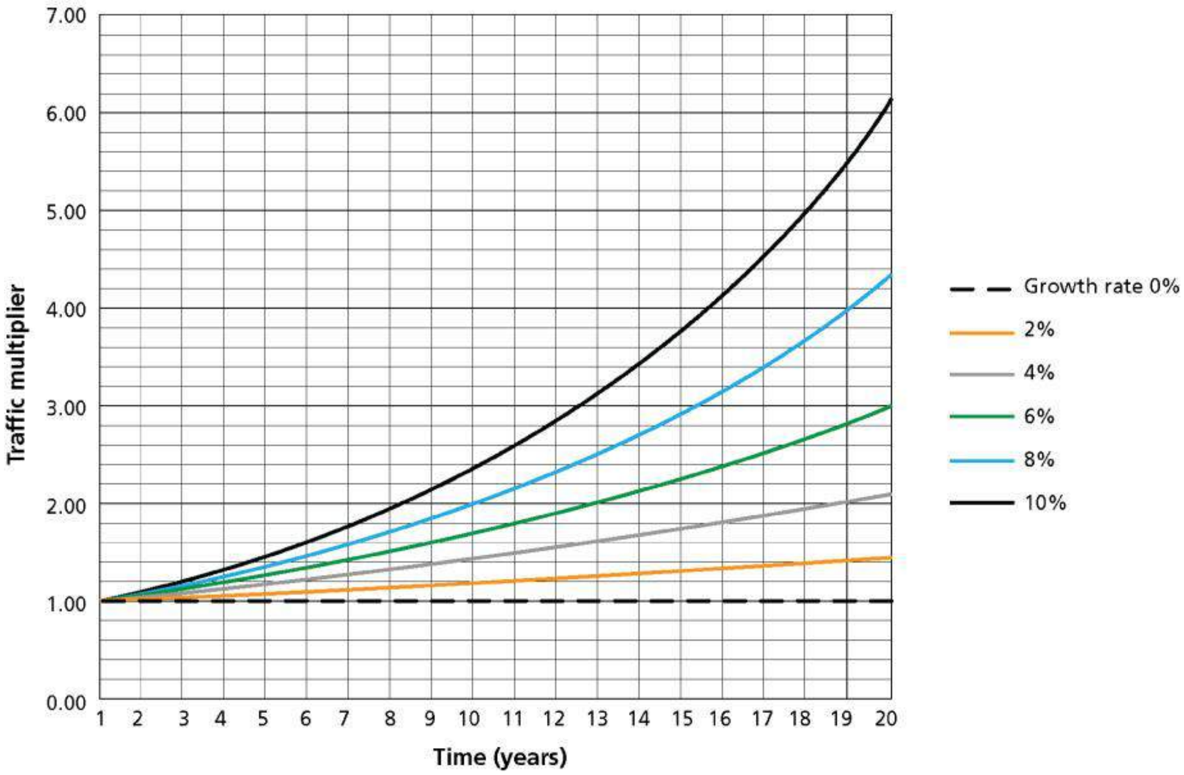

Figure 4-6: Multiplier to obtain AADT in any year for different growth rates

Sensitivity analysis: For the final selection of the Road Class, it is prudent to carry out a sensitivity analysis in order to cater for:

- Different traffic growth rate scenarios.
- The likelihood of future developments in the area, e.g., new industry, mining operations, agricultural development, new road projects, etc., which have not already been accounted for in the traffic growth estimates.

If the estimated mid-life traffic, based on the current assumptions, is close to the upper boundary of LVRR class, and the sensitivity analysis indicates that the upper boundary may be exceeded, it may be prudent to assume the next higher road class and to assess the impact of this on the geometric design. This impact may be negligible if the required material quality is readily available, or significant if the higher TLC would require longer haulage distances or modification of the materials available in the vicinity of the road.

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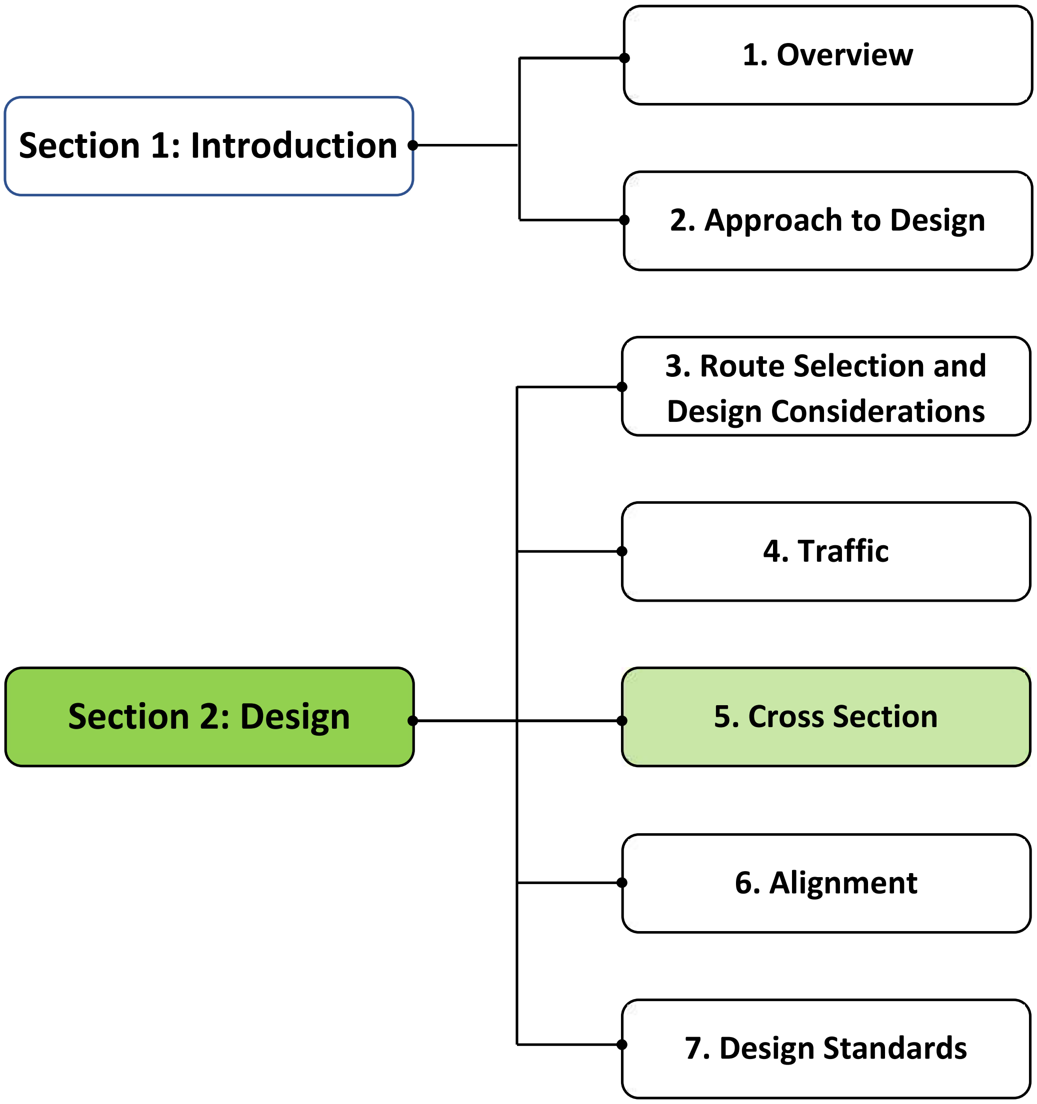

Chapter 5 – Cross Section

Contents

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5.1 Introduction

5.1.1 Background

The cross-sectional dimensions of a road, particularly it's carriageway and shoulder widths, have a significant impact on construction costs and should be minimized subject to operational and safety considerations. Generally, widths are closely related to the classification of the road and are influenced by the controls and criteria described in *Chapter-3 – Route Selection and Design Considerations.* This means that the cross section may vary over a particular route because the controlling factors are varying.

As discussed in *Chapter 2 – Approach to Design,* Section 2.5.3 and illustrated in Figures 2-3 to 2-6, on LVRRs there is a relatively small probability of vehicles meeting, and the manoeuvres can be undertaken at very reduced speeds. Thus, it would not be cost-effective to adopt cross-section widths that are typically used on roads designed for higher traffic levels and serve a mobility function with a much higher incidence of vehicles passing each other in opposite directions.

Of particular importance to LVRRs is catering simultaneously for the requirements of motorized as well as non-motorised traffic (NMT). In some circumstances, it is necessary to consider cost-effective ways of segregating these various types of road users within an appropriately designed cross section. For example, relatively wide shoulders might need to be considered in some mixed traffic situations.

5.1.2 Purpose and Scope

The purpose of this chapter is to provide guidelines for the selection of the various elements that comprise the cross section of a LVRR in order to attain the overall objectives of providing "fit-for-purpose" rural access roads at a reasonable cost.

Each road should be designed in accordance with its specific requirements and no designs will be exactly the same. Thus, instead of prescribing exact design parameters, guidelines are given on ranges within which acceptable designs can normally be accommodated. This provides the required flexibility to adapt the design to the different traffic volumes and compositions and terrains as well as the provision of access with limited budgets.

This chapter addresses all the cross-sectional elements of a typical LVRR including carriageway and shoulder, right-of-way, camber and crossfall, side slopes and low embankments.

5.2 Cross-section Elements

5.2.1 Terminology

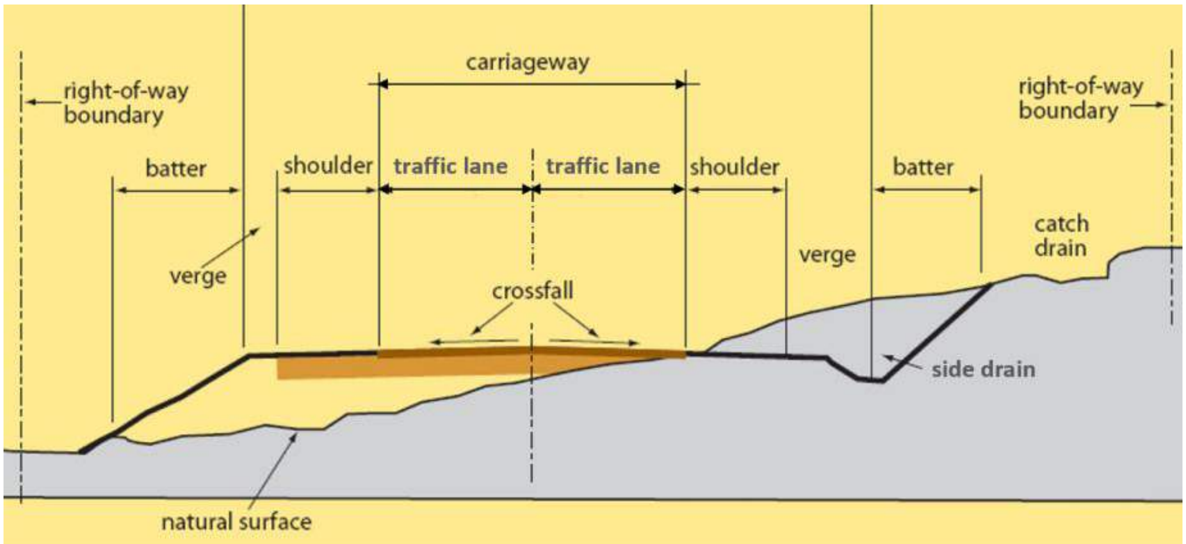

Figure 5-1: Elements of road cross section

5.2.2 Road Width

The LVRR classes and the associated basic cross-section parameters are summarised in Table 5-1 and take account of the following factors:

- **Classification of the road**: The higher the class of road, the higher the level of service expected and the wider the road will need to be.
- **Traffic**: As the traffic volumes increase from class LVRR 1 to LVRR 5, there will be more frequent passing manoeuvres, and therefore, the vehicles will be further from the centreline of the road. As a consequence, the carriageway needs to be wider.
- **Vehicle speeds**: As speeds increase, drivers have less control of the lateral position of vehicles, reducing the required clearances, and so a carriageway is needed.

Full details of the design parameters are shown in the Tables in *Chapter 7 – Design Standards*.

Table 5-1: LVRR Road Classes and associated basic design parameters

Label	Design Criterion	Design Classes				
		LVRR 1	LVRR 2	LVRR 3	LVRR 4	LVRR 5
	Mid-life traffic (AADT)	<50	50-150	150-250	250-350	>350
A	Carriageway width[1] (m) (minimum)	3.5	3.5-4.5	4.5-5.5	5.5-6.5	6.5
B	Shoulder width (m), unpaved	0.50[2]	0.50[2]	n/a	n/a	n/a
	Shoulder width (m), paved, CE>300	n/a	n/a	0.5[3]/1.0-2.0[4]	1.0- 2.0[4]	1.0-2.0[4]
	Camber/crossfall (%) (Paved/Unpaved)[5]	3.0/5.0				
	Shoulder crossfall (%) (Paved/Unpaved)	3.0/5.0				
D	Back slope of drain (v:h ratio)	See Table 5-2				
E	Side slope of drain (v:h ratio)	See Table 5-2				
F	Depth of side drain (m)	Varies				
G	Side slope (v:h ratio)	See Table 5-2				
H	Crown height (m)	Desirable minimum = 0.75; Decreased if grade >1.0% and/or if drain is lined (see Voume 1, Table 9-3)				
J	Cleared width (m)	Desirable A + 2xB +6 (Figure 5-1)				
K	Embankment toe (m)	Varies				
L	Drain width (trapezoidal drain) (m)	Minimum 0.60, varies according to required hydraulic capacity				
	Right of way (recommended)	Secondary Roads: 30 m, Tertiary roads: 20 m				

Notes:

1. The widths of the travelled way and shoulders in Table 5-1 are not prescriptive in that:
   a. They provide ranges within which the designer can select the most appropriate width according to terrain type and difficulty of construction (see tables in *Chapter 7 – Design Standards*).
   b. In flat/rolling terrain the larger widths will normally be provided whereas in steep and mountainous terrain the narrower widths may be used in combination with local widening or passing bays, if so required.
2. On road classes LVRR 1 and LVRR 2, where passing bays are not provided, the minimum width of the roadway will be 4.5 m comprising a carriageway of 3.5 m and 2 x 0.50 m unpaved shoulders.
3. On road class LVRR3, when a 4.5 m carriageway width is adopted, 2 x 0.50 m paved shoulders should be considered on curves and at other appropriate locations to provide a roadway width of 5.5 m which will accommodate the occasional passing of large vehicles.
4. On road classes LVRR 4 and LVRR 5, the carriageway widths recommended are adequate for accommodating mixed traffic with a Car Equivalency (CE) < 300 (see Chapter 4, Table 4.3). Paved shoulders of varying width (depending on particular circumstances) are required when the CE > 300.
5. A camber of 3.0% is recommended on paved roads. Although steeper than traditional requirements, it facilitates more efficient shedding of rainwater on relatively narrow carriageways, accommodates construction tolerances of ±0.5% (taking into account the skills and experience of small-scale contractors and Labour Based Methods (LBM) of construction), and does not adversely affect driving conditions on LVRRs.

The typical cross sections for each terrain type are basically the same for both paved and unpaved roads, the only difference being that the surfacing indicated on Figure 5-2 to Figure 5-5 will not be there on the unpaved roads (Table 5-1 explains the symbols).

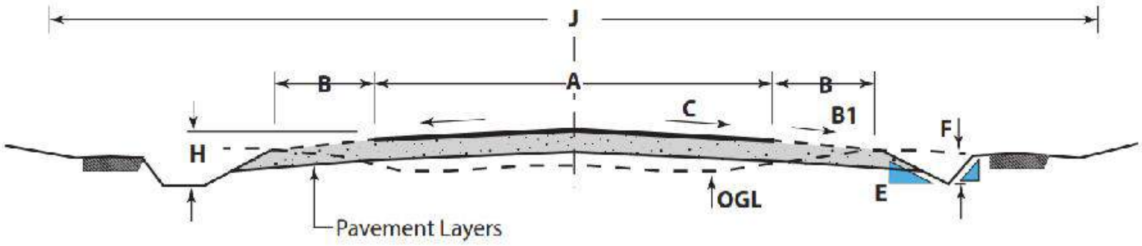

Figure 5-2: Typical cross section in flat terrain

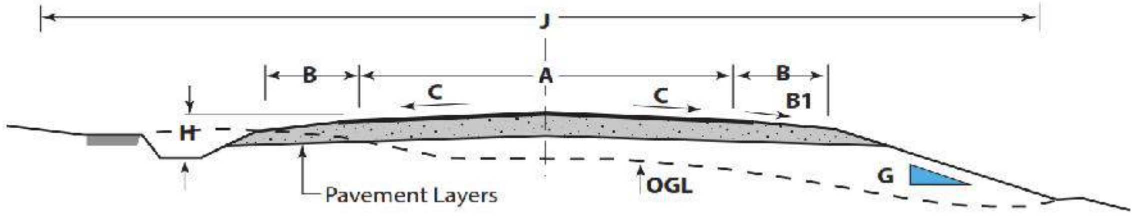

Figure 5-3: Typical cross section in rolling terrain

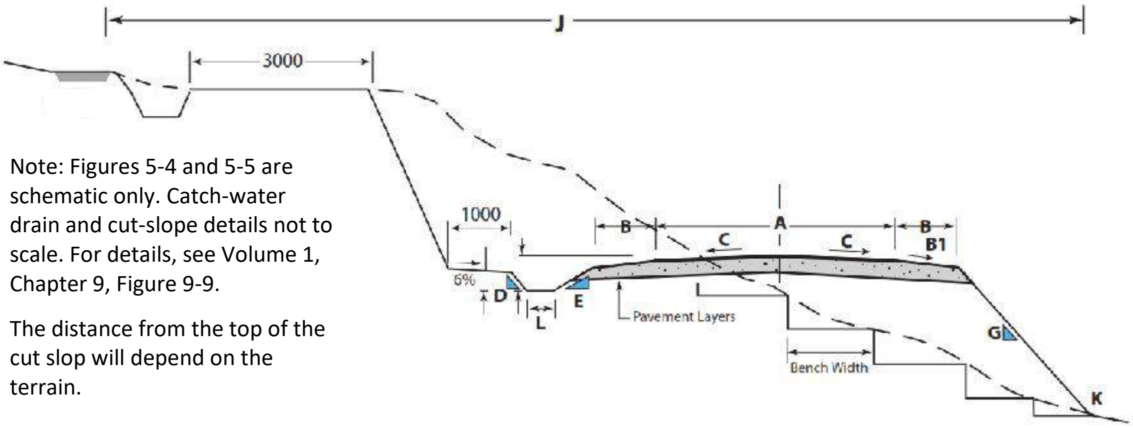

Figure 5-4: Typical cross section in mountainous terrain

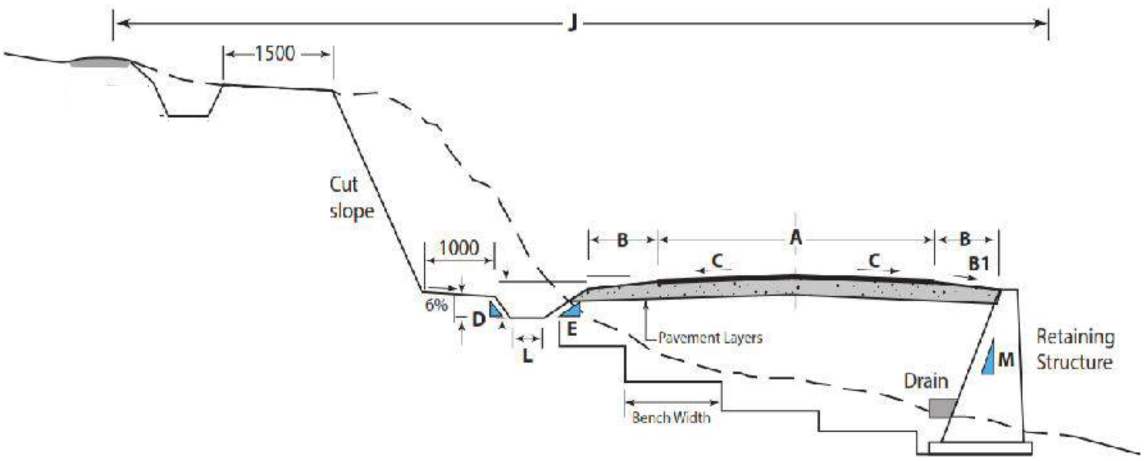

Figure 5-5: Typical cross section for escarpment terrain

Notes to Figure 5-4 and Figure 5-5:

1. For cut slopes refer to Table 5-2.
2. For details on the use of interceptor and cut-off drains see *Volume 1, Chapter 9 – Drainage and Erosion Control*.
3. Cross sections can be in either full fill, full cut or a combination of the two in varying proportions as determined by topography, alignment and underlying geology. Retained full fill is shown here for convenience.

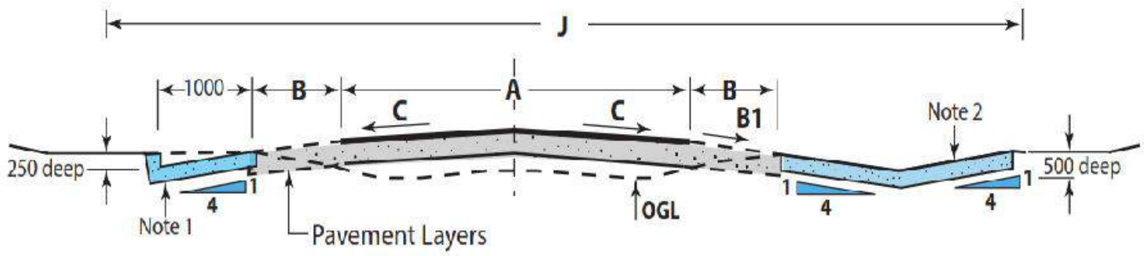

Figure 5-6: Typical cross section for populated areas

Notes to Figures 5 and 6:

1. Open channel Type A – 250 mm thick mortared stone pitching.
2. Open channel Type B – 250 mm thick mortared stone pitching.
3. Choice of open channel dependent on local conditions.
4. Surfacing of shoulder required on paved roads if the side drains are lined.
5. Provide lined channels only where maintenance of road surface and camber at original levels is guaranteed.

5.2.3 Right-of-way

Right-of-way (or the road reserve) is provided to:

- accommodate road width and the drainage requirements;
- provide space for services (water, electricity etc.);
- provide space for self-recovery of run-off road incidents
- enhance safety;
- improve the appearance of the road;
- provide space for non-road travellers; and
- provide space for upgrading and widening in the future.

The width of the right-of-way is shown in Table 5-1. It is important that the right-of-way is strictly enforced to avoid problems in the future when space may be required for upgrading and widening.

5.2.4 Side Slopes and Clear Zone

From a road safety perspective, side slopes should be designed to provide a reasonable opportunity for recovery if a vehicle goes out of control across the shoulders.

Clear zone: The clear zone is the traversable area that starts at the edge of carriageway, includes the shoulder and side slopes, and extends laterally a sufficient distance to allow a driver to stop or return to the road before encountering a hazard or overturning.

Figure 5-7 illustrates the various elements of a typical road cross section, including the clear zone area. The side slope can be characterized in one of three ways:

- Recoverable
- Non-recoverable, but traversable
- Critical

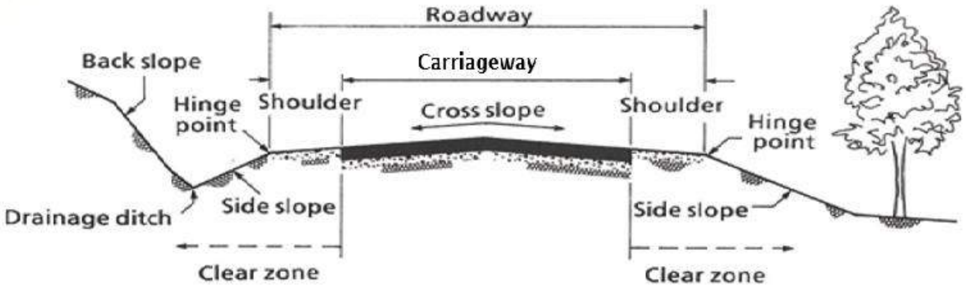

Figure 5-7: Details of road cross section elements

Recoverable: The side slope is defined as 'recoverable' when drivers can generally stop their vehicles or slow them enough to return to the roadway safely. Side slopes of 1:4 or flatter and back slopes of 1:3 or flatter are considered recoverable. Where feasible, recoverable slopes should be provided within the clear zone. Research has also shown that "rounding off" at the hinge point and at the toe of the slope is also beneficial.

Non-recoverable, but traversable: A non-recoverable slope is defined as one that is traversable, but from which most drivers will be unable to stop safely or return to the roadway easily. Such slopes will not cause a vehicle to overturn. Traversable side slopes between 1:3 and 1: 4 are generally non-recoverable. On slopes between 1: 3 and 1: 4, many vehicles will continue to the bottom. Because of this, a clear zone (runout area) at least 3 m wide, is needed beyond the toe of non-recoverable slopes.

Critical: A critical slope is one on which a vehicle is likely to overturn. Side and back slopes steeper than 1:3 are considered critical. If a slope steeper than 1:3 begins closer to the carriageway than the suggested clear zone width, a barrier may be warranted.

The slope dimensions for and safety classification are shown in Table 5-2.

Selection of the side and back slopes is often constrained by topography, embankment and/or cut heights, drainage considerations, right of way limits and available budgets. For rehabilitation and upgrading projects, additional constraints may be present such that it may be very costly to comply fully with the recommendations provided in Table 5-2.

Table 5-2: Slope dimensions and safety classification

Fill slopes (V:H)	Cut slopes (V:H)	Safety classification
1:4 or flatter	1:3 or flatter	Recoverable
1:3 – 1:4		Non-recoverable, but traversable
Steeper than 1:3		Critical

It should be noted that the recommended slope dimensions in Table 5-2 are purely from a road safety perspective. However, the dimensions from a geotechnical perspective, i.e. in terms of slope stability, may be steeper, as discussed in *Volume 1: Pavement Design – Chapter 5: Geotechnical Investigations* (Table 5-2). Thus, the design will have to strike a sensible balance between road safety and slope stability, with more emphasis on road safety on the higher LVRR classes, LVRR 4 and 5, where speeds are generally higher than on the lower classes.

5.2.5 Side Drains

Detailed information concerning side drains is provided in Volume 1, *Chapter 8 – Hydrology and Drainage Structures*.

Depending on the method of construction, the side drains may be either v-shaped (if lined) or trapezoidal. Trapezoidal drains are preferable because they have greater hydraulic capacity and tend to scour less than v-drains.

Substantial side drains should be avoided when the road traverses areas of expansive clays, with a preference for the roadway to be constructed on a low embankment. Water should be discharged uniformly along the road. Where side drains cannot be avoided, they should be a minimum distance of 4 m from the toe of the embankment and should be shallow and trapezoidal in shape.

5.2.6 Shoulders, Flush Kerbs and Edge Beams

The functions of shoulders include:

- Giving structural support to the carriageway.
- Allowing wide vehicles to pass one another without causing damage to the carriageway or shoulder.
- Providing extra room for temporarily stopped or broken-down vehicles.
- Allowing pedestrians, cyclists and other vulnerable road users to travel in safety.
- Limiting the penetration of water into the pavement.

On paved roads, the whole roadway width should normally be sealed, whether shoulders are provided or not.

Gravel shoulders tend to be badly maintained and can pose a serious danger to traffic (edge drop) and trap water that will penetrate into the pavement layers. The level of maintenance available, to a large extent, will determine whether shoulders are to be paved or not.

As much as provision of shoulders may be desirable, it may not always be economically feasible and strictly warranted in very low traffic situations. Other than in populated areas with high CE values, shoulders are generally not recommended on LVRRs. Where shoulders are not provided, other means of providing lateral support, and for protecting the edge of the sealed surface, must be provided.

It is important to ensure even and proper compaction right to the edge of the roadway by initially constructing it slightly wider than the specified width and trim the side slope off with a rounded shape over, say, the first 1.0 m from the edge of the seal. This assists in reducing erosion of the side slope.

Other means of giving lateral support and protecting the edge of the surfaced area include a method that has been used extensively in the past, namely to provide flush kerb stones which may be set in mortar or just properly embedded in the top of the side slope (see Figure 5-8). Such protection should always be provided where vehicles would regularly turn off a paved surfacing onto the shoulder.

Severe edge breaks constitute a major maintenance problem and selective use of kerbs or edge beams will thus contribute to reduced maintenance requirements and enhanced road safety.

Where minor accesses join the road or on sections with frequent “off carriageway” driving or parking occurs, concrete edge beams or flush kerb stones should be used to protect the edge of the surfacing.

Experience has shown that severe edge breaks also occur where commonly used footpaths cross the road. When these are clearly defined at the time of construction, short kerbed sections or edge beams will prevent this from happening.

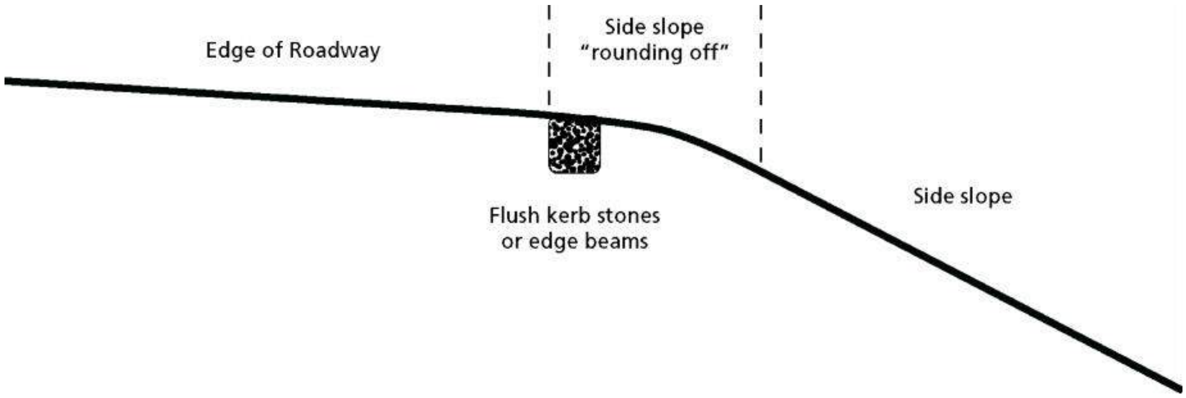

Figure 5-8: Side slope "rounding off" and location of flush kerb stones or edge beams

5.2.7 Single Lane Roads and Passing Bays

Single lane roads are commonly used on very low volume roads (LVRR 1) where it would not be economically justifiable to provide a higher standard facility. Such roads permit two-way traffic but are not wide enough in most places to allow vehicles to pass one another. However, single-lane operation is adequate as there will only be a small probability of vehicles meeting, and the few passing manoeuvres can be undertaken at reduced speeds using either passing bays or local widening, especially at bends.

The recommended single lane travelled way width is 3.5 m. Where feasible, 0.50 m unpaved shoulders may be considered to provide a carriageway of 4.5 mm which is sufficient to cope with the expected traffic and occasional meeting occurrences on these roads. Alternatively, passing bays, as illustrated in Figure 5-9, may be provided. The combined width of the carriageway and passing bay shall be 5.5 m over a length of 5 m (or 10 m where likely to be used by buses or single-axle trucks). 5 m tapers should be provided at each end of the passing bay. Local widening at bends must be determined on a case-by-case basis.

Figure 5-9: Single lane road with passing bay

Passing bays should normally be provided every 300 m to 500 m depending on the terrain and geometric conditions. Care is required to ensure good sight distances and the ease of reversing to the nearest passing bay, if required. Passing bays should be provided at the most convenient/ practicable places rather than at precise intervals provided that the distance between them does not exceed the recommended maximum. Ideally, there should be a clear view from one passing bay to the next.

The same approach for dealing with LVRR 1 roads, as discussed above, is also recommended for LVRR2 and LVRR 3 roads, where local widening at selected, conveniently located sections of about 25 m length will adequately accommodate the relatively few vehicle interactions.

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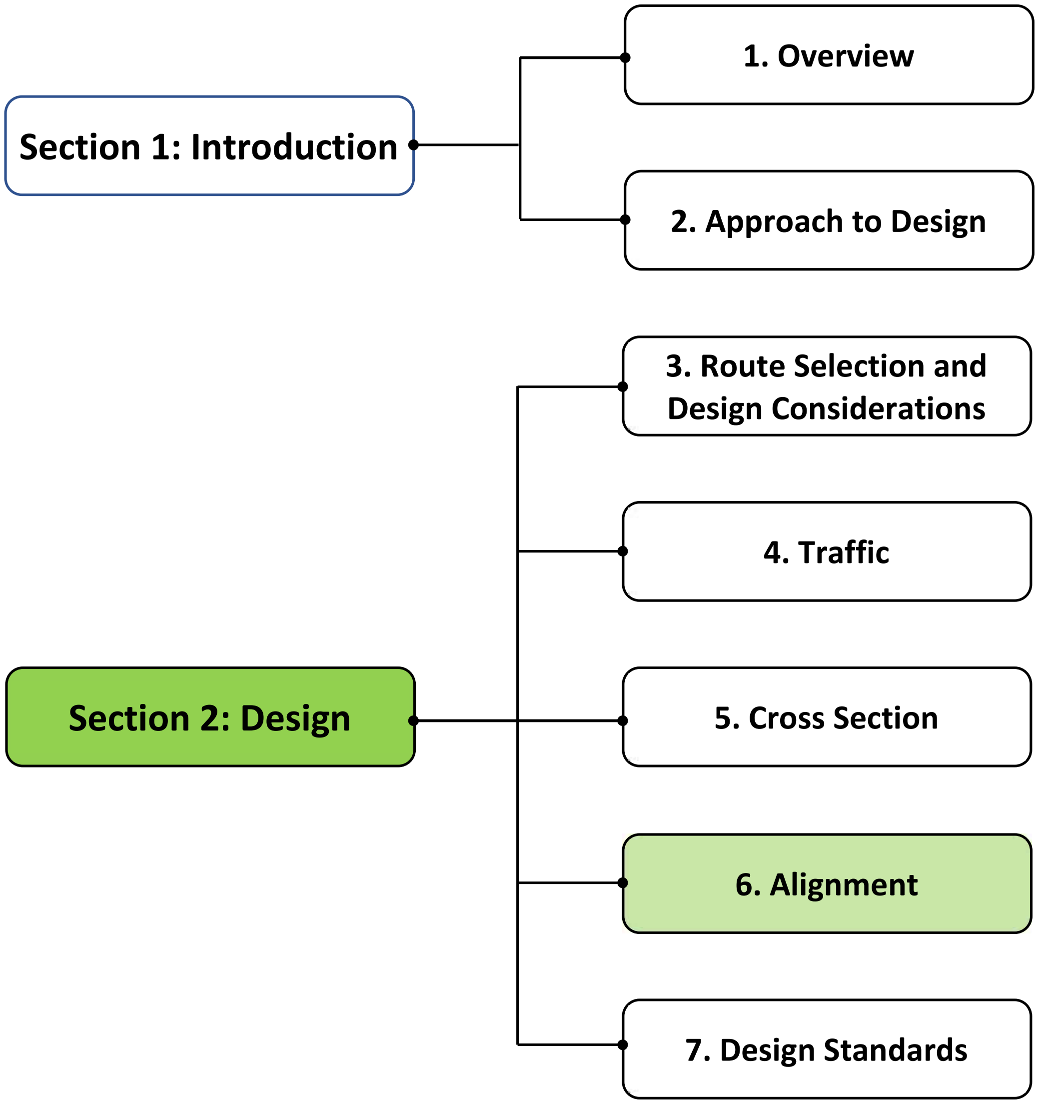

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6.1 Introduction

6.1.1 Background

The design of the road alignment is concerned with selecting the parameters of the geometric features of the road so that they provide a safe, comfortable and efficient means for transporting people and goods. The principal components are the horizontal alignment, which is essentially the road in plan, and the vertical alignment, which is the road in longitudinal profile. Thus, designing the road alignment is primarily concerned with the application of methods of achieving safety and efficiency in the road transport system.

However, for LVRRs designed for access rather than mobility, speed and efficiency are not the primary concerns. For the Option A design method described in *Chapter 3 – Fundamental Design Considerations*, in which an existing alignment is used as much as possible provided that safety concerns are fully addressed, the primary criterion is to provide an all-weather road that is safe.

If Option B for design is selected, then the relationships between safe speed and geometry become very important. Design speed controls many aspects of the alignment, and the resulting design standards are driven primarily by safety requirements. Although the calculations required for the Option B method are not specifically required for Option A, understanding the safety issues that are comprehensively dealt with under Option B is also essential for Option A because every element of the alignment must be checked for safety. For example, adequate sight distances are required for both Option A and Option B designs, but sight distance requirements can be reduced with the installation of appropriate speed reducing and other measures to avoid costly re-alignments.

6.1.2 Purpose and Scope

The purpose of the chapter is to discuss the application of horizontal and vertical alignment principles to form, together with cross-sectional elements, safe and efficient LVRRs. The vertical slopes and horizontal curves of the road must satisfy certain criteria based on how vehicles and humans interact with them. Some of these are specific to either horizontal or vertical alignment while some are common to both.

The chapter covers the various criteria and how they should be applied. Once the criteria have been defined, they are used to design the horizontal alignment and the vertical alignment.

6.2 Design Speed and Geometry

6.2.1 General

Design speed has been introduced in *Chapter 3 – Fundamental Design Considerations*, Section 3.9. It is defined as the maximum safe speed that can be maintained over a specified section of the road when conditions are so favourable that the design features of the road govern the speed. In practice, this comes down to the 85th percentile of operating speeds as observed for the particular design speed.

The concept of design speed is most useful because it allows the key elements of geometric design to be selected for each standard of the road in a consistent and logical way. For example, design speed is relatively low in mountainous terrain to reflect the necessary reductions in standards required to keep construction costs to manageable proportions. The speed is higher in rolling terrain and higher still in flat terrain.

In practice, the speed of motorized vehicles on many roads in flat and rolling terrain will only be constrained by the road geometry over relatively short sections, but it is important that the level of constraint is consistent for each road class and set of conditions.

In view of the mixed traffic that occupies rural roads and the cost-benefit of selecting lower design speeds, it is prudent to select values of design speed towards the lower end of the internationally acceptable ranges. The recommended values are shown in the tables in Chapter 7 – *Design Standards*.

Changes in design speed, for whatever reason, should be made over distances that enable drivers to change speed gradually. Thus, changes should never be more than one design step at a time and the length of the sections with intermediate standards (if there is more than one change) should be long enough for drivers to realize there has been a change before another change in the same direction is encountered. Where this is not possible, warning signs should be provided to alert drivers to the changes.

6.2.2 Stopping Sight Distance

To ensure that the design speed is safe, the geometric properties of the road must meet certain minimum or maximum values to ensure that drivers can see far enough ahead to carry out normal manoeuvres, such as overtaking another vehicle or stopping if there is an object in the road.

The distance a vehicle requires to stop safely is called the stopping sight distance (SSD). It mainly affects the shape of the road on the crest of a hill (vertical alignment), but if there are objects near the edge of the road that restricts a driver's vision on approaching or in a bend, SSD requirements also affect the horizontal curvature.

The driver must be able to see any obstacle on the road; hence the stopping sight distance depends on the size of the object and the height of the driver's eye above the road surface (Table 6-1).

Table 6-1: Parameters Values Used for Calculating Sight Distances

Characteristic	Value
Car driver's eye height	1.05 m
Truck drivers eye height	1.8 m
Height for Stopping Sight Distance for general objects in the road	0.2 m
Height for Stopping Sight Distance for flat objects in the road (e.g. potholes, wash-out)	0.0 m
Height for Stopping Sight Distance for a vehicle in the road	0.6 m
Object height for Passing Sight Distance (e.g. roof of a car)	1.3 m
Object height for Decision Sight Distance	0.0 m
Driver's reaction time	2.5 s
The maximum deceleration rate for cars	3.0 m/s^2
The maximum deceleration rate for trucks	1.5 m/s^2
Friction between tyres and road surface	Appendix A1-3
The gradient of the road	Appendix A1-3

The driver needs time to react and then the brakes of the vehicle need time to slow the vehicle down, hence stopping sight distance is extremely dependent on the speed of the vehicle. The surface characteristics of the road also affect the braking time, so the values for unpaved roads differ from those of paved roads, although the differences are small for design speeds below 60 km/h.

The stopping distance also depends on the gradient of the road as it is harder to stop on a downhill gradient than on a flat road because the momentum of the vehicle acts down the gradient in the opposite direction to the frictional forces that are attempting to stop the vehicle.

Full adherence to the required sight distances is essential for safety reasons. Thus, on the inside of horizontal curves, it may be necessary to remove trees, or other obstacles in the road reserve to ensure adequate lines of sight. If this cannot be done, the alignment must be changed. In rare cases where it is not possible, a change in design speed is necessary, and adequate and permanent signage must be provided. Lines of sight should never go outside the road reserve and preferably should remain between the shoulder breakpoints because vegetation grows back and maintenance teams are often unaware of clearances for sight distance purposes.

Recommended stopping sight distances for paved and unpaved roads in flat terrain and at different design speeds are shown in Table 6-2 and in the detailed design Tables in *Chapter 7 – Design Standards.*

Table 6-2: Stopping Sight Distances (m)

Design speed (km/h)	20	30	40	50	60	70	80
Unpaved roads (1)	20	30	50	70	95	125	160
Paved roads (1)	18	30	45	65	85	110	135

Note: (1) In rolling and mountainous terrain these distances should be increased by 10%.

6.2.3 Stopping Sight Distance for Single Lane Roads (Meeting Sight Distance)

Many LVRRs are single lane roads, and many are quite straight for long stretches. Drivers will drive fast and well in excess of the design speed of the road or of any posted speed limits. Although vehicles travelling in opposite directions meet each other quite rarely (Section 2.2) it is dangerous if the drivers cannot see each other sufficiently early to slow down. Adequate sight distances must always be provided to allow vehicles travelling in the opposite direction to see each other and to stop safely, if necessary. The meeting sight distance must be set to twice the stopping sight distance because two vehicles travelling in opposite directions are involved.

There are several solutions;

1) The meeting sight distance can be enhanced by removing obstacles to vision such as trees and bushes rather than cutting vegetation back (which is only a temporary solution);
2) An extra safety margin of 20-30 m is added. Although a vehicle is a much larger object than is usually considered when calculating stopping distances, these added safety margins are used partly because of the very severe consequences of a head-on collision, and partly because it is difficult to judge the speed of an approaching vehicle, which could be considerably greater than the design speed;
3) Signposts can be erected in an attempt to slow the traffic down, but this is unlikely to be effective even if travelling faster than the posted limit is illegal;
4) Vehicles could be forced to slow down by introducing speed humps on the approach to the point where sight vision is necessary. This is not a popular solution, and the speed humps must be maintained in good condition, and their position signposted clearly;
5) The road could be widened sufficiently to become a two-lane road for the meeting sight distance so that the crossing vehicles are not in the same road space and cannot strike each other.

6.2.4 Sight Distance on Crest Curves

Providing adequate sight distances on crest curves can be accomplished by reducing the slopes of one or both of the approaches to the summit, but this would usually require considerable earthworks and be very costly. The situation is similar to the problem on single-lane roads described in Section 6.2.2 in that a head-on collision is very serious indeed. The safe solution is to widen the road space sufficiently so that opposing vehicles do not occupy the same road space. Single lane roads will need to become two-lane roads for the required distance. Suitable road markings are required to help direct traffic. On two-lane roads, although not strictly necessary, it is prudent to widen the shoulders to:

- Accommodate NMTs;
- Provide an additional safety margin to accommodate any sudden swerving movements resulting from the habit of many drivers driving along the centre line on LVRRs.

6.2.5 Intersection Sight Distance

Intersection sight distance is similar to stopping sight distance except that the object being viewed is another vehicle that may be entering the road from a side road or crossing the road at an intersection. The required safe sight distance for trucks, measured in metres, is about 3 times the vehicle speed in km/hr. On straight sections of road, many vehicles will exceed the road's design speed but, being straight, sight distances should be adequate.

6.2.6 Passing Sight Distances

Factors affecting the safe sight distances required for overtaking are more complicated because they involve the capability of a vehicle to accelerate and the length and speed of the vehicle being overtaken. Assumptions are usually made about the speed differential between the vehicle being overtaken and the overtaking vehicle, but many road authorities have simply based their standards on empirical evidence.

For single-lane roads, overtaking manoeuvres are not possible and passing manoeuvres take place only at the designated passing places or laybys. On the lower classes of 2-lane roads, passing sight distances (PSD) are based on the distance required for a vehicle to safely abort a passing manoeuvre if another vehicle is seen approaching in the opposite direction. These distances are shown in Table 6-3. They are considerably shorter than required to complete an overtaking manoeuvre.

Table 6-3: Passing Sight Distances to Allow Safe Abortion of Passing Manoevre (m)

Design speed (km/h)	**30**	**40**	**50**	**60**	**70**	**80**
Recommended values	115	135	155	180	210	240

6.2.7 Passing Opportunities

Passing Sight Distance is a desirable requirement for two-lane single carriageway roads. Sufficient visibility for passing increases the capacity and efficiency of a road and should be provided for as much of the road length as possible within financial limitations. Ideally, passing opportunities should be available based on the road hierarchy, as indicated in Table 6-4. The percentage is the percentage length of road that provides sufficient passing opportunities at the design speed. For example, since the PSD at 80 km/h is 550 m, an alignment giving a 50% passing opportunity means that one passing opportunity will occur every 1100 m on average. If these percentages cannot be physically or economically achieved in a particular stretch of road, its level of service should be locally evaluated to verify whether special provision (e.g. a passing or climbing lane) should be provided.

Table 6-4: Minimum Provision of Passing Sight Distance (%)

<table>
<tr><th rowspan="2">Design Standard</th><th colspan="5">Percent Passing Opportunity and Terrain</th></tr>
<tr><th>Flat</th><th>Rolling</th><th>Mountainous</th><th>Escarpment</th><th>Urban/Peri-Urban</th></tr>
<tr><td>LVRR 5</td><td rowspan="2">50</td><td>50</td><td rowspan="2">25</td><td rowspan="3">0</td><td rowspan="3">20</td></tr>
<tr><td>LVRR 4</td><td>33</td></tr>
<tr><td>LVRR3</td><td>25</td><td>25</td><td>15</td></tr>
</table>

6.2.8 Control of Sight Distance

Sight distances should be checked during design and adjustments made to meet the minimum requirements. The values shown in the paragraphs above should be used for the determination of sightlines. Details of crest and sag curve design are provided in Section 6.4.

On the inside of horizontal curves, it may be necessary to remove buildings, trees or other sight obstructions or widen cuts to obtain the required sight distance as indicated in Figure 6-1. The distance labelled M in the diagram must be clear of obstruction to allow a clear view along the sightline shown.

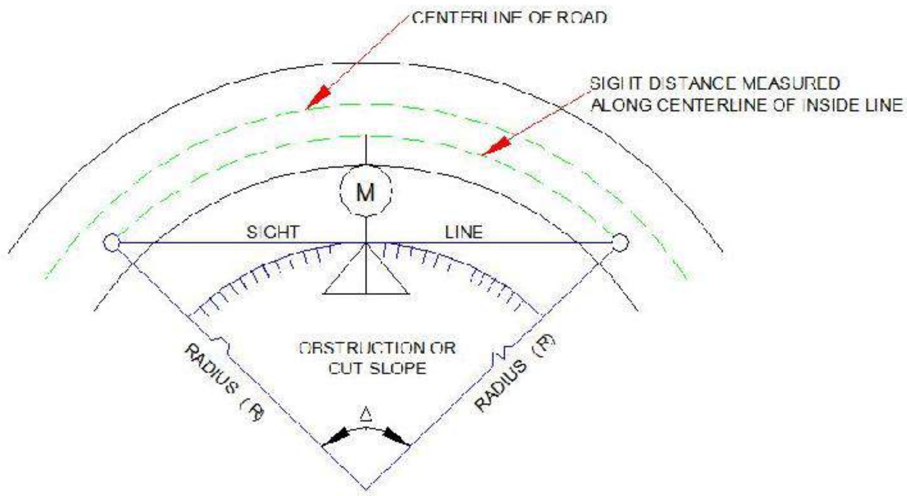


Figure 6-1: Sight Distance for Horizontal Curves

Relevant formulae are as follows:

Length of Sightline (S) = 2R sin(ζ/2) where ζ = Deflection angle (°)

Length of Middle Ordinate (M) = R (1-cos (ζ/2)

Example:

Radius = 1000 m, Δ = 20^0

$$S = 2\,x\,R \quad \left(\frac{\Delta}{2}\right) = 2\,x\,1000\sin(10) = 347m$$

$$M = R(1 - \cos\left(\frac{\Delta}{2}\right) = 1000\,x\,(1 - \cos(10) = 15.2m$$

6.3 Components of Horizontal Alignment

6.3.1 Introduction

The horizontal alignment consists of a series of straight sections (tangents) connected to circular curves. The horizontal curves are designed to ensure that vehicles can negotiate changes in direction safely. The alignment design should be aimed at avoiding sharp changes in curvature, thereby achieving a safe uniform driving speed. Transition curves between straight sections of road, and circular curves whose radius changes continuously from infinity (tangent) to the radius of the circular curve (R), are used to reduce the abrupt introduction of centripetal acceleration that occurs on entering the circular curve. They are not required when the radius of the horizontal curve is large or where the design speed is 80 km/h or lower, and therefore they are normally not required on LVRRs.

6.3.2 Circular Curves

For a vehicle to move in a circular path, an inward radial force is required to provide the necessary centripetal acceleration or, in other words, to counteract the centrifugal force. This radial force is provided by the sideways friction between the tyres and the road surface assisted by the crossfall or superelevation.

The sideways friction coefficient is considerably less than the longitudinal friction coefficient. Its value decreases as speed increases, but there is considerable disagreement about representative values, especially at slower speeds. For paved roads, it ranges from between 0.18 and 0.3 at 20 km/h down to between 0.14 and 0.18 at 80 km/h. For unpaved roads, it can be considerably less.

For both sealed and unsealed roads, there are also constraints on the maximum crossfall. These constraints translate directly into minimum values of horizontal radii of curvature.

6.3.3 Camber and Crossfall

Achieving proper camber and crossfall is essential to ensure rapid shedding of water off the carriageway and to prevent moisture ingress into the pavement from the top.

On paved roads, a camber of 3.0% is recommended for LVRRs, as shown in Figure 6-3. Although steeper than traditional specifications, it does not cause problems for drivers in a low-speed environment. It also accommodates a reasonable construction tolerance of ± 0.5%, taking into account the skills and experience of small-scale contractors and labour-based construction, and provides an additional factor of safety against water ingress into the pavement should slight rutting occur after some time of trafficking.

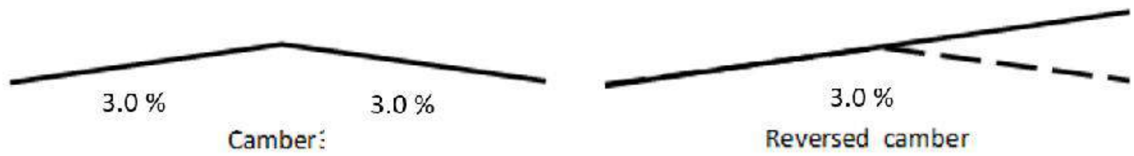


Figure 6-2: Camber and Reverse Camber

6.3.4 Adverse Cross-fall/Camber

The need for removing adverse camber arises on the outside of curves when the cross-fall or camber causes vehicles to lean outwards when negotiating the curve. This affects the cornering stability of vehicles, thereby affecting safety, and is uncomfortable for drivers. The severity of its effect depends on vehicle speed, the horizontal radius of curvature of the road and the side friction between the tyres and the road surface. A side friction factor of 0.07 is considered reasonable and has been used to determine suitable minimum radii below which adverse camber should be removed (Table 6-5). Values for unpaved roads are based on a 6% crossfall, which is the minimum crossfall that should be allowed before maintenance is carried out if effective cross-drainage is still to be provided.

Table 6-5: Radii below which Adverse Crossfall/Camber should be removed

Design speed (km/h)	Radii (m)	
	Paved	Unpaved
<50	500	700
60	700	1000
70	1000	1300
85	1400	
100	2000	

To remove adverse crossfall, the basic cambered shape of the road is gradually changed as the road enters the curve until it becomes simply cross-fall in one direction at the centre of the curve as shown in Figure 6-3, with the cross-fall being the same as that of the inner side of the cambered two-lane road (usually 3.5% for sealed roads). The removal and restoration of adverse cross-fall should take place over similar distances to superelevation as described in Section 6.3.5.

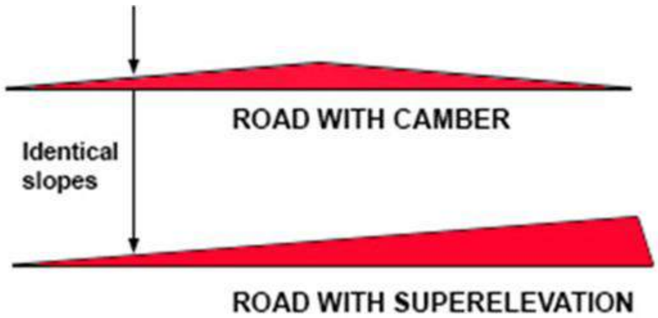


Figure 6-3: Camber and Superelevation

The values shown in Table 6-5 are approximate and cut-off levels should be varied to offer consistency to the driver. For example, two adjacent horizontal curves on a road link, one of which is marginally above the cut-off whilst the other is marginally below the minimum radii shown, should be treated in a similar manner in the design.

For sealed roads, the removal of adverse camber may not be sufficient to ensure good vehicle control when the radius of the horizontal curve becomes too small. In such a situation, additional cross-fall may be required. This is properly referred to as superelevation, but it has become common practice to refer to all additional elevation as superelevation, and this convention will be used here.

6.3.5 Superelevation

General

Superelevation assists vehicles to travel along the curve safely and comfortably for a given design speed.

This section is provided for general guidance only. For the lower LVRR classes, LVRR 1 and 2 being single lane roads, the removal of adverse crossfall is usually all that is required. For all LVRR classes, accurate design and setting out details can be obtained by the application of a commercially available computer software package for road geometric design.

Unpaved roads

Superelevation on narrow, unpaved LVRRs is not necessary. This is because it is recommended that adverse cross-fall or camber is always removed on horizontal curves below 1000 m radius. Since the recommended cross-fall or camber is 6%, the effective 'superelevation' when adverse cross-fall is removed will also be 6% and this, therefore, determines the minimum radius of horizontal curvature for each design speed in the same way as for genuine superelevation. In practice, it may not be possible to maintain such a value of cross-fall during the life of an unsealed road and therefore it is recommended that minimum radii are based on the lower level of 4% cross-fall.

Paved roads

For paved roads, the removal of adverse cross-fall will result in an effective superelevation of 3.0 %, and this should be used to determine minimum radii of curvature for such roads. However, if these radii are difficult to achieve, genuine superelevation of up to 7 % (or, in exceptional circumstances, up to 10 %) can be used with a resulting decrease in horizontal radius of curvature.

Development of superelevation

The change from camber on a straight section to a superelevated section should be made gradually, as shown in Figure 6-4. The length over which superelevation is developed is known as the superelevation development length, which depends on design speed, as shown in Table 6-6. Between 50% and 75% of the superelevation should be achieved before the curve begins, i.e. by the tangent point, but normally 66% is used

Table 6-6 Superelevation development lengths

Design speed (km/h)	Development length (m)
30	25
40	30
50	40
60	55
70	65
80	80

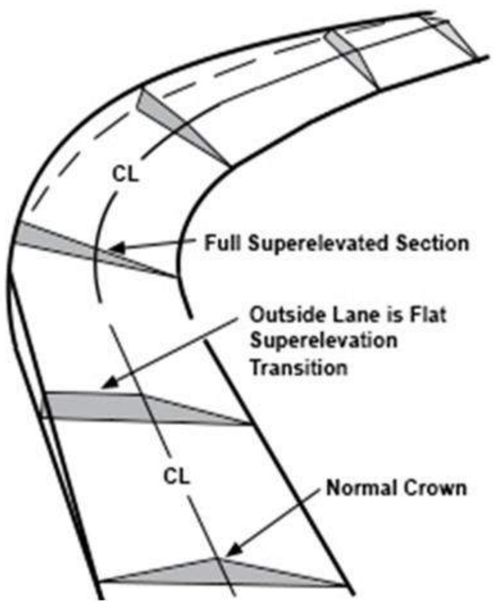


Figure 6-4: Development of superelevation

Chapter 6 – Alignment

6.3.6 Recommended Minimum Horizontal Radii

The recommended minimum values of horizontal curvature were derived on the basis of sideways friction factors (see *Appendix: Characteristics of Horizontal and Vertical Alignment*) and superelevation and are shown in Table 6-7 and Table 6-8 and in the tables in *Chapter 7 – Design Standards*. The use of a higher value of superelevation makes it possible to introduce a smaller horizontal curve based on the same design speed. This can be used for paved roads but not for unpaved roads.

In some situations, sight distance will be the factor controlling minimum radii. Sight distances may be improved by increasing curve radius or sight distance across the inside of the curve.

Where only small numbers of large vehicles are involved and the costs of improving the alignment are high, not all vehicles can expect to traverse a curve on a single lane road in a single manoeuvre and reversing may be necessary.

Table 6-7: Recommended Minimum Horizontal Radii of Curvature: Paved Roads (m)

Design speed (km/h)	20	30	40	50	60	70	80
Minimum horizontal radius for SE = 4%	15	30	55	95	150	220	300
Minimum horizontal radius for SE = 6%	15	27	53	85	135	190	265

Table 6-8: Recommended Minimum Horizontal Radii of Curvature: Unpaved Roads (m)

Design speed (km/h)	20	30	40	50	60	70	80
Minimum horizontal radius for SE = 4%	15	35	65	115	175	255	355
Minimum horizontal radius for SE = 6%	15	30	60	100	155	215	300

6.4 Consistency, Compound and Multiple Curves

6.4.1 General

Horizontal alignment design involves connecting curves and tangents. Under normal circumstances, sections of road will contain many curves whose radii are larger than the minimum radii specified in the design standards.

Compound horizontal curves are defined as curves where the distance between the end of one and the beginning of the next consecutive curve is less than the radius of the larger curve. These can be useful in fitting the road to the terrain, but in some circumstances, they can be dangerous.

Drivers do not usually expect to be confronted by a change in radius whilst in a curve, and therefore in design speed For reasons of safety and driver comfort, it is not advisable for two consecutive curves to differ in radius by a large amount even though they are both greater than the minimum. Figure 6-5 shows the required ratio of radii for consecutive curves. Consecutive horizontal curves are defined as curves where the distance between the end of one and the beginning of the next is less than the radius of the larger curve. The best result will be achieved when the two radii are similar (labelled 'very good' in the diagram). If the ratio of radii falls outside the 'good' category but inside into the 'useable' category, some discomfort or inconvenience will be felt because of the increase in centripetal force when entering the tighter curve. For high-speed roads, such situations can be potentially dangerous and should be avoided, However, for LVRRs the design speed is lower, and it is rarely necessary to modify the alignment for these reasons other than for curve widening. Nevertheless, if the situation can be avoided, it is obviously best to do so unless it is considered too costly.

However, it is not merely the ratio of curve radii that affect consistency. In particular, the length of connecting tangents and the friction between the tyre and the road surface are also important because these affect speed. Thus, for consistency, all the various design elements must be combined in a balanced way, avoiding the application of minimum values for one or a few elements at a particular location when other elements are considerably above the minimum requirements.

In hilly and mountainous terrains, horizontal curves are required more frequently and have small radii because the design speeds are low. The tangent sections become shorter, and a stage can be reached where successive curves can no longer be dealt with in isolation. In cases of reverse curves, broken back curves and compound curves it is often possible to connect curves and tangents that do not fit well together according to normal design standards and in terms of meeting driver expectation and comfort.

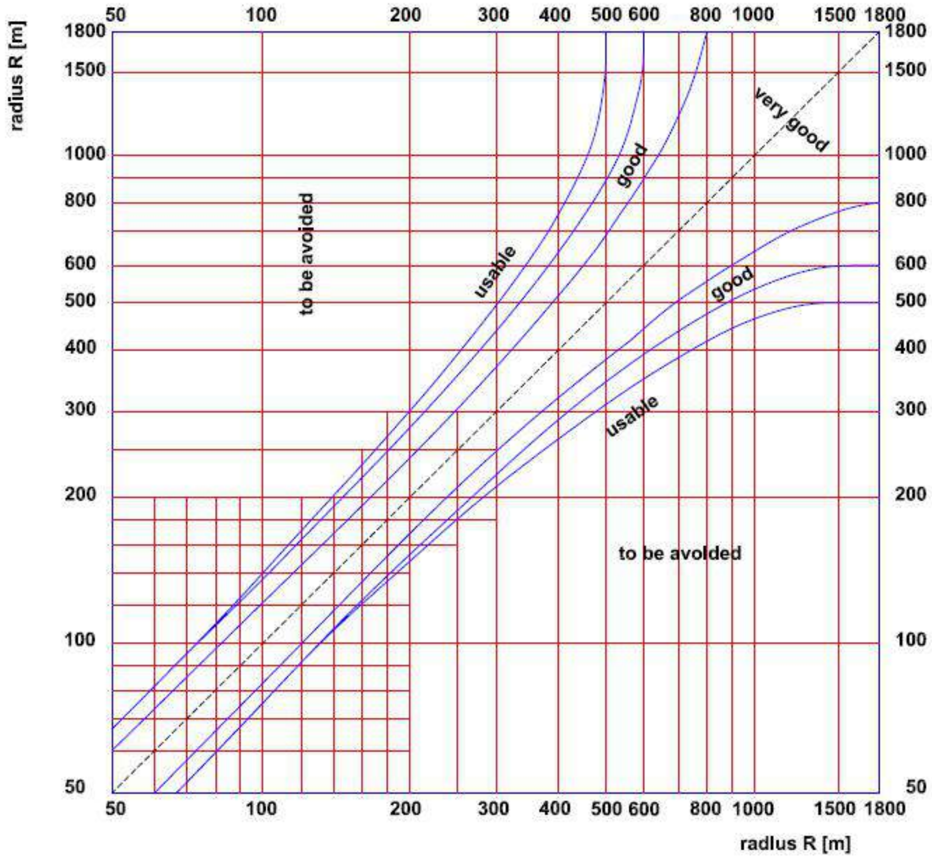


Figure 6-5: Ratio of Radii of Consecutive Horizontal Curves

Source: German Road and Transportation Research Association, Cologne, Germany (1973). *Guidelines for the design of rural roads (RAL), Part II*.

6.4.2 Reverse Curves

A reverse curve (Figure re 6-6) is one which is followed immediately by a curve in the opposite direction. In this situation, it is difficult for the driver to keep the vehicle in its proper lane. It is also difficult for the designer to accommodate the required superelevation within the space available. If it is not possible to realign then warning signs should be provided.

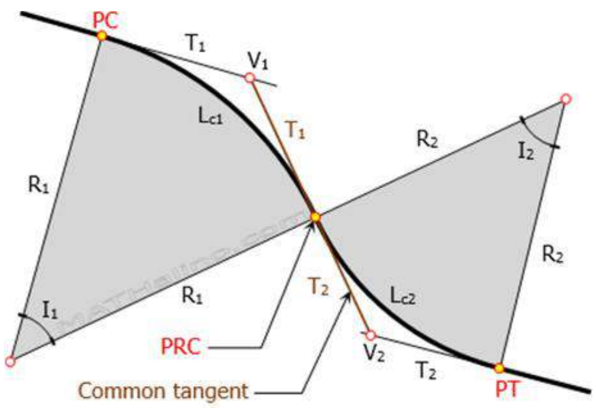


Figure 6-6: Reverse Curves

6.4.3 Broken-back Curves

This is the term used to describe two curves in the same direction connected by a short tangent. Drivers do not usually anticipate that they will encounter two successive curves close to each other in the same direction. There can also be problems fitting in the correct superelevation in the space available. If it is not possible to realign then warning signs should be provided.

6.4.4 Isolated and Long Curves

An isolated curve close to the minimum radius connected by long straight sections is inherently unsafe. Irrespective of the design speed, actual speeds on long straight sections will be relatively high, and therefore a curve of minimum radius will require a significant reduction in speed for most vehicles. It is, therefore, good practice to avoid using minimum standards in such situations. Provided that no extra cutting or filling is required, the use of a larger radius of curvature results in a shorter and less expensive road. However, if a larger radius curve cannot be used, then curve widening can help to alleviate this problem.

On single-lane roads, the use of minimum curve radii after long straights is even more serious than on 2-lane road because of restricted sight distances and greater accident potential (Section 6.2.2).

The same argument is true, but to a much lesser extent, for any small radius curve that is very long (i.e. the road is turning through a large angle). Drivers can negotiate a short curve relatively safely at speeds in excess of the design speed, but they cannot do so if the curve is long; hence a larger radius should be used in such situations.

6.4.5 Curve Length

For reasons of safety and ease of driving, curves near the minimum for the design speed should not be used at the following locations:

- On high fills, because the lack of surrounding features reduces a driver's perception of the alignment.
- At or near vertical curves (tops and bottoms of hills) because the unexpected bend can be extremely dangerous, especially at night.
- At the end of long tangents or a series of gentle curves, because actual speeds may exceed design speeds.
- At or near intersections and approaches to bridges or other water crossing structures.

There are conflicting views about curve lengths, depending on how straight the road could be. Normally, for LVRRs, the horizontal alignment should maximize the length of road where adequate sight distances are provided for safe overtaking. Overtaking is difficult on curves of any radius and hence the length of curved road should be minimized. This requires curve radii to be relatively close (but not too close) to the minimum for the design speed to maximize the length of straight sections. This view is the currently accepted best practice for roads except in very flat terrain, but care should be exercised to ensure the curves are not too tight.

However, very long straight sections should be avoided because they are monotonous and cause headlight dazzle at night. A safer alternative is obtained by a winding alignment with tangents deflecting 5 to 10 degrees alternately from right to left. Some authorities recommend that straight sections should have lengths (in metres) less than 20 x design speed in km/h. However, such 'flowing' curves restrict the view of drivers on the inside of the carriageway and reduce safe overtaking opportunities. Thus, such a winding alignment should only be adopted where the straight sections are very long. In practice, this only occurs in very flat terrain. The main aspect is to ensure that there are sufficient opportunities for safe overtaking and therefore, provided the straight sections are long enough, a semi-flowing alignment can be adopted at the same time. If overtaking opportunities are infrequent, maximizing the length of the straight sections is the best option.

For small changes of direction, it is often desirable to use a large radius of curvature. This improves the appearance and reduces the tendency for drivers to cut corners. In addition, it reduces the length of the road segment and therefore the cost of the road provided that no extra cut or fill is required.

6.4.6 Curve Widening

Widening of the carriageway where the horizontal curve is tight is usually necessary to ensure that the rear wheels of the largest vehicle remain on the road when negotiating the curve; and, on two-lane roads, to ensure that the front overhang of the vehicle does not encroach on the opposite lane. Widening is, therefore, also important for safety reasons. Any curve widening that is considered should only be applied on the inside of the curve.

Vehicles need to remain centred in their lane to reduce the likelihood of colliding with an oncoming vehicle or driving on the shoulder. Sight distances should be maintained as discussed above. The levels of widening shown in Table 6-9 are recommended except for roads carrying the lowest levels of traffic (LVRR 1). Widening should be applied to the inside of the curve and introduced gradually.

Widening on high embankments is often recommended for the higher classes of road. The steep drops from high embankments unnerve some drivers, and the widening is primarily for psychological comfort, although it also has a positive effect on safety. Such widening is not recommended for LVRRs.

Table 6-9: Widening Recommendations (m)

	Single-lane roads				Two-lane roads			
Curve radius	20	30	40	60	<50	51-150	151-300	301-400
Increase in width	1.5[1]	1.0	0.75	0.5	1.5	1.0	0.75	0.5

Notes: 1. See Section 6.6.5 dealing with hairpin stacks

6.5 Road Junctions

Unlike road junctions on high volume roads, on LVRRs they do not pose a significant problem. Where two roads have to cross each other, a simple cross junction is adequate for LVRRs. However, where possible, it is preferable to provide two staggered T-junctions as illustrated in Figure 6-7, rather than one X-cross junction, provided there is no cost penalty of doing so. The most heavily trafficked road is retained as a direct through route. The minor road is then split so that traffic has to enter the major road by making a left turn onto the major road and then a right turn across the traffic stream to re-enter the minor road. This method halves the number of possible manoeuvres where the traffic from the minor road has to cross the traffic stream on the major road. The entry points of the two arms of the minor road should be spaced about 100 m apart.

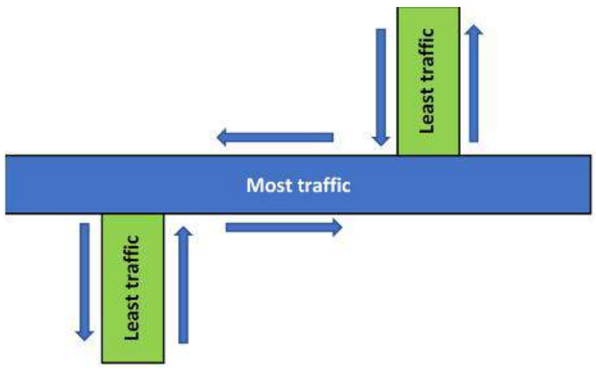


Figure 6-7: Preferred Intersection Design

The result of an accident is likely to be that one or more vehicles will leave the road. Hence, where possible, a safe 'run-off' environment should be created and good sight distances provided. Intersections should, therefore, not be located on high embankments, near to bridges or other high-level water crossings, on small radius curves or on superelevated curves. To ensure good visibility, vegetation should be permanently cleared from the area surrounding the junction.

It is also advisable to avoid having intersections on gradients of more than 3% or at the bottom of sag curves. This is because:

- stopping sight distances are greater on downhill descents, and drivers of heavy vehicles have more difficulty in judging them; and
- it is advantageous if heavy vehicles are able to accelerate as quickly as possible away from the junction.

The ideal angle that intersecting roads should meet is 90° because this provides maximum visibility in both directions, but visibility is not seriously compromised as long as the angle exceeds 70°.

6.6 Vertical Alignment

6.6.1 Vertical Controls

The two major elements of the vertical alignment are the gradient, which is related to vehicle performance and level of service, and the vertical curvature, which is governed by safe sight distances and comfort criteria.

The vertical alignment of a road seems more complicated than the horizontal alignment, but this is simply because of difficulties in presentation due to the inclusion of the algebraic difference in gradient (G %) between the uphill and downhill sides. In addition, the equation of the vertical curve is a parabola rather than a circle, because the parabola effects a constant rate of change in grade along the vertical curve and hence eases passenger comfort.

The required sight distance for safety is the basic stopping sight distance.

6.6.2 Crest Curves

The minimum length of the curve (L metres) over the crest of the hill between the points of maximum gradient on either side is related to G and the stopping-sight distance, therefore, to the design speed. Note that although drivers would like to overtake on hills, the required sight distance for safe passing on crests is much too large to be economical on LVRRs.

The minimum value of the L/G ratio (K value) can be tabulated against the stopping sight distance and therefore also the design speed, to provide the designer with a value of L for any specific value of G. The international comparisons give the values shown in Table 6-10.

Table 6-10: Minimum Values of L/G for Crest Curves

Design speed (km/h)	30	40	50	60	70	80
Sealed roads	2	4	7	12	21	37
Unsealed roads	3	6	11	19	34	58

6.6.3 Sag Curves

Sag curves are the opposite of crest curves in that vehicles first travel downhill and then uphill. In daylight, the sight distance is normally adequate for safety, and the design criterion is based on minimizing the discomforting forces that act upon the driver and passengers when the direction of travel changes from downhill to uphill. On rural roads, such considerations are less important than road safety issues. However, at night time, the problem on sag curves is the illumination provided by headlights to see far enough ahead. This depends on the height of the headlights above the road and the angle of divergence of the headlight beams.

The provision of sag vertical curvature that allows the driver to see sufficiently far ahead using headlights while driving at the design speed at night is usually too expensive for LVRRs. In any case, the driving speed should be much lower at night on such roads. As a result of these considerations, it is recommended that the minimum length of the curve is determined by the driver discomfort criterion. The results are shown in Table 6-11.

Table 6-11: Minimum Values of L/G for Sag Curves

Design speed (km/h)	30	40	50	60	70	80
Minimum L/G	0.7	1.3	2.2	3.5	4.8	7.5

6.6.4 Gradient

For four-wheel drive vehicles, the maximum traversable gradient is about 18%. Two-wheel drive trucks can generally cope with gradients of 15%, except when heavily laden. Bearing in mind the likelihood of having heavily laden small trucks on LVRRs, international rural road standards have a general recommended limit of 12%, but with an increase to 15% for short sections (< 250 m) in areas of difficult terrain. Slightly higher standards are recommended for LVRR 4 with a preferred maximum of 10%, and an absolute maximum of 12% on escarpments where relief gradients of less than 6% are required for a minimum distance of 250 m following a gradient of 12%.

For driving consistency, and hence safety, in terrains other than in mountainous or escarpment regions, absolute limiting values of the gradient are also often specified. Thus, in flat terrain, a maximum gradient of 6% or 7% is recommended, whereas in rolling terrain a maximum of 9% or 10% is recommended, especially where there is a possibility of the occurrence of ice forming on the road surface in low-temperature environments.

On gravel roads a maximum gradient of 7% is recommended as, above this value, travel becomes difficult due to lack of sufficient traction on the road surface, as well as for pavement maintenance reasons.

6.6.5 Hairpin Stacks

Climbing sections on mountain and escarpment roads are often best designed using hairpin stacks. The advantages are that the most favourable site for ascending the escarpment can be selected and a more direct and therefore shorter route will often be possible. However, there are several problems with this approach.

The limited space to construct cut and fill slopes necessitates either a reduction in geometric standards or more expensive retaining structures. For LVRRs, the former solution should be adopted.

Lack of suitable sites for the disposal of spoil and access difficulties for plant can pose problems during construction.

If there are problems of instability, they may extend from one loop to another and so the advantage of attempting to choose the most stable section of the escarpment is lost.

Stormwater run-off will, of necessity, become very concentrated, so although the number of drainage structures and erosion controls may be reduced, their capacity will need to be increased. The risk associated with failure of the drainage is, therefore, correspondingly high, and minimizing this risk adds to the costs. If the topography allows, some of the problems of stacked hairpins can be reduced by creating several stacks that are offset from each other and staggered across the slope (i.e. not immediately above or below each other). This will reduce drainage problems and limit the danger of instability to fewer hairpin loops.

The key aspect of their geometric design is that the curves should be as flat as possible, and the tangents should be used to achieve the ascent. This is because vehicle traction is much more efficient when the vehicle is travelling in a straight line. The maximum gradient through the hairpin curve itself should be 4% for LVRR 4 and LVRR 3 but could be up to 6% for LVRR 2 and LVRR 1.

Considerable curve widening will be required where the curve radius is small to ensure that large vehicles can negotiate the bends. Widening is also required for safety reasons and, if space allows, to provide a refuge area if a vehicle breaks down.

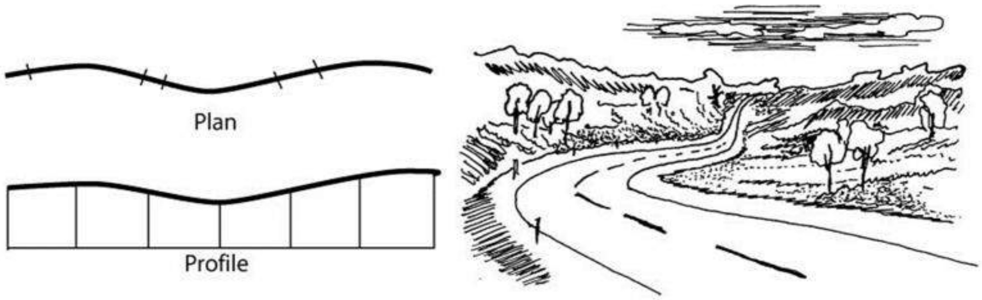
For LVRRs, it is recommended that the curves should be designed to allow the passage of the design vehicle discussed in *Chapter 3 – Fundamental Design Considerations*. This means that the curve radius at the centre line of the road should be an absolute minimum of 13 m.

6.7 Coordination of Horizontal and Vertical Alignment

The alignment design must ensure that all the design elements are complementary to each other. There are a number of design situations that could produce unsatisfactory combinations of elements, despite the fact that the design standards have been followed for the particular class of road in question. These are designs that could provide surprises for drivers by presenting them with unfamiliar conditions. They are, therefore, comparatively unsafe.

Avoiding such designs is more important for the higher classes of road because design speeds are higher, traffic volumes are much greater and, consequently, any accidents resulting from poor design are likely to be more severe and more frequent. However, in many cases, avoidance of such designs does not necessarily impose a significant cost penalty, and therefore, the principles outlined below should be applied to roads of all classes.

The horizontal and vertical alignment should not be designed independently. Hazards can be concealed by inappropriate combinations of horizontal and vertical curves, and therefore such combinations can be very dangerous. Some examples of good and poor phasing are illustrated in Figure 6-8.



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

Below: Example of a poor alignment design – uncoordinated horizontal and

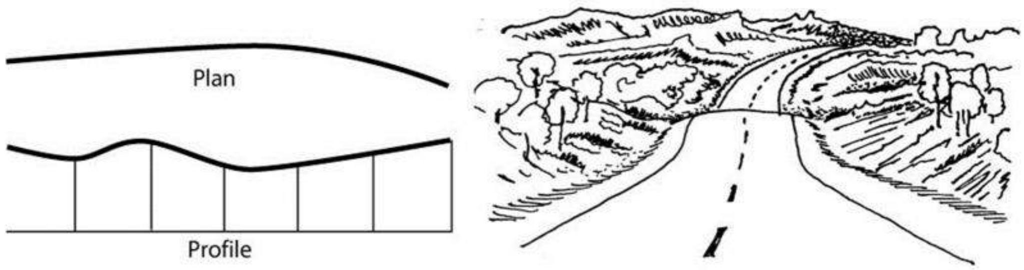


Figure 6-8: Examples of good and poor combinations of horizontal and vertical alignment

6.8 Balance

It can be seen that there are several competing factors in providing the optimum horizontal alignment. Smaller radii curves, still meeting design requirements, maximize the length of straight sections and optimize overtaking opportunities. This should be the controlling factor where the terrain is such that overtaking opportunities are infrequent and actual speeds are close to the design speeds. However, in more gentle terrain where overtaking is less of a problem and vehicles generally travel at speeds higher than the design speed, the use of larger radius curves is preferred for the reasons outlined previously.

In summary, engineering choice plays a part in the final design which should aim to achieve a balance between competing requirements.

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Appendix: Characteristics of Horizontal and Vertical Alignment

A1-1 Introduction

This Appendix describes the calculations for computing the principal parameters for the alignment of the road that are based on the physical properties of the road, vehicle and drivers. The results of these calculations comprise the contents of some of the Tables in Chapter 6 but the methodology is presented here so that the user can compute the alignment details for other combinations of the variables e.g. friction, speed, gradient etc.

A1-2 Sight Distances

Drivers must be able to see objects in the road with sufficient time to either stop or to manoeuvre round them. There are several situations requiring different sight distances i.e.:

- Stopping sight distance
- Intersection sight distance
- Decision sight distance
- Passing sight distance

Each depends on the initial speed of the vehicle and the factors listed in Table A1-1.

Table A1-1: Parameters Values Used for Calculating Sight Distances

Characteristic	Value
Car driver's eye height	1.05 m
Truck driver's eye height	1.8 m
Height for Stopping Sight Distance for general objects in the road	0.2 m
Height for Stopping Sight Distance for flat objects in the road (e.g. potholes, wash-outs)	0.0 m
Height for Stopping Sight Distance for vehicle in the road	0.6 m
Object height for Passing Sight Distance (e.g. roof of car)	1.3 m
Object height for Decision Sight Distance	0.0 m
Driver's reaction time	2.5 s
The maximum deceleration rate for cars	3.0 m/s^2
The maximum deceleration rate for trucks	1.5 m/s^2
Friction between tyres and road surface	Section A1-3
Gradient of the road	Section A1-4

A1-3 Friction between Tyres and Roadway

The coefficient of friction in the longitudinal direction between the vehicle tyres and the road surface is the ratio of the frictional force on the vehicle and the component of the weight of the vehicle perpendicular to the frictional force. Longitudinal friction depends on:

- vehicle speed;
- type, condition and texture of the roadway surface;
- weather conditions; and
- type and condition of tyres.

Its value decreases as speed increases and there are considerable differences between studies, especially at the lower speeds, because of the wide range of conditions that are encountered. Thus, it is difficult to select representative values because of variations in tyre wear (worn tyres are common), as well as variations in the climate from wet to arid with the time of year. Gravel roads can have particularly low friction characteristics.

Side friction coefficients are also dependent on vehicle speed, type, condition and texture of the road surface, weather conditions, and type and condition of tyres.

The coefficient of friction values considered most suitable for LVRR design are shown in Table A1-2 using representative results of friction tests. The values allow a reasonable safety factor to cater for the wide range of conditions. For unpaved roads, a systematic reduction in the values used for paved roads has also been used.

Table A1-2: Friction factors

Friction Type	**Road Type**	**Design speed (km/h)**									
		30	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
Longitudinal friction	Paved	0.40	0.37	0.35	0.33	0.32	0.305	0.295	0.285	0.29	0.28
	Unpaved	0.32	0.30	0.28	0.26	0.25	0.24	0.235	0.23	0.23	0.23
Side friction	Paved	0.21	0.19	0.17	0.16	0.14	0.13	0.12	0.10	0.10	0.095
	Unpaved	0.165	0.15	0.135	0.125	0.12	0.11	0.10	0.095	0.09	0.09

A1-4 Stopping Sight Distance

The Stopping Sight Distance is the distance a vehicle, travelling at design speed, requires to stop safely after the driver has spotted a stationary object or other dangerous situation on the road ahead. This mainly affects the design of vertical curves, e.g. the shape of the road over the crest of a hill, but if there are objects near the edge of the road that restrict a driver's vision on approaching a bend, then it also affects the horizontal curvature. The stopping sight distance is given by the following formula:

$$d = (0.278)(t)(V) + \frac{V^2}{(2\quad(f+g/1\quad))}$$ Equation A1.1

where:

d = stopping distance (m)

t = driver reaction time (sec)

V = initial speed (km/h)

f = longitudinal coefficient of friction between tyres and roadway

g = gradient of road as a percentage (downhill is negative)

For speeds above 50 km/h, the gradient of the road makes a significant difference and must be taken into account in establishing safe sight distances. On a flat road, the value of g is zero. At 80km/hr on a 10 % gradient, the stopping sight distance is nearly 28 percent longer than on a flat road.

Table A1-3 applies to cars and trucks with anti-lock braking systems. Trucks with conventional braking systems require longer stopping distances. Although the driver's eye height is greater than that of a car driver, hence the driver can see objects sooner, this does not always compensate for the poorer braking system. However, separate stopping sight distances for trucks and passenger cars are not generally used in highway design.

Table A1-4 is for unpaved roads where the coefficients of friction are lower and much more variable, depending on the properties of the gravel or soil.

It is important to note that the values in the tables are for dry weather conditions. Stopping sight distances can be much longer in unfavourable wet conditions but are not generally used in the design as it is assumed that drivers would drive slower under such circumstances. Driving at the design speed with worn tyres in very wet conditions is fortunately, not a common activity. Most drivers slow down until they feel safe, but accident rates do increase in wet weather.

Table A1-3: Minimum Stopping Sight Distances for Paved Roads

Design Speed (km/h)	Coefficient of Friction (f)	Stopping Sight Distance (m)		
		g = 0	g = -5%	g = -10%
20	0.42	18	18	18
25	0.41	23	24	25
30	0.40	30	31	33
40	0.37	45	47	50
50	0.35	65	70	75
60	0.33	85	95	105
70	0.32	110	120	140
80	0.30	140	155	180
85	0.29	155	175	205
90	0.29	170	195	230
100	0.28	205	235	280
110	0.29	245	285	340
120	0.28	285	335	405

Table A1-4: Minimum Stopping Sight Distances for Unpaved Roads

Design Speed (km/h)	Coefficient of Friction (f)	Stopping Sight Distance (m)		
		g = 0	**g = -5%**	**g = -10%**
20	.34	19	19	20
25	.33	23	24	25
30	.32	32	34	37
40	.30	49	55	60
50	.28	70	80	90
60	.26	95	110	130
70	.25	125	145	175
80	.24	160	190	235
85	.24	180	215	270
90	.235	200	240	305
100	.23	240	290	370

A1-5 Stopping Sight Distance for Single Lane Roads (Meeting Sight Distance)

Meeting Sight Distance (sometimes called Barrier Sight Distance) is the distance that needs to be provided on a single-lane road to allow vehicles travelling in the opposite direction, usually because one vehicle is executing a passing manoeuvre, to see each other and to stop safely if necessary.

It is measured for an object height of 1.3 m (i.e. the height of an approaching passenger car) and an eye height of 1.05 m. This distance is normally set at twice the stopping sight distance for a vehicle that is stopping to avoid a stationary object in the road. An extra safety margin of 20-30 m is also sometimes added

It is particularly important to check Meeting Sight Distance on existing roads that have a poor vertical alignment that may contain hidden dips that restrict sightlines. However, single-lane roads have a relatively low design speed, hence meeting sight distances should not be too difficult to achieve.

A1-6 Intersection Sight Distance

Intersection sight distance is determined from the point of view of a driver of a vehicle on the cross road that wants to cross or merge with traffic on the "main" road. Intersection sight distances are longer than stopping sight distances.

On straight sections of road, many vehicles will exceed the road's design speed but, being straight, sight distances should be adequate for vehicles that are travelling straight through the junction on the major road. The situation is quite different for vehicles that may need to slow down or stop at the junction. This is because the time required to accelerate again and then to cross or turn at the junction is now much greater, hence longer sight distances are required.

A1-7 Decision Sight Distance

Stopping sight distances are usually sufficient to allow reasonably competent drivers to stop under ordinary circumstances. However, these distances are often inadequate when drivers need to make complex decisions or when unusual or unexpected manoeuvres are required. The driving task is constrained or limited by the human factors involved.

Decision sight distance, sometimes termed 'anticipatory sight distance', is the distance required for a driver to:

- detect an unexpected or otherwise 'difficult-to-perceive' information source or hazard in a roadway environment that may be visually cluttered;
- recognize the hazard or its potential threat;
- select an appropriate speed and path; and
- complete the required safety manoeuvre safely and efficiently.

Although it is not likely to be a common problem for LVRRs, some critical locations where errors are likely to occur are included here for completeness. It is desirable to provide decision sight distance in the following locations:

- Areas of concentrated demand where sources of information such as roadway elements, opposing traffic, traffic control devices, advertising signs and construction zones, compete for attention (i.e. visual noise);
- Approaches to interchanges and intersections;
- Railway crossings, bus stops, bicycle paths, entrances of villages and towns;
- Newly upgraded road sections or the change of road hierarchy;
- Changes in cross-section such as at toll plazas and lane drops; and
- Design speed reductions.

The minimum decision sight distances that should be provided for such situations are shown in Table A1-5. If it is not feasible to provide these distances because of horizontal or vertical curvature, or if relocation is not possible, special attention should be given to the use of suitable traffic control devices for advance warning.

It may be noted that although a sight distance is shown in the Table A1-5 for the right side (off-side) exit, exiting from the right side, except on LVRRs, is undesirable because, to be safe, crossing a fast-moving traffic stream requires traffic control; the efficiency of the junction is thus severely reduced. Furthermore, a right-side exit is also in conflict with the expectancy of most drivers and this further compromises safety. The reason for providing this value is to allow for the possibility that an off-side (right side) exit might be necessary sometimes, usually with traffic control.

In measuring decision sight distances, the 1.05 m eye height and 0 mm object height have been adopted.

Table A1-5: Decision Sight Distances for Various Situations (m)

Design Speed km/h	Situations				
	Junctions/interchanges.		Lane, merge	Lane shift	Intersections.
	Sight distance to nose		Sight distance to taper area	Sight distance to beginning of shift	Sight distance to turn lane
	Near-side exit	Off-side exit			
50	NA	NA	150	85	150
60	200	275	200	100	200
80	250	340	250	150	250
100	350	430	350	200	350
120	400	500	400	250	400

A1-8 Passing Sight Distance (PSD)

The minimum sight distance required by a vehicle to overtake or pass another vehicle safely on a two-lane single carriageway road is the distance that will enable the overtaking driver to pass a slower vehicle without causing an oncoming vehicle to slow below the design speed. The manoeuvre is one of the most complex but important driving tasks. It is also relatively difficult to quantify for design purposes because of the various stages involved, the large number of relative speeds of vehicles that are possible and the lengthy section of the road needed to complete the manoeuvre.

A driver finding that he has insufficient distance after initiating the passing manoeuvre can choose to abort the manoeuvre. The Minimum Passing Sight Distance is then the sight distance required on a two-lane road to enable the passing manoeuvre to be aborted. The recommended minimum PSDs are shown in Table A1-6 and summarised in Table 6-3.

Table A1-6: Passing Sight Distances

Design Speed (km/h)	Minimum PSD allowing driver to abort (m)[1]	Recommended PSD (m)[2]
30	115	195
40	135	275
50	155	345
60	180	420
70	210	485
80	240	550
90	275	615
100	310	670
110	350	730
120	395	780
130	440	830

Source: Manual on Uniform Traffic Control Devices (MUTCD) and Harwood et al. (2008). NCHRP Report 605.

A1-9 Headlight Sight Distance

Headlight sight distance is used to design the rate of change of gradient for sag vertical curves (Section 6.4.3). Where the only source of illumination is the headlamps of the vehicle, the illuminated area depends on the height of the headlights above the road and the divergence angle of the headlight beam relative to the grade line of the road at the position of the vehicle on the curve. For cars, a headlight height of 0.6 m and a beam divergence of 1 degree are usually used for calculation purposes. At speeds above 80 km/h, only large, light coloured objects can be perceived at the generally accepted stopping sight distances.

A2 Design of Horizontal Alignment

A2-1 Introduction

The horizontal alignment consists of a series of straight sections (tangents), circular curves and transition curves (spirals) between the tangents and the circular curves.

In order for a vehicle to move in a circular path, an inward radial force is required to provide the necessary centripetal acceleration or, in other words, to counteract the centrifugal force. This radial force is provided by the sideways friction between the tyres and the road surface assisted by the superelevation.

The objective is to provide a safe road that can be driven at a reasonably constant speed. Therefore, sharp changes in the geometric characteristics of both horizontal and vertical alignments must be avoided. A transition curve whose radius changes continuously between a straight section of road and a circular curve is used to reduce the abrupt introduction of centripetal acceleration that occurs on entering the circular curve. Transition curves are not required when the radius of the horizontal curve is large and are not normally used on the lower classes of road.

A2-2 Horizontal Radius of Curvature

The minimum horizontal radius of curvature, R_{min}, for a particular design speed is:

$$R_m = \frac{V^2}{1 \times (e+f)}$$ Equation A2.1

where:

VD = design speed (km/h)

e = maximum superelevation as a fraction (%/100)

f = side friction coefficient (Section 4.3.2)

The minimum radii of curvature for different design speeds and degrees of superelevation based on this formula and pragmatic coefficients of friction are shown in Table A2-1 for paved roads and Table A2-2 for unpaved roads. For convenience, they are also included in the summary of specifications for each` road class in the Tables in Chapter 7. As the radius increases, the accident rate decreases hence the minimum values should be used only under the most critical conditions and the deviation angle of each curve should be as small as the physical conditions permit.

Table A2-1: Minimum Radii for Horizontal Curves for Paved Roads (m)

Design speed (km/h)	30	40	50	60	70	80	85	90	100
Side Friction Factor (f)	0.21	0.19	0.17	0.16	0.15	0.13	0.13	0.12	0.11
Superelevation = 4%	30	55	95	150	220	300	350	400	520
Superelevation = 6%	27	53	85	135	190	265	305	350	455
Superelevation = 8%	25	50	80	120	175	240	280	320	415
Superelevation = 10%	25	50	75	110	155	210	245	285	370

For unpaved roads, the friction is usually considerably less than on paved roads. In these calculations, it has been assumed that it is 80% of the value for paved roads but this is dependent on a tightly knit and dry surface of good quality gravel with no loose stones; in other words, a surface on which the design speed can be maintained. A poorly bound surface with many loose particles has a very low value of friction and it must be assumed that vehicles will be driven on such a surface at a speed that is much lower than the nominal design speed dictated by the sight distances and radii of curvature.

Table A2-2: Minimum Radii for Horizontal Curves for Unpaved Roads (m)

Design speed (km/h)	20	30	40	50	60	70	80	85	90	100
Side Friction Factor	0.19	0.165	0.15	0.14	0.12	0.12	0.10	0.10	0.10	0.09
Super-elevation=4%	15	35	65	115	175	255	355	415	475	610

A3-1 Introduction

On LVRRs, as on high-speed roads, a smooth grade line is required rather than a series of successive short lengths of grades and vertical curves. Vertical alignment is the combination of parabolic vertical curves and tangent sections of a particular slope designed to achieve this objective. Thus, the design of vertical alignment is concerned with gradients, crest and sag curves. A crest curve is a convex vertical curve. A sag curve is a concave vertical curve, as shown in Figure A3-1 and Figure A3-2, respectively.

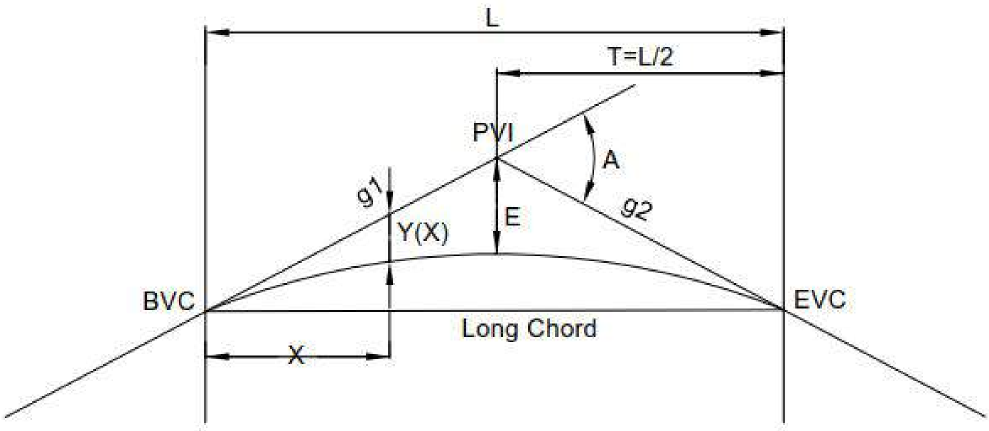

Figure A3-1: Crest curve

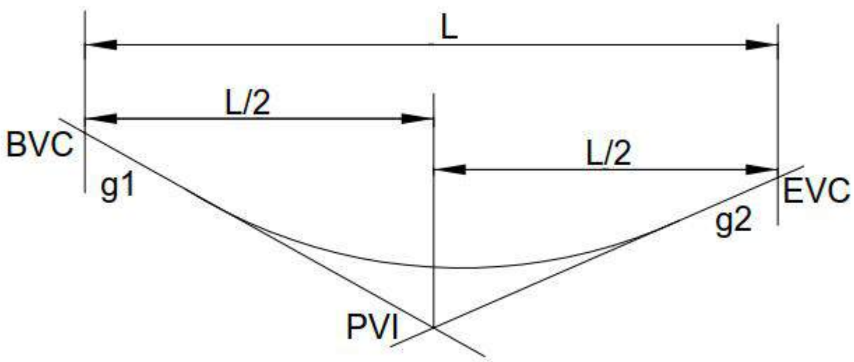

Figure A3-2: Sag curve

A3-2 Vertical Curve Formula

Vertical curves are required to provide smooth transitions between consecutive gradients. The parabola is specified for vertical curves, because the parabola provides a constant rate of change of curvature and, hence, acceleration and visibility, along its length. Equations relating the various aspects of the vertical curve (both crest and sag) are as follows:

$$Y(x) = r \times \frac{x^2}{2} + X \times \frac{g1}{1} + Y_B$$ Equation A3.1

$$r = \frac{(g2-g1)}{L} = \frac{G}{L} = \frac{1}{K}$$ Equation A3.2

where:

- BVC = Beginning of the vertical curve.
- EVC = End of the vertical curve.
- Y(x) = Elevation of a point on the curve (m)
- x = Horizontal distance from the (BVC) (m)
- g1 = Starting gradient (%),
- g2 = Ending gradient (%),
- r = Rate of change of grade per section (%/ m),
- L = Length of curve (horizontal distance) in m,
- G = g2 – g1 (%),

Useful relationships are:

Equation of tangent g1:

$$Y(x) = Y(0) + \frac{g1 \times x}{1}$$ Equation A3.3

Equation of tangent g2:

$$Y(x) = Y(L) + \frac{g2 \times (x-L)}{1}$$ Equation A3.4

The y coordinate of the EVC:

$$Y(L) = \frac{(g1-g2) \times L}{2} + Y(0)$$ Equation A3.5

The Vertical Point of Intersection (VPI) always occurs at an x coordinate of 0.5L hence, from equation 6.1, the elevation is always;

$$Y(V\quad) = Y\left(\frac{L}{2}\right) = Y(0) + \frac{g1 \times x}{1} = Y(0) + \frac{g1 \times L}{2}$$

Example:

For the crest curve shown in Figure A3-1, the two tangent grade lines are +6% and -3%. The Beginning of the Vertical Curve is at chainage 0.000 and its elevation 100.0 m. The length of the vertical curve is 400 m. Compute the End of the Vertical Curve and the coordinates of the Intersection Point.

The y coordinate of the EVC is	Y(L)	= (g1+g2)L/200 + Y(0)
		= (6 - 3) x 400/200 + 100.0 = 106.0
The x coordinate of the EVC is	X(L)	= 400.0
The coordinates of the VPI are	X(IP)	= L/2 = 200.0 and
	Y(VPI)	= Y(0) + 6.400/200 = Y(0) + 12 = 112m

A3-3 Crest curves

Two possible situations could present themselves when considering the minimum sight distance criteria on vertical curves. The first is where the required sight distance (S) is less than the length of the vertical curve (L), and the second is where sight distance required extends beyond the vertical curve. Consideration of the properties of the parabola results in the following relationships for minimum curve length to achieve the required sight distances:

For S < L (the most common situation in practice):

$$L_m = \frac{G \times S^2}{\left[2 \times \left(h_1^{0.5} + h_2^{0.5}\right)^2\right]} = K \times G \qquad \text{Equation A3.6}$$

where

L_{min} = minimum length of vertical crest curve (m)

S = required sight distance (m)

h_1 = driver eye height (m)

h_2 = object height (m)

K = is a constant for given values of h1 and h2 and stopping sight distance (S) and therefore speed and surface friction.

For S > L:

$$L_m = 2 \times S - \frac{\left[2 \times \left(h_1^{0.5} + h_2^{0.5}\right)^2\right]}{G} \qquad \text{Equation A3.7}$$

On computation, it will be found that the differences in curve lengths require to meet these conditions are minimal and hence a single set of K values have been selected for use in this Manual, where K= L/G.

Minimum values of K for crest curves are shown in Table A3-1 and Table A3-2 for stopping sight distances, distinguishing between different object heights, as well as passing sight distances. The eye height has been taken as 1.05 m

Table A3-1: Minimum Values of K for Crest Vertical Curves (Paved Roads)

Design Speed (km/h)	K for Stopping Sight Distance (g = 0%)			K for Minimum Passing Sight Distance
	h_2 = 0 m	h_2 = 0.2 m	h_2 = 0.6 m	
25	3	1	1	30
30	5	2	1	50
40	10	5	3	90
50	20	10	7	130
60	35	17	12	180
70	60	30	20	245
80	95	45	30	315
85	115	55	37	350
90	140	67	45	390
100	205	100	67	480
110	285	140	95	580
120	385	185	125	680

Table A3-2: Minimum Values for Crest Vertical Curves (Unpaved Roads)

Design Speed (km/h)	K for Stopping Sight Distance			K for Minimum Passing Sight Distance
	$h_2 = 0$ m	$h_2 = 0.2$ m	$h_2 = 0.6$ m	
25	3	1	1	30
30	5	2	2	50
40	11	6	4	90
50	25	11	8	135
60	45	20	15	185
70	75	35	25	245
80	120	58	40	315
85	150	72	50	350
90	185	90	60	390
100	270	130	88	480

It may be noted that high values of K are required to meet passing sight distance requirements (Table A3-1 and Table A3-2) and therefore, to achieve the passing sight distance, the volume of earthworks required may also be large. Although as much passing sight distance as possible should be provided along the length of the road, it may be impossible to achieve passing sight distance over the crest curve itself. Encouraging drivers to overtake when sight distances have not been fully achieved is dangerous, hence shortening the crest curve, but still meeting stopping sight distance requirements, in order to increase the lengths of the grades on either side is a better option.

Where a crest curve and a succeeding sag curve have a common end and beginning of curve, the visual effect created is that the road has suddenly dropped away. In the reverse case, the illusion of a hump is created. Either effect is removed by inserting a short length of straight grade between the two curves. Typically, 60 m to 100 m is adequate for this purpose.

A3-4 Sag Curves

During daylight hours or on well-lit streets, sag curves do not present any problems concerning sight distances. For such situations, it is recommended that sag curves are designed using a driver comfort criterion of vertical acceleration. A maximum acceleration of 0.3 m/s^2 is often used. This translates into:

$$K > V^2/395$$

Where V is the speed in km/h.

Where the only source of illumination is the headlamps of the vehicle, the illuminated area depends on the height of the headlights above the road and the divergence angle of the headlight beam relative to the grade line of the road at the position of the vehicle on the curve. Using a headlight height of 0.6 m and a beam divergence of 1^o, the values of K are approximately twice the values obtained from the driver comfort criterion which should be used for design. The resulting K values for both situations are shown in Table A3-3.

Table A3-3: Minimum Values of K for Sag Curves

Design Speed (km/h)	K for driver comfort	K for headlight distance
20	1.0	2
25	1.5	3
30	2.5	5
40	4	9
50	6.5	14
60	9	19
70	12	25
80	16	32
85	18	36
90	20	40
100	25	50
110	30	60
120	36	70

Low Volume Rural Roads Guideline and Standards
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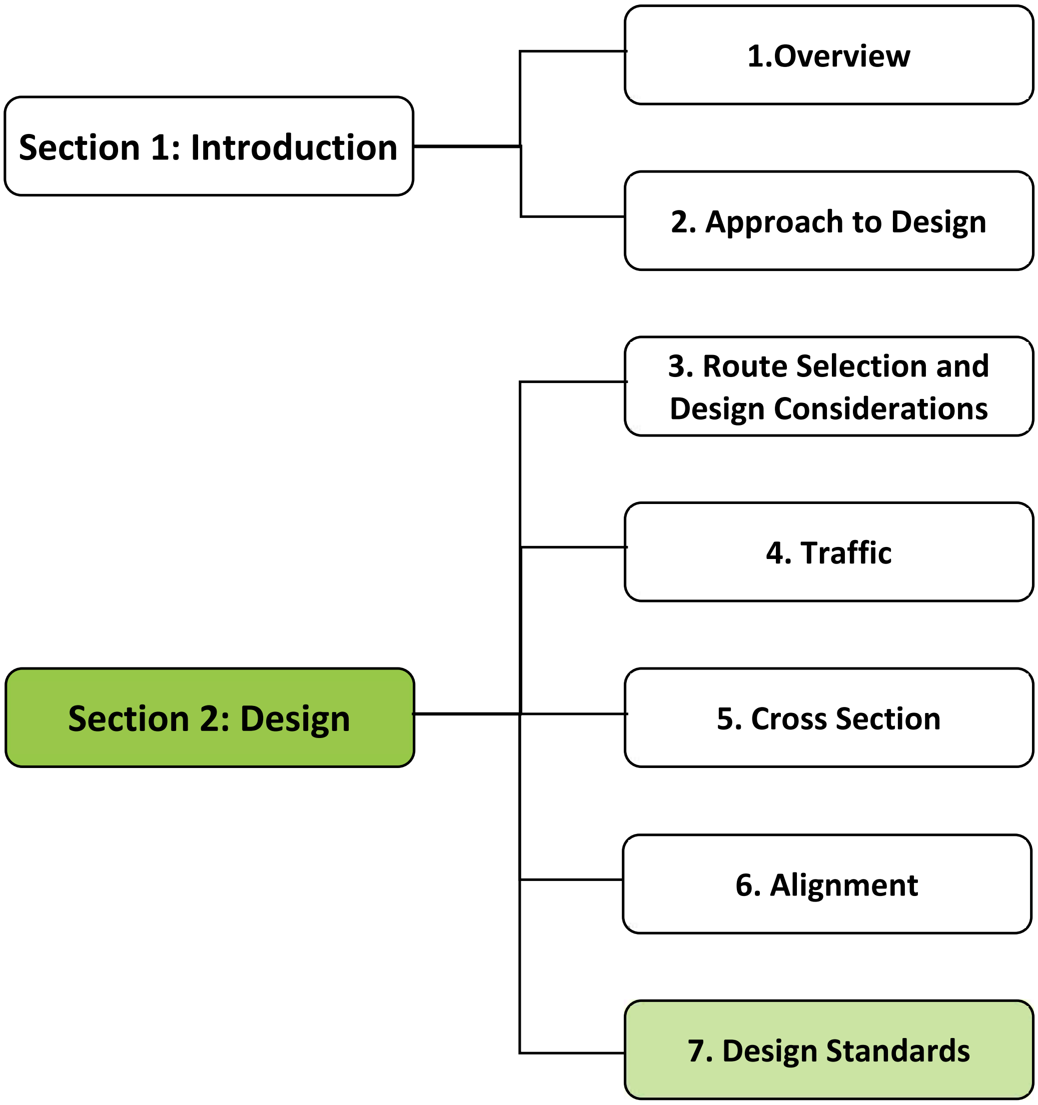

Chapter 7 – Design Standards

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7.1 Introduction

7.1.1 Background

A national 'standard' is not a specification, although it could, and often is, incorporated into specifications and contract documents. Rather, a standard is a specific level of quality that should be achieved at all times and nationwide. Amongst other things, this ensures consistency across the country. For the geometric standards, this means that road users know exactly what to expect. Drivers, for example, are not 'surprised' by unexpected changes in quality. Thus, they will not unexpectedly find that a road is too narrow, or that they have to alter their speed drastically to avoid losing control of their vehicle. Thus, standards are a guarantee of a particular quality level and, for roads, this is vital for reasons of safety.

The problem of safety is closely related to traffic level and design speed, therefore, for high volume roads designed for speed and mobility, safety takes on an extremely vital role that has an enormous impact on the costs of the facility. In contrast, the traffic on LVRRs is very low, and it is now very apparent that the likely number of interactions between vehicles is also surprisingly small (see Table 2-2 in *Chapter 2 – Approach to Design*). Coupled with the fact that the design speed on LVRRs is also quite low, LVRRs are very safe, and many of the strict reengineering rules of geometric design that are based on safety considerations for high volume roads simply do not apply. That is not to say that safety is not an issue for LVRRs, especially in mountainous areas, it is just that the items that are important differ substantially from the considerations of high mobility roads and the design of LVRRs allows the incorporation of safety without high costs.

7.1.2 Purpose and Scope

This Chapter is a summary of the design standards that have been discussed in previous chapters, but with all components or elements for each road class brought together in tabular form to provide a quick look-up system for each one. The Option B designs, i.e. the fully engineered designs for new roads discussed in Section 2.5.4, also provide a method of identifying where along a road the Option A designs are not satisfactory and where modifications are required. A step by step guide to the process of selecting a design standard is also provided. Important differences exist between paved and unpaved roads because of the different friction values between the tyres and the road. These differences are highlighted.

7.2 Basic Methodology

7.2.1 General

The preferred Option A design method for upgrading an existing LVRR or track is recommended for traffic classes LVRR 1 to LVRR 4. It can also be used for higher traffic classes, but these fall outside the scope of this Guideline. Option A utilises the existing alignment as much as possible and therefore also the effective existing operating speeds. These may vary along the road, and so it is important to identify any sections of the road that are sufficiently unsafe to warrant either improvement or modification. Such improvements include:

- ensuring adequate sight distances along the entire road;
- controlling traffic speeds using traffic calming methods;
- minor alignment to ensure a more uniform traffic speed;
- controlling traffic by means of warning signs.

However, for Option A, these improvements are only required when the components of the existing alignment differ by a significant amount from an extremely safe alignment designed for higher traffic levels. Given that the number of vehicle interactions on a LVRR will be very small (*Chapter 2 – Approach to Design*, Table 2.2), a LVRR is inherently very safe provided that vulnerable road users are protected, especially by controlling traffic speeds.

At present, there are no golden rules for identifying and ranking areas of poor safety on LVRRs because road accident data is insufficient for such a detailed analysis, but it is suggested that if the new road parameters differ by more than 25 % from the values that would be obtained using a full Option B engineering design, then consideration should be given to either improvement or modification locally as listed above. Clearly, this also requires engineering judgement and experience that will be enhanced by future research.

7.2.2 Large vehicles

In the specification Tables, 'large vehicles' are defined as trucks with three or more axles and gross vehicle weights greater than 10 tonnes.

7.2.3 Flexibility

Sometimes there will be cases where it is impossible to meet some of the standards, mainly due to severe terrain conditions. Under such circumstances, the standards must be relaxed at the discretion of the Engineer and suitable permanent signage used to warn road users.

For example, alignment design in severe mountainous terrain can sometimes be difficult. A minimum curve radius of 70 m to 85 m suitable for a design speed of 50 km/h might not be possible without massive earthworks and potential problems of slope instability, disposal of spoil and environmental damage. In such terrain, the design speed can be reduced with the associated alterations in the alignment standards that can be achieved more easily and less expensively. Each situation should be treated on its merits. The Tables provide specifications for design speeds from 20 km/h to 80 km/h, but if the specifications for the proper design class need to be changed, approval of the client is usually required.

7.3 Selection of Design Standards for Rural Roads

7.3.1 General

It is important to note that there is no reason why a higher standard than the standard appropriate to the traffic and conditions should not be used in specific circumstances. For example, for reasons of national and international prestige or for strategic or military reasons, a road may be built to a higher standard than would normally be justified, e.g. a road to an international sports facility (where the traffic is very low for most of the time but can be quite high for short periods), the road to an airport, and roads to military establishments. Thus, higher standards can be used if required, but lower standards should not be used except in exceptional circumstances, for example, in particularly difficult terrain.

The decisions and actions that are required for the final design are summarised in Figure 7-1. The steps illustrated are not usually carried out in the sequence shown. Indeed, some of the decisions will have been made at the planning stage, some following a feasibility study, whilst others cannot be made until most of the information has been obtained.

7.3.2 Procedure

Step 1 - Traffic Volume: The first step is to determine the basic traffic level because this defines the road class (*Chapter 2 – Approach to Design*). This, in turn, determines possible design speeds and overall level of service, but subject to modification depending on the other controlling factors. At this point, the proportion of heavy vehicles in the traffic stream is also determined. This step is not specific to the geometric design and will usually have been done by the time it is necessary to determine the geometric characteristics of the road. However, more details of the traffic are required for the geometric design in terms of the other road users such as NMT and motorcycles. These are taken into account in Steps 2, 5 and 6.

Step 2 - Road Class: The numbers and characteristics of all the other road users are considered (*Chapter 4 – Traffic Volume and Composition*, Section 4.6). It is here that the road layout may be altered and additional widths provided for safety and to improve serviceability for all road users (e.g. reduce congestion caused by slow-moving vehicles).

Step 3 – Terrain Class: The terrain class; flat, rolling, mountainous and escarpment is determined (*Chapter 3 – Fundamental Design Considerations*, Section 3.2.7).

Step 4 – Roadside development: The 'size' of the villages through which the road passes is evaluated to determine whether they are large enough to require parking areas and areas for traders (*Chapter 3 – Fundamental Design Considerations*, Section 3.10).

Step 5 – Road Type (paved or unpaved): For most road classes, there are options for road type, and therefore, the next step is to decide which type will be built. In many cases, the adoption of a flexible policy might mean that different parts of the road may be designed with a different surfacing. The choice of road type is described in Chapter 3 - *Fundamental Design Consideration* (Section 3.2.10) and the details are discussed in subsequent chapters.

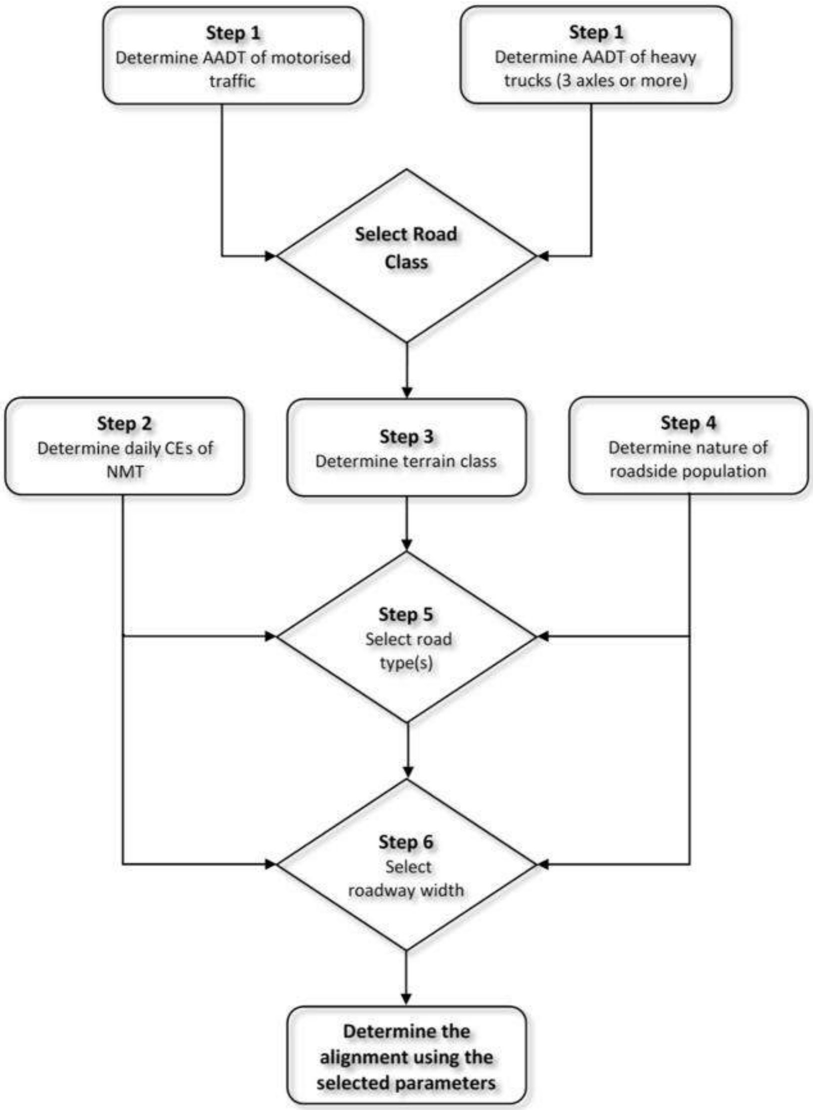

Figure 7-1: Procedure for selecting the design standard

Step 6- Road Width: From the available data, the widths of the travelled way and shoulders should be determined (*Chapter 5 – Cross Section*). At this stage, additional factors that affect the geometric standards are also considered, such as additional road safety features and the construction technology to be employed. Opportunities for the relaxation of standards should also be identified.

Step 7 - Alignment: The initial stage in selecting an alignment for a new road is to sketch a route on a contoured map or aerial photograph. A similar process can be carried out when investigating the upgrading of an existing road. By reference to the standards, the designer will have some knowledge of appropriate minimum radii for the scale of the map or photograph. Consideration will be given to gradient by reference to the contours of a map, or by relief when using stereo photographs. Several alternative alignments should be tried. The design process should be carried out in conjunction with on-site inspections and surveys. One or two of the alignments should be chosen for further design and assessment prior to possible construction.

On two-lane roads, the horizontal alignments should be designed to maximise overtaking opportunities by avoiding long, continuous curves. Instead, relatively short curves at, or approaching, the minimum radius for the design speed should be used in conjunction with straights or gentle, very large radius curves. This is the safest option for LVRRs. An alignment of flowing curves may reduce real overtaking opportunities, thus encouraging injudicious driver behaviour. On two-lane roads, the provision of adequate overtaking opportunities may be particularly important because of the proportions of slow-moving vehicles.

Often a new road will be built to replace an existing facility. The structural features of the existing road, including bridges, embankments and cuttings, may have substantial residual value and influence alignment choice.

The geometric standard of individual elements of the road will vary with the terrain. It is necessary that elements of lower geometric standard are identified to ensure that they will not result in unacceptable hazards to approaching vehicles. These elements will be readily identifiable from the preliminary horizontal and vertical curvature profiles. The tests for the necessary consistency are simple, as described below, and should be carried out if there is any doubt as to the acceptability of an element.

7.4 Design Standards

7.4.1 General

The geometric standard of individual elements of the road will vary with the terrain. It is necessary that elements of lower geometric standard are identified to ensure that they will not result in unacceptable hazards to approaching vehicles. These elements will be readily identifiable from the preliminary horizontal and vertical curvature profiles. The tests for the necessary consistency are simple, as described below, and should be carried out if there is any doubt as to the acceptability of an element.

7.4.2 Option A Alignments

As discussed in *Chapter 2 – Approach to Design*, *Section 2.5.4*, this option provides for the adoption of an alignment that primarily fulfils an access function by making maximum use of the existing alignment, even though the curvature may not comply fully with formal requirements. This option provides a very economical standard for road classes LVRR 1, LVRR 2 and LVRR 3, and in appropriate circumstances, may even be considered for LVRR 4 and LVRR 5. However, if it is required to adopt a more formal approach to the alignment design of such roads, then recourse should be made to the adoption of the Option B approach, as discussed below.

7.4.3 Option B Alignments

In this option, the alignment is designed to fulfil a mobility and access function in accordance with the requirements of the particular design speed.

7.4.4 Choice of Standard

Table 7-1 and Table 7-7 summarise the values of all the alignment design variables for paved and unpaved roads respectively and can be used to check whether the actual values on the existing alignment are acceptable. In this regard, stopping sight distances are probably the most significant. If the differences between the tabled values and what can be achieved following an Option A approach are greater than about 25%, then Option B would be appropriate. However, if they are less than about 25%, then Option A should be the first choice.

For greenfield sites, and when fully engineered designs are required, the detailed design standards for each design class are shown in Tables 7-2 to 7-6 for paved roads and Tables 7-8 to 7-12 for unpaved and single lane roads. The terrain classes in these tables are given for guidance only as there may be sections in both mountainous and escarpment terrain that allow for higher design speeds than those indicated for the respective terrain class, in which case the geometric design parameters for the relevant design speed should be applied.

Table 7-1: General design variables - Paved roads

Design Speed		km/h	100	90	80	70	60	50	40
Minimum Stopping Sight Distance	g = 0%	m	205	170	140	110	85	64	45
	g = 5%	m	235	195	155	120	95	68	47
	g = 10%	m	280	230	182	140	105	75	50
Minimum Passing Sight Distance		m	310	275	240	210	180	155	135
% Passing Opportunity		%	50	50	50	50	33	33	25
Minimum Horizontal Curve Radius(2)	SE = 4%	m	520	400	300	220	150	95	55
	SE = 6%	m	455	350	265	190	135	85	50
	SE = 8%	m	415	320	240	175	120	80	50
Transition curves required			Yes	Yes	Yes	Yes	Yes	No	No
Maximum Gradient (desirable)		%	4	5	6	6	7	7	7
Maximum Gradient (absolute)		%	6	7	8	8	9	9	9
Minimum Gradient[1]		%	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Maximum Superelevation		%	6	6	6	6	6	6	6
Minimum Crest Vertical Curve		K	100	67	45	30	17	10	5
Minimum Sag Vertical Curve Comfort criterion		K	25	20	16	12	9	7	4
Minimum Sag Vertical Curve Headlights criterion		K	50	40	32	25	19	14	9
Normal Camber/Crossfall		%	3.0	3.0	3.0	3.0	3.0	3.0	3.0

Table 7-2: Paved LVRR 1[(1)] Geometric parameters (AADT <50)[(1)]

Design Element		Unit	Flat	Rolling	Mountain[(8)]
Design Speed		km/hr	60	50	40
Width of Carriageway (Table 5-1)			3.5		
Width of Shoulders[(2, 3)]		m	0.5		
Minimum. Stopping Sight Distance	g = 0%	m	85	64	45
	g = 5%	m	95	68	47
	g = 10%	m	105	75	50
Minimum passing sight distance		m	180	155	135
Minimum Horizontal Curve Radius [(4)]	SE = 4%	m	150	95	55
	SE = 6%	m	135	85	50
	SE = 8%	m	120	80	50
Maximum Gradient (desirable)[7,8]		%	6	7	7
Maximum Gradient (absolute)		%	8	10	10
Minimum Gradient[(5)]		%	0.5	0.5	0.5
Maximum Superelevation		%	6	6	6
Minimum Crest Vertical Curve[(6)]		K	17	10	5
Minimum Sag Vertical Curve		K	9	7	4
Normal Cross-fall/Camber		%	3	3	3
Shoulder Cross-fall		%	3	3	3

Notes

1. If there are more than 10 Large Heavy Vehicles, then LVRR 2 should be used.
2. Where passing bays are not provided, the minimum width of the roadway will be 4.5 m comprising a carriageway of 3.5 m and 2 x 0.50 m unpaved shoulders.
3. In urban and peri-urban areas, parking lanes and footpaths may be required.
4. On hairpin stacks, the minimum radius may be reduced to a minimum of 13 m.
5. In some circumstances in very flat terrain, this can be reduced to 0.3%.
6. These values are based on an object height of 0.2 m. Use of a different sized object requires approval.
7. Maximum gradient also depends on road class.
8. In escarpment terrain, design speeds can be lower, and hairpin stacks may be required (Section 6.6.5).

Table 7-3: Paved LVRR 2[1] Geometric Parameters (AADT 50-150)[1]

Design Element		Unit	Flat	Rolling	Mountain [7]
Design Speed		km/hr	70	60	50
Width of Carriageway (Table 5-1)		m	3.5 – 4.5		
Width of Shoulders [2,3]		m	0.5		
Minimum. Stopping Sight Distance	g = 0%	m	110	85	64
	g = 5%	m	120	95	68
	g = 10%	m	140	105	75
Minimum Passing Sight Distance		m	210	180	155
Minimum Horizontal Curve Radius[4]	SE = 4%	m	220	150	95
	SE = 6%	m	190	135	85
	SE = 8%	m	175	120	80
Maximum Gradient (desirable)		%	6	7	7
Maximum Gradient (absolute)		%	8	9	10
Minimum Gradient[5]		%	0.5	0.5	0.5
Minimum Crest Vertical Curve[6]		K	30	17	10
Minimum Sag Vertical Curve		K	12	9	7
Normal Camber/ Cross-fall		%	3	3	3
Shoulder Cross-fall		%	3	3	3

Notes

1. If there are more than 20 Large Heavy Vehicles, then LVRR 4 should be used.
2. Where passing bays are not provided, the minimum width of the roadway will be 4.5 m comprising a carriageway of 3.5 m and 2 x 0.50 m unpaved shoulders.
3. In urban and peri-urban areas, parking lanes and footpaths may be required.
4. On hairpin stacks, the minimum radius may be reduced to a minimum of 15 m.
5. In some circumstances in very flat terrain, this can be reduced to 0.3%.
6. These values are based on an object height of 0.2 m. Use of a different sized object requires approval.
7. In escarpment terrain, design speeds can be lower (see Table 7-1), and hairpin stacks may be required (Section 6.6.5).

Table 7-4: Paved LVRR 3 (1) Geometric Parameters (AADT 150-250)(1)

Design Element		Unit	Flat	Rolling	Mountain(7)
Design Speed		km/hr	70	60	50
Width of Carriageway		m	4.5 – 5.5		
Width of Shoulders(2,3) (Table 5-1)		m	0.5/1.0 -2.0		
Minimum. Stopping Sight Distance	g = 0%	m	110	85	64
	g = 5%	m	120	95	68
	g = 10%	m	140	105	75
Minimum Passing Sight Distance		m	210	180	155
Minimum Horizontal Curve Radius(4)	SE = 4%	m	220	150	95
	SE = 6%	m	190	135	85
	SE = 8%	m	175	120	80
Maximum Gradient (desirable)		%	6	7	7
Maximum Gradient (absolute)		%	8	9	10
Minimum Gradient (5)		%	0.5	0.5	0.5
Maximum Super-elevation (LVRR4)		%	6	6	6
Minimum Crest Vertical Curve(6)		K	30	17	10
Minimum Sag Vertical Curve		K	12	9	7
Normal Camber/Cross-fall		%	3	3	3
Shoulder Cross-fall		%	3	3	3

Notes

1 If there are more than 20 Large Heavy Vehicles, then LVRR 4 should be used.

2 On road class LVRR3, when a 4.5 m carriageway width is adopted, 2 x 0.50 m paved shoulders should be considered on curves and at other appropriate locations to provide a roadway width of 5.5 m which will accommodate the occasional passing of large vehicles. In areas with heavy mixed traffic and CE > 300, paved shoulders 1.0 – 2-0 m wide should be considered.

3 In urban and peri-urban areas, parking lanes and footpaths may be required.

4 On hairpin stacks, the minimum radius may be reduced to a minimum of 15 m.

5 In some circumstances in very flat terrain, this can be reduced to 0.3%.

6 These values are based on an object height of 0.2 m. Use of a different sized object requires approval.

7 In escarpment terrain design speeds can be lower ((see Table 7-1) and/or hairpin stacks may be required (Section 6.6.5).

Table 7-5: Paved LVRR 4 [(1)] Geometric Parameters (AADT 250-350)[(2)]

Design Element		Unit	Flat	Rolling	Mountain[(7)]
Design Speed		km/hr	70	60	50
Width of Carriageway (Table 5-1)		m	5.5 – 6.5		
Width of Shoulders [(2)] (High CE only) (Table 5-1)		m	1.0 – 2.0		
Minimum. Stopping Sight Distance	g = 0%	m	110	85	64
	g = 5%	m	120	95	68
	g = 10%	m	140	105	75
Minimum Passing Sight Distance		m	210	180	155
Minimum Horizontal Curve Radius[(3)]	SE = 4%	m	220	150	95
	SE = 6%	m	190	135	85
	SE = 8%	m	175	120	80
Maximum Gradient (desirable)		%	6	7	7
Maximum Gradient (absolute)		%	8	9	10[(4)]
Minimum Gradient[(5)]		%	0.5	0.5	0.5
Maximum Superelevation (LVRR4)		%	6	6	6
Minimum Crest Vertical Curve[(6)]		K	30	17	10
Minimum Sag Vertical Curve		K	12	9	7
Normal Camber/Cross-fall		%	3	3	3
Shoulder Cross-fall		%	3	3	3

Notes

1. If there are more than 30 Large Heavy Vehicles, then Table 7-5 for LVRR 5 should be used.
2. In urban and peri-urban areas, parking lanes and footpaths may be required.
3. On hairpin stacks, the minimum radius may be reduced to a minimum of 15 m.
4. If the number of Large Heavy Vehicles <10 this can be increased to 12%.
5. In some circumstances in very flat terrain, this can be reduced to 0.3%.
6. These values are based on an object height of 0.2 m. Use of a different sized object requires approval.
7. In escarpment terrain design speeds can be lower (see Table 7-1) and/or hairpin stacks may be required (Section 6.6.5).

Table 7-6: Paved LVRR 5 Geometric Parameters AADT > 350)[1]

Design Element		Unit	Flat	Rolling	Mountain[7]
Design Speed		km/h	80	70	60
Width of Carriageway		m	6.5		
Width of Shoulders (high CE only)[2] (Table 5-1)		m	1.0 – 2.0		
Minimum. Stopping Sight Distance	g = 0%	m	140	110	85
	g = 5%	m	155	120	95
	g = 10%	m	180	140	105
Minimum Passing Sight Distance		m	240	210	180
Minimum Horizontal Curve Radius [3]	SE = 4%	m	300	220	150
	SE = 6%	m	265	190	135
Maximum Gradient (desirable)		%	4	6	7
Maximum Gradient (absolute)		%	6	9	10
Minimum Gradient[5]		%	0.5	0.5	0.5
Minimum Crest Vertical Curve [6]		K	45	30	10
Minimum Sag Vertical Curve		K	16	12	7
Normal camber/Cross-fall		%	3	3	3
Shoulder Cross-fall		%	3	3	3

Notes

1 If there are more than 80 Large Heavy Vehicles, then the specifications for the classification of the next traffic level should be used.
2 In urban and peri-urban areas, parking lanes and footpaths may be required.
3 On hairpin stacks, the minimum radius may be reduced to a minimum of 15 m.
4 If the number of Large Heavy Vehicles <10 this can be increased to 12%.
5 In some circumstances in very flat terrain, this can be reduced to 0.3%.
6 These values are based on an object height of 0.2 m. Use of a different size object requires approval.
7 In escarpment terrain design speeds can be lower (see Table 7-1) and/or hairpin stacks may be required (Section 6.6.5).

Table 7-7: General Design Variables - Unpaved and Single Lane Roads

Design Speed		**km/h**	**80**	**70**	**60**	**50**	**40**	**30**
Minimum. Stopping Sight Distance	g = 0%	m	160	125	95	70	50	32
	g = 5%	m	190	145	110	80	55	35
	g = 10%	m	235	175	130	90	60	37
Min. Passing Sight Distance to abort		m	240	210	180	155	135	115
Min. Horizontal Radius 4 % SE		m	355	255	175	115	65	35
Max. Gradient (desirable)		%	4	4	6	6	6	6
Max. Gradient (absolute)		%	7	7	7	7	7	7
Minimum Gradient		%	0.5	0.5	0.5	0.5	0.5	0.5
Max. Super-elevation		%	6	6	6	6	6	4
Min. Crest Vertical Curve		K	58	35	20	11	6	2
Min. Sag Vertical Curve Comfort criterion		K	16	12	9	7	4	2.5
Min. Sag Vertical Curve Headlights criterion		K	32	25	19	14	9	5
Normal Camber/Cross-fall		%	5	5	5	5	5	5

Table 7-8: Unpaved LVRR 1 Geometric Parameters (AADT <50[1])

Design Element		Unit	Flat	Rolling	Mountain	Escarp't
Design Speed		km/hr	60	40	30[2]	20
Width of Carriageway (Table 5-1)		m	3.5			
Width of shoulders		m	0.5[3]			
Min. Stopping Sight Distance	g = 0%	m	95	50	30	20
	g = 5%	m	110	55	35	20
	g = 10%	m	130	60	37	20
Min. Horizontal Radius		m	175	65	35	15[4]
Max. Gradient	Desirable	%	6	6	6	6
	Absolute	%	7	7	7	7
Min. Gradient[5]		%	0.5	0.5	0.5	0.5
Min. Crest Vertical Curve[6]		K	20	5	3	1
Min. Sag Vertical Curve		K	9	4	3	1
Normal Camber/Cross-fall		%	5	5	5	5

Notes

1 If there are more than 10 Large Heavy Vehicles, then LVRR 2 should be used.
2 Design speed adjusted to provide the same minimum radii of curvature as for paved standard.
3 On road class LVRR 1, where passing bays are not provided, the minimum width of the roadway will be 4.5 m comprising a carriageway of 3.5 m and 2 x 0.50 m unpaved shoulders.
4 On hairpin stacks, the minimum radius may be reduced to 13 m.
5 In some circumstances in very flat terrain, this can be reduced to 0.3%.
6 These values are based on an object height of 0.2 m. Use of a different sized object requires approval.

Table 7-9: Unpaved LVRR 2[1,2] Geometric Parameters (AADT 50-150)[1]

Design Element		Unit	Flat	Rolling	Mountain	Escarp't
Design Speed		km/hr	60	50	35[2]	20
Width of Carriageway (Table 5-1)		m	3.5 – 4.5			
Width of shoulders		m	0.5[3]			
Min. Stopping Sight Distance	g = 0%	m	95	70	45	20
	g = 5%	m	110	80	47	20
	g = 10%	m	130	90	50	20
Min. Horizontal Radius		m	175	115	55	15[4]
Max. Gradient (desirable)		%	6	6	6	6
Max. Gradient (absolute)		%	7	7	7	7
Min. Gradient[5]		%	0.5	0.5	0.5	0.5
Max. Superelevation		%	6	6	6	6
Min. Crest Vertical Curve [6]		K	20	10	5	1
Min. Sag Vertical Curve		K	9	7	4	1
Normal Camber/Cross-fall [7]		%	5	5	5	5

Notes

1. If the number of Large Heavy Vehicles >20 then LVRR 4 should be used.
2. Design speed adjusted to provide the same minimum radii of curvature as for paved standard.
3. On road class LVRR2, where passing bays are not provided, the minimum width of the roadway will be 4.5 m comprising a carriageway of 3.5 m and 2 x 0.50 m unpaved shoulders.
4. On hairpin stacks, the minimum radius may be reduced to a minimum of 13 m.
5. In some circumstances in very flat terrain, this can be reduced to 0.3%.
6. These values are based on an object height of 0.2 m. Use of a different sized object requires approval.
7. Cross-fall can be reduced to 4% where warranted (e.g. poor gravel-for safety, low rainfall).

Table 7-10: Unpaved LVRR 3(1, 2) Geometric Parameters (AADT 150-250)(1)

Design Element		Unit	Flat	Rolling	Mountain	Escarp't
Design Speed		km/hr	70	60	45(2)	25
Width of Carriageway (Table 5-1)		m	4.5 – 5.5			
Min. Stopping Sight Distance	g = 0%	m	125	95	60	25
	g = 5%	m	145	110	70	25
	g = 10%	m	175	130	75	30
Min. Horizontal Radius		m	255	175	90	25(3)
Max. Gradient (desirable)		%	6	6	6	6
Max. Gradient (absolute)		%	7	7	7	7
Min. Gradient(4)		%	0.5	0.5	0.5	0.5
Max. Superelevation		%	6	6	6	6
Min. Crest Vertical Curve (5)		K	35	20	9	1
Min. Sag Vertical Curve		K	12	9	5	2
Normal Camber/Crossfall(6)		%	5	5	5	5
Shoulder Cross-fall		%	5	5	5	5

Notes

1 If there are more than 20 Large Heavy Vehicles, then LVRR 4 should be used.
2 Design speed adjusted to provide the same minimum radii of curvature as for the paved LVRR3 standard.
3 On hairpin stacks, the minimum radius may be reduced to a minimum of 15 m.
4 In some circumstances in very flat terrain, this can be reduced to 0.3%.
5 These values are based on an object height of 0.2 m. Use of a different sized object requires approval.
6 Cross-fall can be reduced to 4% where warranted (e.g. poor gravel -for safety, low rainfall).

Table 7-11: Unpaved LVRR 4[1] Geometric Parameters (AADT 250-350)[1]

Design Element		Unit	Flat	Rolling	Mountain	Escarp't
Design Speed		km/hr	70	60	45[2]	25
Width of Carriageway (Table 5-1)		m	5.5 – 6.5			
Min. Stopping Sight Distance	g = 0%	m	125	95	65	23
	g = 5%	m	145	110	70	24
	g = 10%	m	175	130	75	25
Min. Passing Sight Distance		m	210	180	145	50
Min. Horizontal Radius		m	255	175	90	15[3]
Max. Gradient (desirable)		%	6	6	6	7
Max. Gradient (absolute)		%	7	7	7	7
Min. Gradient[4]		%	0.5	0.5	0.5	0.5
Max. Superelevation		%	6	6	6	6
Min. Crest Vertical Curve [5]		K	35	20	10	3
Min. Sag Vertical Curve		K	25	19	11	3
Normal Camber/Crossfall[6]		%	5	5	5	5
Shoulder Cross-fall		%	5	5	5	5

Notes

1. If there are more than 30 Large Heavy Vehicles then LVRR 5 should be used.
2. The design speed has been adjusted to provide the same minimum radii of curvature as for the paved LVRR4 standard.
3. On hairpin stacks, the minimum radius may be reduced to a minimum of 15 m.
4. In some circumstances in very flat terrain, this can be reduced to 0.3%.
5. These values are based on an object height of 0.2 m. Use of a different sized object requires approval.
6. Cross-fall can be reduced to 4% where warranted (e.g. poor gravel – for safety, low rainfall).

Table 7-12: Unpaved[2] LVRR 5 Geometric Parameters (AADT > 400)[1]

Design Element		Unit	Flat	Rolling	Mountain
Design Speed		km/h	80	70	50
Width of Carriageway (Table 5-1)		m	6.5		
Min. Stopping Sight Distance	g = 0%	m	160	125	70
	g = 5%	m	190	145	80
	g = 10%	m	235	175	90
Min. Passing Sight Distance		m	240	210	155
Min. Horizontal Curve Radius	SE = 4%	m	355	255	115[2]
	SE = 6%	m	265	190	85
Max. Gradient (desirable)		%	6	6	6
Max. Gradient (absolute)		%	7	7	7
Min. Gradient[3]		%	0.5	0.5[3]	0.5
Min. Crest Vertical Curve [4]		K	58	35	11
Min. Sag Vertical Curve		K	16	12	7
Normal Camber/Crossfall		%	5	5	5
Shoulder Crossfall		%	5	5	5

Notes

1 If there are more than 80 Large Heavy Vehicles, then the specifications for the classification of next traffic level should be used.

2 On hairpin stacks, the minimum radius may be reduced to a minimum of 15 m.

3 In some circumstances in very flat terrain, this can be reduced to 0.3%.

4 These values are based on an object height of 0.2 m. Use of a different sized object requires approval.

7.5 Basic Access Requirements

For the lowest category of road, it may sometimes be necessary to adopt a basic access-only approach. For such roads, it may be too expensive to provide a design speed, but absolute minimum standards must be applied. These are summarised in Table 7-13.

Table 7-13: Minimum Standards for Basic Access Only

Characteristic	Minimum requirements	
Radius of horizontal curvature	12 m absolute but up to 20 m depending on expected vehicles	
Vertical curvature K value for crests K value for sags	 2.0 0.6	
Maximum gradients: Open to all vehicles Open only to cars and pick-ups	 14% 16%	
Minimum stopping sight distance	Flat and rolling terrain Mountainous Escarpments	50 m 35 m 20 m

7.6 Cross Sections

A summary of the recommended dimensions for the various cross-section elements for both paved and unpaved roads is shown in *Chapter 5 – Cross Section*, Figure 5-1 to Figure 5-5.

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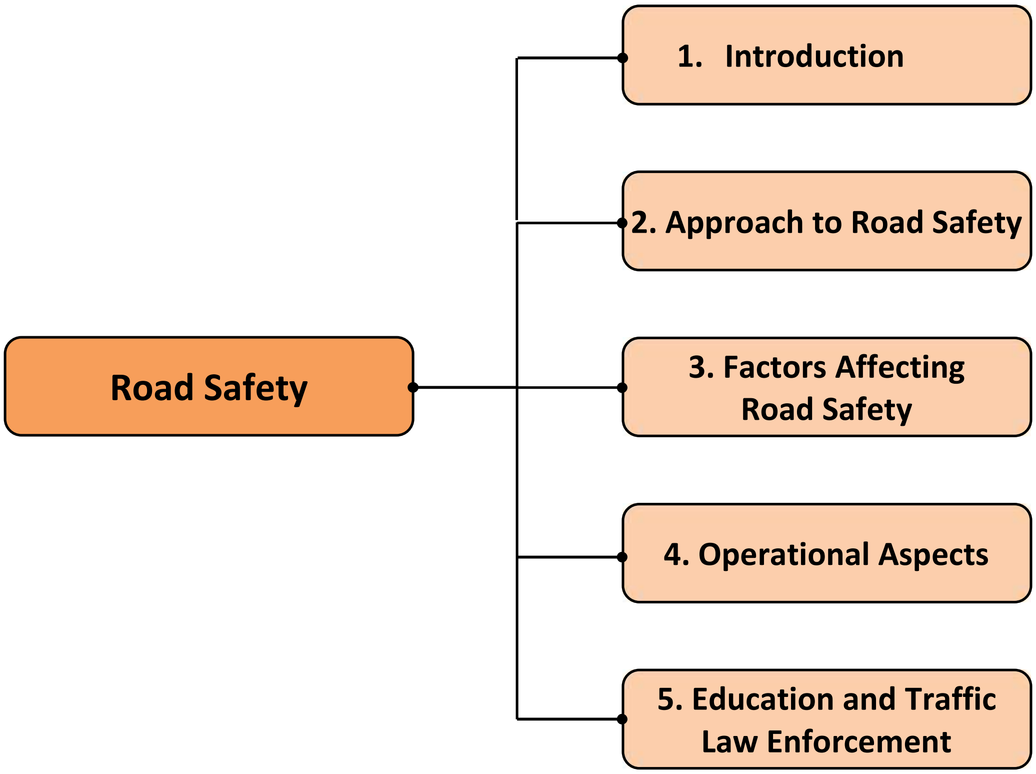
Part B
Road Safety

Low Volume Rural Roads Guideline and Standards
Volume 2: Part B – Road Safety



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1 Introduction

1.1 Background

Road safety is of prime importance for all Afghans and not only road users. The consequences of accidents impact significantly on the national economy in terms of property damage, loss of earnings, road administration and hospital costs resulting from physical injury, in addition to the emotional consequences of pain, suffering and death. The number of fatalities per 100 000 of the population and the number of road accidents is higher than in many other countries, despite the country's much lower traffic densities. These statistics highlight the importance of applying road safety measures in a holistic and proactive manner on all roads, including LVRRs, which are used by a large proportion of the rural Afghan population.

Figure 1-1: Vulnerable road users

Road safety issues on LVRRs tend to be different to those on high volume roads mainly because there are usually a higher number of vulnerable road users present on LVRRs such as pedestrians, cyclists, motorcyclists, three-wheeler transport including motorcycle trailers, human drawn carts, mule transport and other vulnerable road users that are generally not adequately catered for. Walking constitutes the main mode of transport in many rural Afghan villages. Thus, specific design considerations are required to deal with the challenge of catering for a mix of traffic modes (such as motorized and non-motorized, fast and slow-moving traffic) in villages and on rural roads. Figure 1-1 illustrates the conflict potential between motorized and non-motorized modes of traffic. Moreover, motorcycles have become a popular form of transport in rural Afghanistan because of the inaccessibility of some areas to other vehicles, and their use has unfortunately resulted in a high incidence of accidents. Thus, special attention is also given to measures for safeguarding these vulnerable road users.

The class of LVRR will influence the level of road safety measure(s) that will be required. Furthermore, LVRRs in villages need a different approach to those outside villages. In villages, traffic movements are more complex and the potential conflict between through traffic and local crossing movements makes speed management essential. *Chapter 4 - Operational Aspects* provides guidance on how to deal with this complex challenge. Moreover, paved and unpaved LVRRs also require different approaches with regard to the application of road safety measures such as signage, road markings and traffic calming. Other aspects that should be considered from a road safety perspective include:

- street lighting in villages;
- bridge structures and culverts;
- trails and mule tracks.

The planning, design and maintenance of trails and mule tracks are important because of the inaccessible mountainous terrain, which makes many remote villages not easily accessible by road. These aspects are addressed in Volume 1: Pavement Design.

1.2 Purpose

The main purpose of Part B of *Volume 2: Geometric Design and Road Safety* is to highlight important aspects of design that affect road safety and to provide guidance on dealing with them in a holistic manner in low volume rural road environments. Part B does so in a manner that is not only appropriate to the specific needs of rural Afghans but also recognizes the need to strike a balance between road investment, safety and service level.

1.3 Scope

Part B firstly presents the approach to road safety on LVRRs, followed by the main factors that affect road safety. Consideration is then given to various operational aspects that enhance road safety, such as traffic calming, road signage and markings. Finally, measures for improving road safety through education and traffic law enforcement are presented.

1.4 Structure

Part B is divided into five chapters, as shown in Table 1. There is also an extensive bibliography that provides links to many of the topics discussed in the document. Because the chapters are relatively short and the issues interrelated, the bibliography is provided after the last chapter of Part B.

Table 1-1: Structure

Part B – Road Safety	
Section	**Chapter**
Road Safety	1. Introduction 2. Approach to Road Safety 3. Factors Affecting Road Safety 4. Operational Aspects 5. Education and Traffic Law Enforcement

Appendices	
Appendix A	**Glossary of Terms**

1.5 Benefits of Using the Guideline

There are several benefits to be derived from adopting the approaches advocated in the Guideline, including:

- Recognition of the multi-casual nature of road accidents and adoption of the Safe Systems approach for managing all the elements that contribute to improved road safety.
- The application of Road Safety Audits and Road Safety Inspections to ensure that LVRRs are designed and constructed to comply with minimum operational road safety requirements.
- Engendering a better understanding of the road safety needs in a mixed traffic environment where the different road used have to share limited road space.
- Recognition of the importance of road maintenance to ensure safe operational conditions in the different natural environments found in Afghanistan.
- The involvement of communities and law enforcement officers to educate road users and enforce traffic laws.

1.6 Sources of Information

In addition to providing general information and guidance, the Guideline also serves as a valuable source document because of its comprehensive lists of references from which readers can obtain more detailed information to meet their particular needs. A bibliography can be found at the end of each chapter of the Guideline. Where the sources of any tables or figures are not specifically indicated, they are attributed to the authors.

1.7 Updating of the Guideline

As LVR technology is continually being researched and improved, it will be necessary to update the Guideline periodically to reflect improvements in practice. All suggestions to improve the Guideline should be in accordance with the following procedures:

- Any proposed amendments should be sent to the MRRD, motivating the need for the change and indicating the proposed amendment.
- Any agreed changes to the Guideline will be approved by the MRRD, after which all stakeholders will be advised accordingly.

1.8 Departure from Standards

There may be situations where the road safety practitioner may be compelled to deviate from a road safety requirement presented in this Guideline. Where this is necessary, the practitioner must obtain written approval and authorization from the MRRD. The practitioner shall submit the following information to the MRRD.

- The aspect of the road safety requirement from which departure is desired.
- A description of the road safety requirement, and the extent of departure from that requirement.
- The reasons for the departure from the requirement.
- Any mitigation measure(s) to be applied for reducing the risk of accidents.

2 Approach to Road Safety

2.1 General

Several approaches aimed at achieving sustainable road safety have been successfully adopted internationally to ensure that the road and its environment are optimally designed to cater for all road users. The most important concept relevant to LVRRs is the '*Safe Systems'* approach, as discussed below.

2.2 Sustainable Road Safety

2.2.1 General

A sustainably safe road traffic system aims at preventing deaths, injuries and damage to all road users and property by systematically reducing the underlying risks of the entire traffic system. Human factors, as discussed in Chapter 3, are the primary focus. By starting from the needs, competences, limitations and vulnerability of people, the traffic system can be realistically adapted to achieve maximum safety.

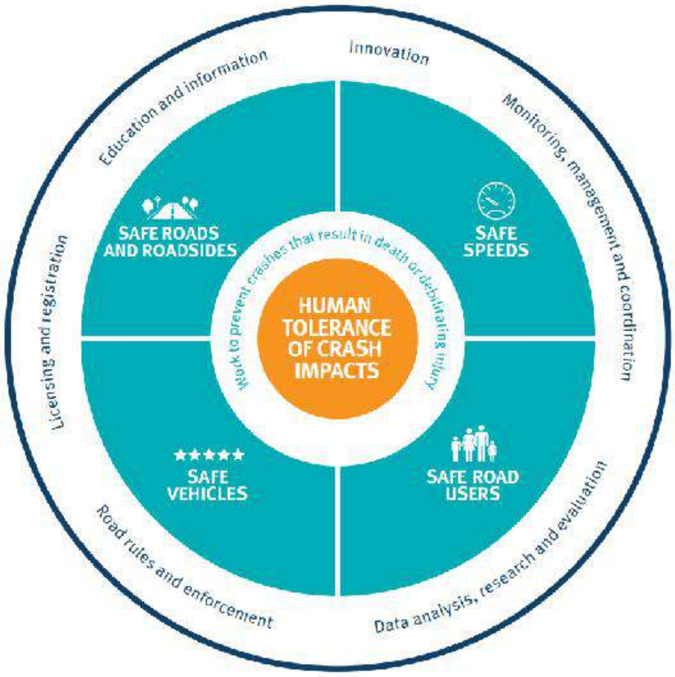
2.2.2 'Safe Systems' Approach

The concept behind the 'Safe Systems' approach is to build a road transport system that tolerates human error and minimizes casualties following road accidents. The guiding principles of this approach are:

- **People make mistakes.** Humans will continue to make mistakes, and the transport system must accommodate these errors. The transport system should not result in death or serious injury as a consequence of errors on the roads.

- **Human physical frailty.** There are known physical limits to the amount of force the human body can take before it is injured.

- **A 'forgiving' road transport system.** A 'Safe System' ensures that the impact forces in accidents do not exceed the limits of human tolerance. Speeds must be managed, so that road users are not exposed to impact forces beyond their physical tolerance. System designers and operators need to take into account the limits of the human body in designing and maintaining roads, vehicles and speeds.



Source: Department of Transport and Main Roads, Queensland, 2015.

Figure 2-1: 'Safe Systems'approach

The four key elements of the 'Safe Systems' approach are 'Safe People', 'Safe Roads and Roadsides', 'Safe Speeds', and 'Safe Vehicles', as illustrated in Figure 2-1. In contrast to traditional road safety approaches that primarily focus on road users and risky behavior, the 'Safe System' approach provides a systematic method to reduce accident occurrence and subsequent injuries in the event of an accident.

2.3 Road Safety Audit and Inspection

2.3.1 General

The undertaking of Road Safety Audits (RSAs) and Road Safety Inspections (RSIs) are critical to ensure that all road safety aspects are incorporated into and maintained from inception through the project life cycle of each LVRR as illustrated in Figure 2-2.

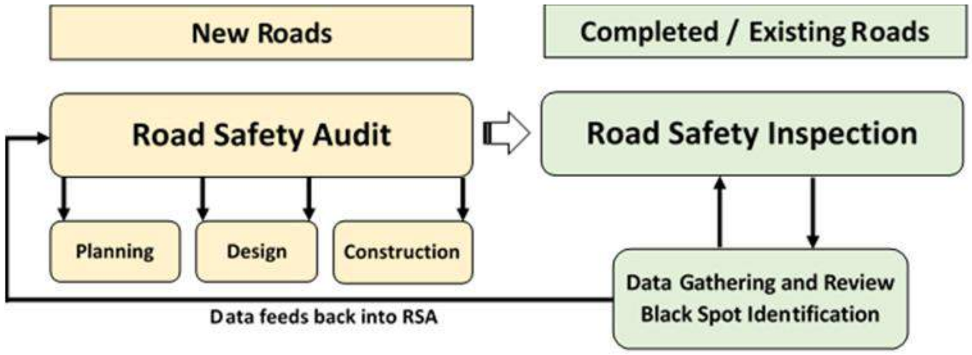


Figure 2-2: Road Safety Audits and Road Safety Inspections

As illustrated in Figure 2-2, the aim of an RSA is to ensure that necessary provisions for road safety have been taken into account in the project design and sustained throughout the entire duration of its operation. This means that road safety should be considered throughout the entire project cycle, from the planning, design, construction, pre-opening and during operation of the road.

2.3.2 Road Safety Audits

General

A Road Safety Audit (RSA) is defined as a formal examination of the safety aspects a road project and follows a clearly defined process for assessing the operation of a road from the perspective of all road users, motorized as well as non-motorized. The RSA concludes with a written report that identifies road safety issues and makes recommendations to remove or reduce the impact of these issues. The responsibility to implement these recommendations remains with the executing agency.

Currently, such audits are not carried out in Afghanistan. However, the Central Asian Regional Economic Community (CAREC), of which Afghanistan is a member country, has adopted the use of RSAs. The CAREC Road Safety Audit Manual, as well as other international road safety audit manuals listed in the bibliography, provides guidance to road engineers in Afghanistan.

There are six internationally recognized stages carrying out a RSA, namely:

- feasibility stage
- preliminary design stage
- detailed design stage
- road construction stage
- pre-opening stage; and
- operational stage(RSIs).

A road safety audit should be carried out by a team of independent and qualified auditors. Each auditor must be independent of the project design, and each must be qualified in road safety engineering practices. Working as a team of auditors with different educational backgrounds and experiences increases the likelihood that all potential safety concerns will be identified and recorded in the final report.

Source: CAREC Road Safety Audit Manual

Figure 2-3: Multi-disciplinary audit team assessing an existing road upgrade

The cost of a RSA and the consequent cost of changing a design is invariably significantly less than the cost of remedial treatments after the works have been constructed. For further information, reference is made to the CAREC Road Safety Engineering Manual 1: Road Safety Audit.

The different aspects to be considered during the planning and design of LVRRs are discussed in more detail hereunder.

Planning

It is often possible to improve road safety characteristics at markedly little or no extra cost, provided the road safety implications of design are considered at the planning stage. This requires adherence to a number of key principles inherent in the design process, as follows:

- Undertaking appropriate traffic counts
  - Ensuring that traffic counts include the counting of NMT, e.g., pedestrians, bicycles and animal-drawn carts. Such information will be influential in planning aspects of the geometric layout of the road, such as shoulder widths.
- Catering for all road users
  - Includes catering for non-motorized and vulnerable road users.
  - Has implications for almost all aspects of road design, including carriageway width, shoulder design, bridge width, side slopes and side drains.
- Creating a forgiving road environment
  - Forgives a driver's mistakes or vehicle failure to the extent possible without significantly increasing costs.
- 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 behavior
  - 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
  - Conflict cannot be avoided entirely but can be reduced by design, including staggering junctions or channelizing pedestrians to safer crossing points.
  - Ensures that demands beyond the driver's ability to manage, are not placed upon the driver.

Design

The geometric design of LVRRs, which is addressed in Part A of the Guideline, deals with the technical aspects of design. However, the road safety aspects must be incorporated as part of the design criteria during the development of the detailed design of the project. Generally, there are three main aspects of road design which, in combination, have a direct effect on road safety:

- Road alignment (horizontal and vertical)
- Road width
- Sight distance

Horizontal alignment: This is one of the factors which controls the speeds of vehicles. The greater the curvature (sinuosity of the road in degrees/km), the lower the speed tends to be, and the lower the speed, the safer the road.

Accidents may arise where straight sections of the road are followed by sharp bends without due warning to the drivers. In such cases, a driver will feel comfortable traveling at a relatively high speed on the straight sections, and the sharp bends will present an unexpected hazard. In such a situation, typical safety countermeasures that would appear to be both feasible and effective include:

(a) Increasing the radius of curvature of the sharp bend to accommodate a higher speed.

(b) Adopting traffic calming countermeasures, such as rumble strips, road humps and road signage, to reduce the driver's speed.

The above options present different costs and different levels of effectiveness. Ideally, a cost-benefit analysis of the two options should be undertaken to decide on the preferred option. However, in practice, there are often insufficient accident statistics and accident analyses on LVRRs on which to base such a decision. Thus, a pragmatic decision will have to be made taking account of such factors as:

- the severity of the problem;
- ease of implementing the option; and, importantly
- the amount of traffic likely to use the road over its design life.

Accidents tend to occur when speeds are high and the circumstances unfavorable. In the example opposite, the curve radius should be 850 m. However, because of the high cost of improving the curve, cheaper measures have been adopted, including the placement of two sets of rumble strips on the approach to the curve, followed by a road hump just prior to the start of the curve, and the installation of a guardrail.

It is important not to locate the road hump too far away from the last set of rumble strips, about 50 m is appropriate so that the driver does not have time to start accelerating after the last set of rumble strips before decelerating again to cross over the road hump.

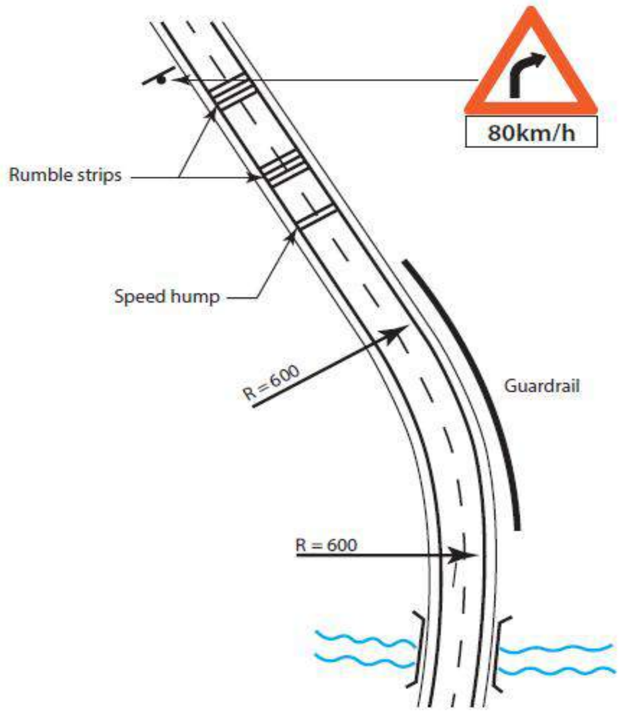


Figure 2-4: Adoption of traffic-calming measures before a sharp bend

Vertical alignment: Like horizontal alignment, this factor also controls vehicle speed. The greater the rise and fall of the road, the lower the speed and, hence the safer the road, unless the length of the summit (crest) vertical curve suffers from inadequate sight distance. Such a situation would then give rise to possible collisions between oncoming vehicles. Typical countermeasures would include:

(a) Increasing the length of the vertical curve by flattening the crest of the curve. This would incur earthworks costs, the extent of which would depend on the length of the vertical curve required.

(b) Adopting traffic calming measures, such as rumble strips, road signage and road markings to reduce the driver's speed (see Figure 2-5 below).

The preferred option would be based on consideration of the cost-benefit issues discussed above in relation to inadequate horizontal curvature.

Figure 2-5: Use of edge markings to improve road safety on vertical crest curve

Road width: Road width has an impact on accident risk by affecting speed: generally, the wider the road, the higher the speed and vice versa, i.e., the narrower the road, the lower the speed. However, international studies have shown that sufficiently wide LVRRs generally have a better safety record than too narrow ones. The key question is – what is a sufficiently wide LVRR? The answer to that question depends crucially on the estimated number of average interactions (head-on meetings) per day, which is reproduced below from *Part A of Volume 2 – Geometric Design* and *Road Safety* (Table 2-3).

Table 2-1: Avg. no of interaction/km/hour and time between interactions/km on LVRRs

	Average no of interactions/km/hour				Minutes between interactions/km			
ADT	**300**		**100**		**300**		**100**	
Speed km/h	**Traffic directional split**				**Traffic directional split**			
	50/50	**75/25**	**50/50**	**75/25**	**50/50**	**75/25**	**50/50**	**75/25**
40	7.81	5.86	0.43	0.65	7.7	10.2	69.1	92.2
60	5.21	3.91	0.58	0.43	11.5	15.4	103.7	138.2
80	3.91	2.93	0.87	0.33	15.4	20.5	138.2	184.3

As clearly shown in Table 2-1, many vehicles traveling on LVRRs will only very infrequently meet an opposing vehicle. Thus, the need for overly wide roads cannot be justified and should be decided based on the road standard (LVRR1 to LVRR5), anticipated ADT and average vehicle speed over the length of the LVRR or, at least, major sections of it. It is on that basis that the roadway widths (carriageway plus shoulders) have been determined for the various classes of LVRRs as presented in *Part A – Geometric Design, Chapter 5 – Cross Section*.

Where the incidence of motorcycles and NMTs is high, shoulders are recommended for all but the lowest design class and will normally be paved when the carriageway is paved. Apart from their structural function, they are also intended to perform several safety functions, such as:

- To provide additional maneuvering space on roads of lower classification and traffic flows.
- To provide parking space at least partly off the carriageway for broken down vehicles.
- To reduce the tendency of non-motorized traffic to travel on the carriageway.

Sight distance: Sight distance has, together with road width, an impact on road safety. Both of these factors should be adequate for the standard of road, traffic (ADT) and average travel speed expected on a LVRR. A combination of narrow road widths and inadequate sight distance must be avoided by consideration of such measures as:

- Widening of the road, especially at sharp bends.
- Provision of shoulders, especially where there are high levels of NMT users, such as in the vicinity of villages.
- Provision of appropriate traffic calming measures.

The preferred option would be based on consideration of the issues discussed above in relation to inadequate horizontal or vertical curvature.

Construction

Special road safety measures must be taken to ensure the safe passage of traffic during construction, including:

- Provision of adequate signage to warn drivers sufficiently in advance of the construction zone.
- Deployment of flagmen/women and/or stop-go lights to provide a clear demarcation of the movement of vehicles.
- Use of temporary speed humps.
- Watering of unfinished works and detours to minimize dust emission.
- Provision of protective work wear (e.g. high-visibility clothing) to project workers.

The measures to be taken by the contractor are normally specified in the contract documents and must be adhered to. More details regarding road safety considerations at road works, e.g., work zone traffic management plans (WZTMPs), are given in Chapter 4 on Operational Aspects and in the Pavement Design Manual.

2.3.3 Road Safety Inspections

General

Once a road is fully operational, Road Safety Inspections (RSIs) must be carried out on an ongoing basis to ensure the safe performance of the road. RSIs are carried out to identify traffic hazards related to the road environment characteristics and to propose interventions to mitigate the detected hazards. Guidelines for RSIs include inspection of important road safety elements such as the quality and condition of road signs and road markings, quality of the road surface characteristics (potholes, rutting, undulations, etc.), adequacy of sight distances, safety of bridges and culverts; and the absence of permanent or temporary obstacles, presence of roadside traffic hazards, etc.

It is important that a system is established to ensure that the information gathered during an RSI is fed back into the RSA audit process. Preferably the RSA and RSI should be carried out by the same personnel, but a formal feedback system will ensure that the institutional memory is not lost with the change of personnel.

The RSI will be instrumental for the identification of potential "critical spots" and for providing feedback to the maintenance organization on issues that need attention, as discussed below. For further information about RSIs, reference is made to the *CAREC Road Safety Engineering Manual 1: Road Safety Audit* or any other recognized international road safety audit manual.

Critical spot identification and treatment

Critical spots are locations on a road that are considered to be dangerous because accidents tend to occur much more frequently, for whatever reason, than on the road in general. Critical spots are normally identified through the analysis of accident data that are collected by the Police. The local community can also provide information regarding the location of accidents.

The situation at the critical spot must be analyzed, and the most appropriate countermeasures identified, e.g., speed reduction measures, widening of the road at horizontal curvature, provision of NMT facilities such as walkways and space for bicycle traffic.

Maintenance

Regular maintenance of rural road infrastructure not only prolongs the life of the road but, importantly, ensures that safety hazards are minimized. In situations as listed below, lack of maintenance could affect road safety:

- Vegetation growth at intersections and sharp curves.
- Tree roots damaging the pavement and causing traffic to swerve.
- Potholes in the roadway that cause the swerving of vehicles.
- Gravel roads with uneven riding surface, loose gravel, corrugation, ruts, high dust emissions, etc.
- Faded, dirty, damaged, vandalized or missing traffic signs.
- Blocked drains that could causing flooding and slippery surface.
- Avalanches or snow on roads during the winter season. Measures to improve road safety include the use of marker poles to guide drivers, clearing of snow, use of salt to de-ice roads because it lowers the freezing point of ice capping.
- Sand on the roadway as a result of dust storms.
- Faint road markings, especially the loss of visibility of road humps.
- Damaged bridge rails and guardrails.
- Edge drop, especially on roads that are not lit at night.
- Lack of maintenance of breakaway posts.

As illustrated in Figure 2-6, failure to carry out adequate road maintenance can impact adversely on road safety in that it prevents road users, particularly cyclists, motorcyclists and animal-drawn carts, from using the shoulders when required to move off the road due to on-coming motorized traffic. Thus, maintenance must focus on keeping the road safe and serviceable and ensure that the intended purpose and design of the road is maintained. Maintenance programs can also enable incremental improvements in road safety through simple, low-cost attention to pavement conditions, barriers, signs and line-marking, sight-distance and visibility constraints, road debris or snow removal, road clearing after avalanches, etc. to make roads passable and safe.

Figure 2-6: Typical maintenance problems on LVRRs

2.3.4 Motorcycle safety

Background

Motorcycles are a common and popular means of transport on LVRRs and, in some rural areas, constitute an important means of transport. However, motorcycles are also a dangerous form of transport in comparison with other motorized means and need to be specifically catered for during the design process. Having only two wheels in contact with the ground, their small size, lack of protection and overloading, makes them more susceptible to loss of control and puts drivers and their passengers at greater risk of serious injury.

Injuries suffered in accidents involving motorcycles on rural roads are more severe than those involving other modes. Poor road user behavior, generally as a result of a lack of training and a lack of law enforcement in rural areas, is the most common contributory factor in motorcycle accidents on rural roads. On LVRRs, speed-related motorcycle accidents often occur as a result of several factors, including:

- an unevenness of the unpaved road surface caused by corrugations, ruts, potholes;
- loose material or snow on the road surface;
- lack of road shoulders and recovery areas.

Figure 2-7 illustrates some of the challenges facing motorcyclists and cyclists.

Figure 2-7: Road safety risks on LVRRs

Road safety design considerations to improve motorcycle safety on LVRRs

The following safety measures are considered important on LVRRs and tracks/trails, over and above safety measures generally applied:

- Speed humps must be appropriately designed not to create obstacles that can cause a motorcycle driver or cyclist to lose control.
- Avoid the use of sharp horizontal bends to minimize the risk of motorcyclists either running off the road if approached at too high a speed or colliding with other road users due to poor visibility. Widen sharp horizontal bends as a safety mitigation measure.

- Adequate road width is critical for motorcycle safety. The road must be wide enough for a motorcycle to pass a four-wheeled vehicle safely without being forced to leave the road. A minimum carriageway width of 3.5 m on the lowest road class (LVRR1) is recommended. This width will also be advantageous to motorcyclists because roads on fill pose a specific hazard to them and should be wide enough to allow for recovery maneuvers.

3 Factors Affecting Road Safety

3.1 General

Because of its multi-dimensional nature, road safety cannot be discussed in isolation of a number of related factors. As illustrated in Figure 3-1, road safety is linked to, and influenced by, various factors including road design, road construction, road maintenance and related pavement condition, as well as the road environment and road user behaviour.

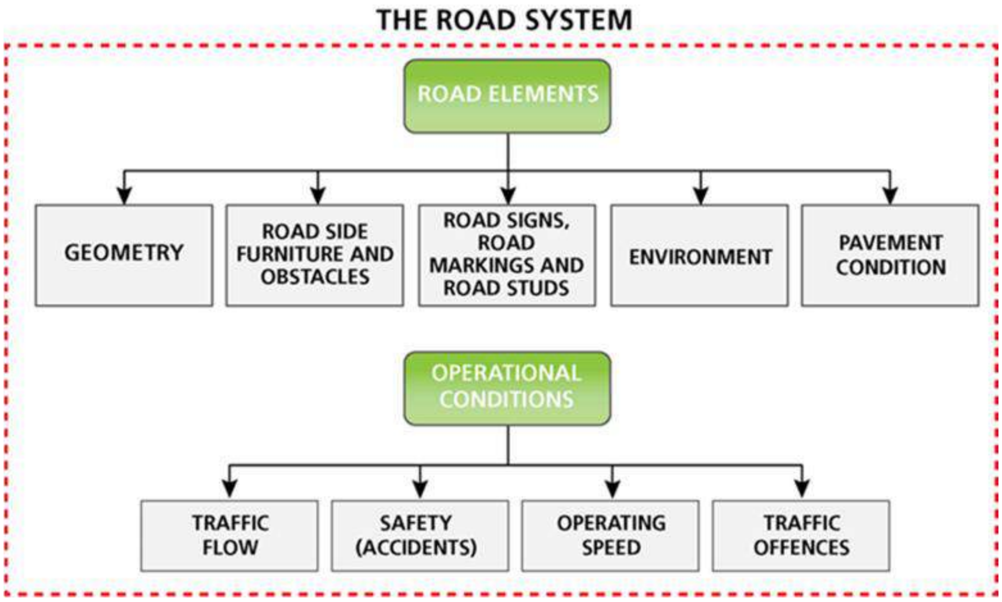


Figure 3-1: Elements of the road system and operational conditions

Many of the road elements and operational conditions are also interrelated. For example, as illustrated in Figure 3-2, overloading has an important influence on pavement condition and is influenced by law enforcement, while speeding is also influenced by the road geometry and traffic law enforcement. Both overloading and speeding, in turn, have an influence on road safety in terms of accidents while the environment, coupled with the maintenance standard applied, affects pavement condition and, in turn, road safety.

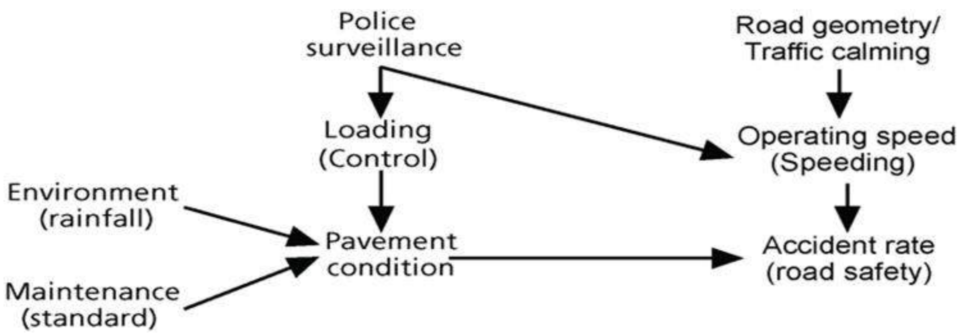
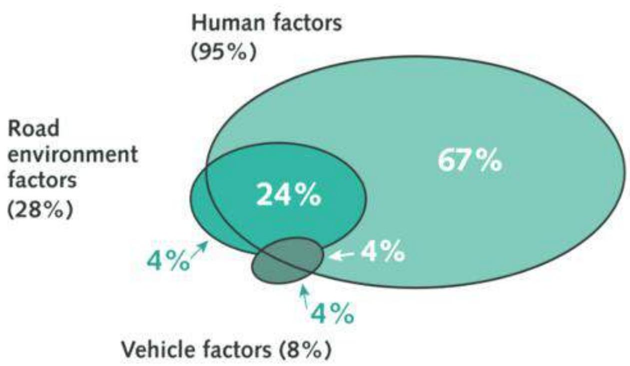


Figure 3-2: Interrelationship between road elements and operational conditions

3.2 The Nature of Accidents

Road accidents, including those on LVRRs, are generally unpredictable and tend to be 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 typically contributing to an estimated combined 95% of all accidents, the road environment about 28%, and vehicles about 8%, as shown in Figure 3-3.

It is apparent from Figure 3-3 that tackling the challenge of poor road safety requires proactive strategies such as the "Safe Systems" approach that treat the main contributing factors. The "human factor" is concerned with the general and stable reactions of common road users and deals with identifying road characteristics that are not according to human threshold limit values and therefore, potentially, trigger accidents. A road should confirm what drivers expect based on previous experience and should present clear clues as to what is expected of them. If these expectations are violated, problems are likely to occur which, in the most severe cases, may lead to accidents and even death. Therefore, the objective is to design the road and its immediate environment in a manner that is conducive to the prevention of accidents and to a reduction of damage potential when accidents occur.



Source: Austroads (1994). Road Safety Audits, New South Wales

Figure 3-3: Multi-causal nature of road accidents

Information, training and traffic law enforcement will contribute to improving human behavior, but the physiological and psychological aspects can only be addressed through improved road design.

3.3 Typical Factors Contributing to Accidents

The following are factors that typically contribute to accidents on LVRRs:

- Inadequate planning and designing for road safety due in part to the non-inclusion of pedestrian and slow-moving traffic in traffic surveys, and consequent failure to take proper account of the operational environment.
- The provision of relatively steep cambers, typically 5% - 7% on gravel roads, to shed water off the road. This camber may provide little difficulty to motorized vehicles which tend to travel along the centre of the road. However, it can be very dangerous for cyclists and motorcyclists who often carry very large/heavy loads and, as a result, are unable to easily manoeuvre out of the way of fast-approaching traffic.
- The right-of-way outside the side drain may be obscured by vegetation and structures. In such situations, there is potentially a considerably increased risk to pedestrians, particularly young children, as there is little warning to motorized traffic when pedestrians or animals decide to cross the road.

Figure 3-4: Typical problems encountered on rural roads

- A combination of poor motorcycle driver behaviour and poor road condition, e.g. driving at inappropriate speed on a potholed or slippery surface, causing the motorcyclist to lose control.
- Relatively fast-moving motorized traffic competing for limited road space with slower-moving farm vehicles and NMTs.
- Narrow LVRRs on embankments leave little space for recovery for vehicles involved in single or multiple vehicle accidents.

Figure 3-5: Limited maneuvering and recovering space on embankments

- The right-of-way outside the side drain may be obscured by vegetation and structures. In such situations, there is potentially a considerably increased risk to pedestrians, particularly young children, as there is little warning to motorized traffic when pedestrians or animals decide to cross the road.

A comprehensive list of factors contributing to road accidents is presented in Table 3-1.

Table 3-1: Factors contributing to road accidents

Human factors	Road environment	Vehicle factors
- Misjudgement, overtaking, inattention, distraction o Untrained and inexperienced drivers o Distracted driving, e.g. eating, use of mobile phones o Driving with overloaded bicycle, motorbike or car o Distracted walking, e.g. use of mobile phones - Jaywalking or walking in the roadway - Speeding o Inappropriate/excessive speed - Drink-driving and drink-walking o Driving under the influence of alcohol/drugs o Intoxicated pedestrians/cyclists - Negligence by drivers, pedestrians or cyclists o Non-use of seatbelts, child restraints or helmets o Sheer disregard/lack of knowledge of road traffic rules and regulations - Fatigue o Driving for excessively long periods without adequate rest.	- Poor road design o Inadequate road capacity o Failure to separate NMTs from motorized traffic o Inadequate sight distance particularly blind crest curves o Sharp horizontal curve immediately after a sharp crest o Sharp curves requiring a reduction in speed of more than 20 km/h o Road geometry that does not encourage and enforce a reduction of speed on hazardous sections o Inadequate road signage and markings o Hazards close to the edge of the road o Animals crossing over or straying onto the road o Inappropriate choice of road surfacing o Unmarked changes in road surfaces (particularly from paved to unpaved) - Poor maintenance o Deterioration of surfacing and pavement structure o Deterioration of road signs and markings o Deterioration of passive safety installations	- Speed differential between fast and slow moving vehicles, e.g. farm vehicles - Unroadworthy vehicles o Poor brakes, no horn, no lights o Steering deficiencies

Figure 3-6: Typical road safety challenges encountered on rural roads

3.4 Measures for Reducing Road Accidents

Although LVRRs are inherently quite safe due to the low traffic volumes, there is significant potential for reducing the incidence of accidents through the adoption of low-cost engineering measures at critical spots. However, it is essential to adopt a systematic approach to identify the factors contributing to road accidents so that the most appropriate treatments are selected and implemented.

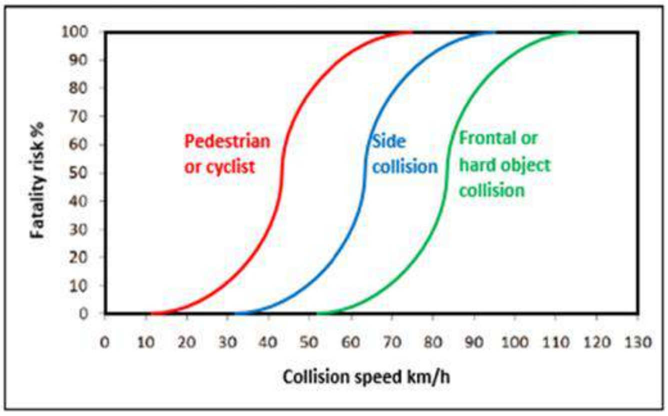
There are a variety of measures for reducing road accidents, including:

- road safety audits and road safety inspections;
- traffic calming measures;
- segregation of NMTs from motorized traffic;
- traffic signs and road markings;
- road safety features of culverts and bridges;
- road lighting;
- safe rail crossings;
- road safety education and traffic law enforcement.

4 Operational Aspects

4.1 General

Speed is the primary factor in most vehicle accidents – increasing both risk and severity. As drivers move faster, they have less time to respond to road conditions and any resulting collision causes more damage. As illustrated in Figure 4-1, the fatality risk of vulnerable road users increases dramatically when speeds are greater than 30 km/h. In the case of side-, frontal- or hard object impacts, these risks increase dramatically at 50 km/h and 70 km/h, respectively.



Source: World Bank Road Safety Facility (Undated)

Figure 4-1: Relationship between fatality risk and vehicle speed

In areas where vulnerable road users come into conflict with other traffic, there will be a need to introduce appropriate speed reduction and other road safety measures to improve this situation. Such measures can be applied through the selective use of traffic management and other techniques to improve traffic operations and thereby create safer road networks.

Typical road safety measures that may be adopted in rural environments include:

- Traffic calming
- Traffic segregation
- Road signs and markings
- Guardrails and pedestrian barriers
- Road furniture
- Street lighting from renewable sources
- Roadside control

The general approach is based upon recognition of the following underlying principles:

- Reducing speeds in villages or potentially hazardous locations.
- Segregation of pedestrians, cyclists and other slow-moving traffic from faster moving vehicles.

4.2 Prioritization of Road Safety Countermeasures

Although the prevention of loss of life, injuries and damage to property (in order of priority) should be the guiding principle of road design, the stark fact is that the cost of attempting to achieve this goal must be balanced against the benefits. International research has established quite favorable cost-benefit ratios for various traffic safety measures, but invariably these ratios are for much higher traffic levels than those found on LVRRs. Thus, there will be a threshold for how much it is worth spending on road safety improvement in low traffic environments. For LVRRs the focus should, therefore, be on the application of low-cost, but effective, road safety measures.

The process for prioritizing and selecting road safety countermeasures for implementation can range from a quantitative benefit/cost ratio (data permitting) to a qualitative rating process using, for example, high, medium and low ratings. The purpose of the countermeasure evaluation and prioritization is to review the potential countermeasures and select the most feasible one based on criteria such as:

- Anticipated road safety effectiveness
- Construction and maintenance costs and environmental impacts
- Stakeholder input and community expectations

In practice, in view of the relatively low number of vehicle interactions on LVRRs, particularly on the LVRR1 and LVRR2 classes, the more expensive types of traffic safety countermeasures may well not be justified on an economic cost-benefit basis.

4.3 Traffic Calming

4.3.1 General

Traffic calming typically comprises the use of a combination of physical measures that can reduce the negative effects of motor vehicle use, such as speeding, alter driver behavior, and thereby improve conditions for other vulnerable road users. Such measures focus on reducing speeds by use of self-enforcing traffic engineering techniques or through road design.

The application of traffic-calming measures is an effective way to control speed. The problems connected to them are normally due to poor design, e.g., the humps may be too high or too short or both, whilst the rumble strips may be too high or incorrectly spaced or both. When used in combination with each other, the spacing between them must also be appropriate. Failure to observe these shortcomings can even generate accidents. Thus, special attention must be paid to their design and, during construction, to their drainage, which must be carefully studied to avoid ponding during heavy rains. The designer should consult recognized international traffic calming guideline documents, some of which are listed in the bibliography.

4.3.2 Traffic-calming Measures

On LVRRs outside villages, the aim is to force vehicles to reduce their speed before encountering spots on the road that are not designed for the normal traveling speed or in front of junctions with other roads.

In rural villages, the aim is to slow down vehicles to acceptable (and posted) speed limits and to ensure that this reduced speed is maintained through the length of the road section. Traffic-calming measures in villages require special attention because the roads serving these villages are often required to serve two conflicting functions in that they must cater to both inter- and intra-village traffic. As a result, traffic entering the village often does so at speeds that are much too high for a village environment with slow-moving and turning traffic, parking outside shops and stalls and pedestrians and bicyclists moving along or across the road, often in an unpredictable manner. The typical road safety challenges experienced in villages are illustrated in Figure 4-2. This includes the opportunity to speed through the village, lack of separation of motorized and vulnerable road users, no road delineation or designated parking, shopping activities up to the road edge, no drainage, etc.

Figure 4-2: Typical Afghan village that will benefit from traffic calming measures

The "total village treatment", illustrated in Figure 4-3, has been developed with the objective of instilling in the driver a perception that the village is a low-speed environment in which driving speed should be reduced. In essence, the road through the village is treated as being in three zones, namely:

- The approach zone
- The transition zone
- The core zone.

In the approach zone, a "gateway" can be used to signal to the drivers that they are entering a low-speed environment, such as a village. Generally, it is desirable to apply traffic-calming measures in areas where horizontal sight distance is restricted because of sharp bends or other factors such as the absence of corner splays, buildings close to roadway edge, or other limiting factors. Other areas in rural villages that should be considered include pedestrian sensitive areas such as schools, local shops, community facilities, clinics and service centers.

In a rural environment, a "gateway", as illustrated in Figure 4-4, can be used to signal to the drivers that they are entering a low-speed environment. The "village treatment scheme" is, in principle, no different from an urban street, with the same type of measures being used in both cases. The only difference between rural and urban in this regard is that in the urban setting, there's no need for a "gateway".

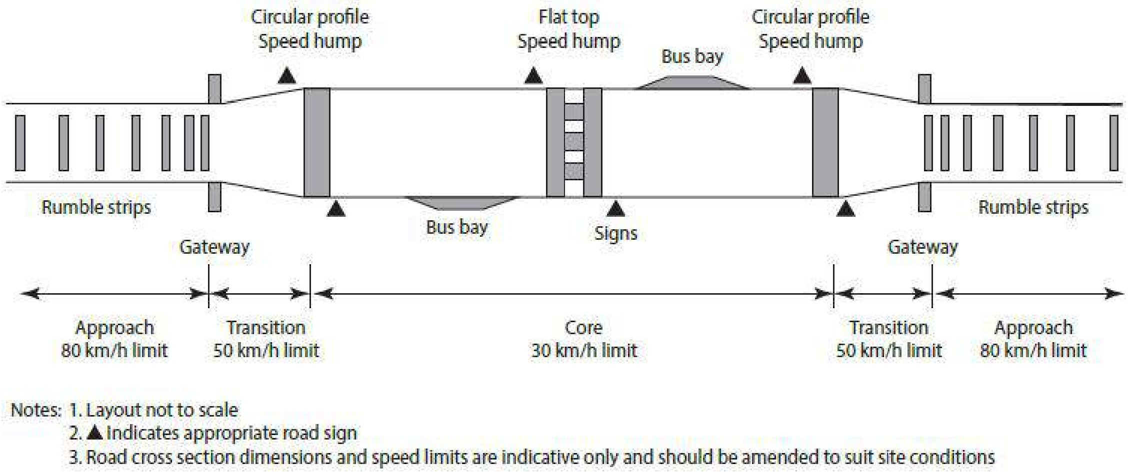


Figure 4-3: Village treatment scheme

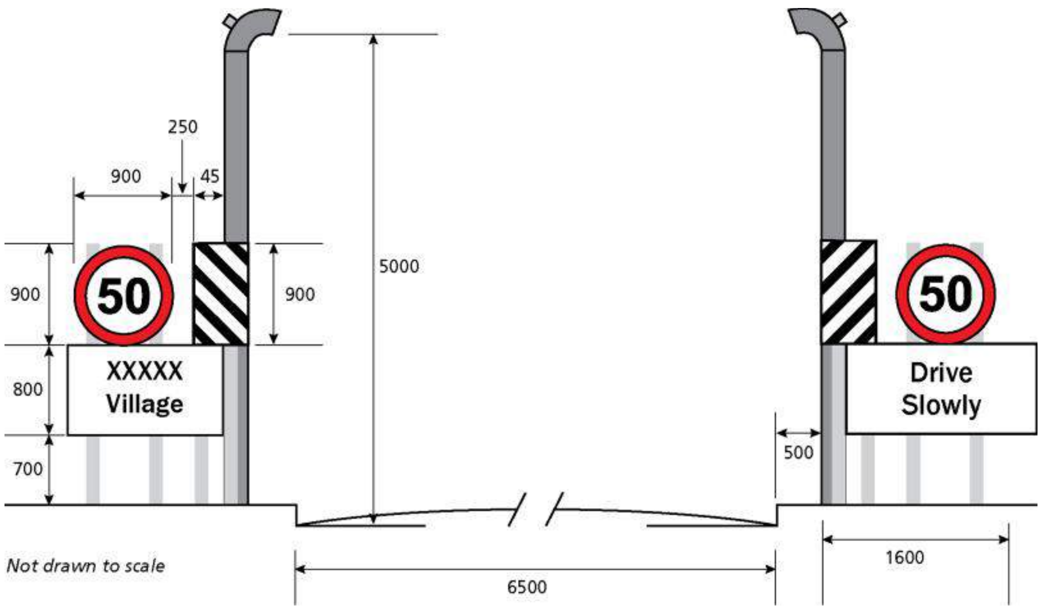


Figure 4-4: Example of a gateway at the entrance of villages

Although roads through villages could still be gravel, speed humps and rumble strips constructed of concrete or any other suitable material complying with the standards as shown in Section 4.3.4 and 4.3.5 can be installed. All traffic calming installations must be supplemented with appropriate road signage, including speed reduction signage.

Measures that are considered appropriate for low volume rural roads include:

- rumble strips
- speed humps
- mini circles (villages only).

4.3.3 Rumble Strips

These are transverse strips that are placed across the road. Their main purpose is to alert motorists of a hazard, dangerous road location or whatever requires their special attention, by causing a tactile vibration and audible rumbling, without the need for the driver to reduce speed.

Rumble strips are typically used in the following ways:

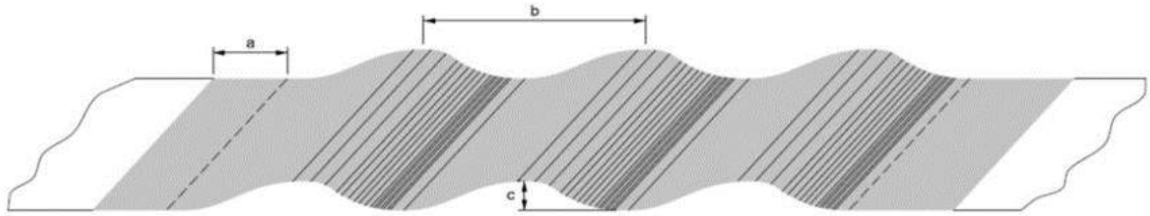
- before a hump or a flat-top hump used singly or in combination, in both driving directions;
- at an approach to a dangerous junction; or
- to give emphasis to a warning sign, e.g., before a sharp bend or at a railway crossing.

The following principles should be observed when using rumble strips:

- They should be placed in groups of 3 – 5 strips.
- The maximum thickness of the strips shall be 10 mm – 15 mm (strips higher than this could be a hazard for motorcyclists and, in extreme situations, unnecessarily severe for vehicles).
- The strips can be of varying designs: Wide and flat 500 mm wide or narrow ± 100 mm wide.
- The length of the strips shall be that of the road, including the shoulders.
- The first (or only) set shall be placed 30 m – 50 m before the hazard (e.g. a hump).

A common problem is the construction of rumble strips that are excessively high and serve as an irritation to road users who then tend to avoid them. In the example to the right in Figure 4-5, the strips are so severe that vehicles are forced to stop before attempting to cross over them. The technical details for safely designed speed humps are shown in Figure 4-6.

Figure 4-5: Examples of well designed (left) and poorly designed (right) rumble strips



a = 1,000 mm b = 350 mm c = 6–7 mm

Figure 4-6: Design details for rumble strips

4.3.4 Speed Humps

Speeds humps are the common name for a family of traffic calming devices that use vertical deflection to slow motor-vehicle traffic by making it uncomfortable to drive over them at excessive speed and thereby improving road safety conditions.

If properly designed, and supplemented with ample warning signs, these countermeasures are by far the most effective speed management measures that can be placed on low volume paved roads. They are very effective in controlling speeds to 50 km/h or less, depending on their profile, without causing significant discomfort to drivers and passengers, or damage to vehicles. Unfortunately, however, due to poor design, this is often not the case, and the intended objective of their use is not attained in practice.

In villages, the maximum distance between speed humps should be as shown in Table 4-1, to ensure that most of the vehicles do not exceed the desired (and posted) speed limit.

Figure 4-7: Watts speed hump profile

At junctions, where a LVRR joins a main road, a speed hump must be provided on the LVRR at a distance of about 6-8 m from the junction to ensure that vehicles reduce speed before entering the main road.

Table 4-1: Recommended distance between speed humps

Speed limit km/h	Recommended distance between speed humps
30	± 75 m
40	± 100 m
50	± 150 m

Table 4-2 shows the key dimensions of speed humps designed for various speed limits. The detailed dimensions and profile of a speed hump designed for a speed of 40 km/h are shown in Table 4-3 and Figure 4-8.

Table 4-2: Key dimensions for speed humps for various speed limits

Speed limit km/h	Radius	Height	Length
30	20 m	0.10 m	5.0 m
40	53 m	0.10 m	7.5 m
50	113 m	0.10 m	11.0 m

Table 4-3: Design measurements for speed hump for 40 km/h

Speed hump length (m)	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75
Height (mm)	0	4	10	19	28	41	52	62	71	79	85	91	95	98	99	100
Pos. tolerance (mm)	10	10	9	9	9	8	8	8	7	7	7	6	6	5	5	5
Neg. tolerance (mm)	0	-1	-1	-2	-3	-3	-4	-5	-5	-6	-7	-7	-8	-9	-9	-10

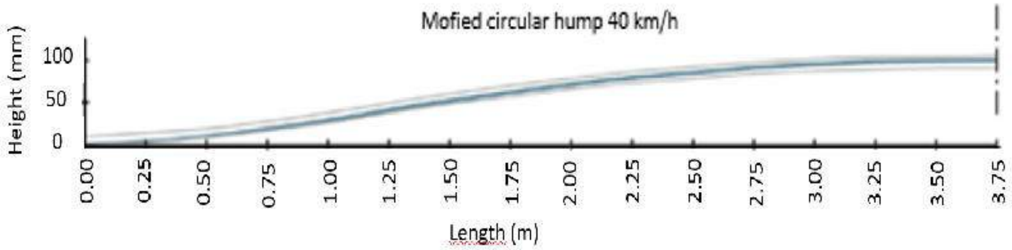


Figure 4-8: Profile of speed hump 40 km/h

Source: Vegdirektoratet (Norway)HåndbokV128

4.3.5 Speed Humps on Unpaved Roads

Although traffic levels on unpaved roads in villages generally tend to be lower than on paved roads, traffic speeding, combined with dust emissions, are major problems for which appropriate traffic calming measures are also required. Such measures are, in principle, similar to those for paved roads in terms of signage. However, special measures need to be taken to embed road humps in the gravel substrate so as to anchor them and minimize their horizontal movement under the action of traffic (see a typical layout in Figure 4-9).

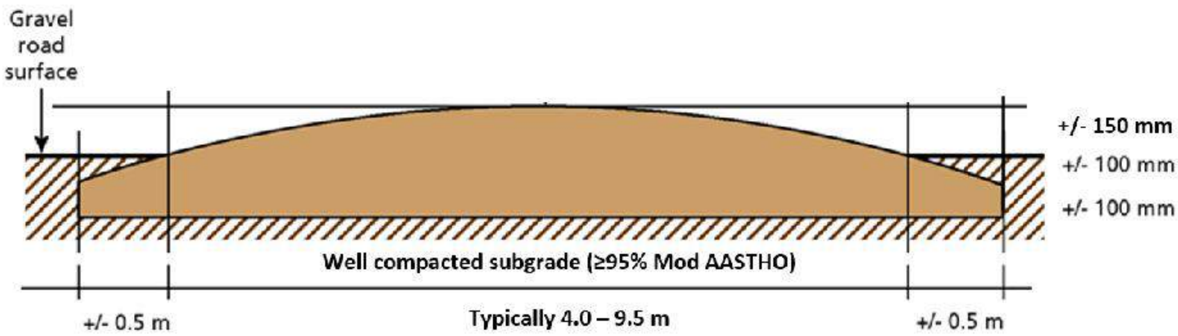


Figure 4-9: Longitudinal profile of a circular speed hump

4.3.6 Mini Circles

Mini-circles are basically raised circular islands constructed in the center of intersections. They retain all of the standard features of a full-scale roundabout, including yield on entry, deflection, flare, and a low design speed, but are less expensive to construct. They reduce vehicle speeds by forcing motorists to maneuver around them. However, they must be properly designed to benefit pedestrians and cyclists.

Figure 4-10: Mini circle used as a speed reducing measure in a village

4.4 Traffic Segregation

Where roads pass through rural villages, substantial conflict usually exists between non-motorized and motorized traffic and often poses a major road safety problem. The situation is exacerbated when these roads are also used as footpaths, which place pedestrians at considerable risk of personal safety to fast-moving motorized traffic. In such a situation, the segregation of these different modes of traffic can significantly reduce the incidence of accidents.

Means of traffic segregation that can be considered for reducing accidents in rural areas include:

- Demarcating areas where pedestrians can walk (e.g., sidewalks) by using relatively inexpensive bollards, which should have a diameter of less than 100 mm not to endanger motorists during an accident.
- Channeling pedestrian traffic through road safety barriers by separating the sidewalk from the carriageway.
- Providing segregated footpaths on narrow bridges or next to the carriageway in rural areas, to offer safe access for pedestrians.
- Providing sealed shoulders where a segregated footpath is not possible.
- Providing bicycle lanes by allocating part of a road to bicycles or by building off-road paths.
- Providing a separate, protected footpath on bridges.

It must be appreciated, however, that the above options are cost-increasing and need to be justified based on a cost-benefit analysis, as discussed in Section 4.2 above.

Typical examples of the above traffic segregation options on bridges and along roads and are shown in Figure 4-10 and Figure 4-11, respectively.

Figure 4-11: Traffic segregation on bridges

Figure 4-12: Cost-effective measures of traffic segregation along roads

4.5 Roadside Environment

4.5.1 General

The roadside environment plays an important role in influencing the severity of accidents. The area where vehicles end up after an accident generally extends to some 9 m from the carriageway. The area of the most severe impact extends up to 3 m from the roadside. It is, therefore, important that a clear roadside area is provided to allow for the recovery of errant vehicles and to avoid collisions with roadside objects. This “clear zone” is necessary to achieve a “forgiving” roadside and includes the total roadside border area, starting at the edge of the carriageway, which should be available as a refuge for errant vehicles.

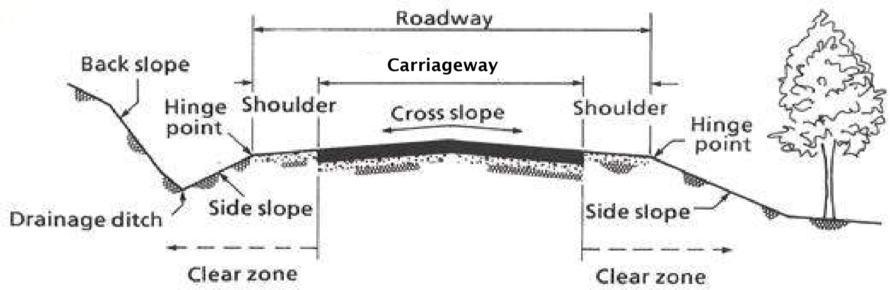


Figure 4-13: Illustration of the clear zone area

Factors which contribute to increased accident risk as well as the extent of the damage, include the location of the following concerning their proximity to the carriageway:

- Roadside furniture, including road signs, information signs, lamp posts.
- Roadside obstacles including large trees, shrubs, culvert headwalls, badly designed guardrails.
- Deep, narrow (lined) drains.

Whilst fulfilling potentially important safety functions, both roadside furniture and obstacles can have negative implications. Thus, the correct design and location of roadside furniture and the avoidance of roadside obstacles in the road verge can significantly reduce accident rates on LVRRs.

Big trees to close to the road

Badly designed bridge railing

Figure 4-14: Various roadside features impacting on road safety

4.5.2 Arboriculture

Arboriculture -the planting of trees on roadsides - covers the management and study of individual trees, and how these plants grow and respond to their environment. The services of an arboriculturist should be sought to provide guidance on the spacing of trees and to ensure that the tree species planted do not impede the safe operation of LVRRs and village roads.

Arboriculture along LVRRs
It is recommended that a clear roadside zone 3 m wide is provided along LVRRs. Thus, vegetation must not be planted in the clear zone to avoid obscuring intersection and curvature sight distance lines, as specified in Part A of this Guideline.

The planting of trees beyond the clear zone is essential for safe road usage along LVRRs. Knowledge about the physical properties of various trees and the configurations of tree placement enables the integration of plant life as a road safety feature. Other benefits of well-spaced trees include:

- Improving driver comfort by providing relief from sun and wind and cutting cross-glare.
- Providing apartial barrier to snow drifts.
- Enhancing the beauty of the roadside environment.
- Reducing storm water runoff and soil erosion.

Arboriculture in villages
Trees can enhance the physical environment in villages. From a geometric design and road safety perspective, however, there are several aspects that need to be considered, such as:

- Existing trees with an expected mature trunk size of greater than 200 mm should be considered fixed objects. Accordingly, geometric design practice shall be applied to maintain adequate sight distances and clear zone setbacks.
- Designers should consider the impact of root growth, with preference given to species with taproot systems. Tree roots should not interfere with the function of the pavement, utilities and other road structures and appurtenances.

4.6 Road Signs and Markings

4.6.1 General
Road signs and markings are an important road safety feature on LVRRs by guiding and providing the driver with the information necessary to negotiate conflict points or hazardous locations on the road network. The installation and preservation of signs and markings represent a significant financial investment for road agencies, both to apply and maintain. Thus, the value, cost and necessity of road signs and markings on paved or gravel LVRRs, other than regulatory signs required, must be fully considered in order to make optimum use of available budgets.

The traffic rules and regulations of Afghanistan were last updated in 1981. More recent general guidance on the application of road signs and markings applicable on the road network in Afghanistan is provided in the Kabul Drivers’ Handbook. The application of these road signs and marking needs to be adapted to the requirements of LVRRs in order to achieve a balance between the cost and safety effectiveness of their application.

4.6.2 Road Signs
Road signs provide an important road safety function by providing essential information to drivers for their safe and efficient maneuvering on the road. The Kabul Driver’s Handbook differentiates between the following classes of road signs:

- Danger warning signs
- Regulatory signs
- Information signs
- Supplemental signs

Experience from neighboring countries, such as India, suggests that smaller road signs can be used on LVRRs than what is generally used on major roads because of lower operating speeds and as a cost-saving measure. The dimensions of such signs must, however, comply with the requirements of the Afghan road traffic legislation and regulations.

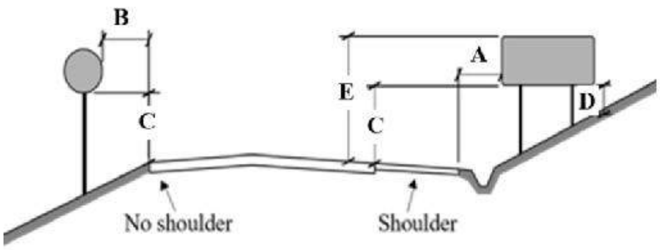
Signage is especially useful on rural gravel roads where road markings cannot be applied. In particular, warning signs should be provided where there are unexpected changes in the driving conditions, for example, where:

- The geometric standards for a particular class of road have been changed along a section of road, for example, a sharp bend, a culvert, a sudden narrowing of the road, or an unexpectedly steep downhill gradient.
- A bend occurs after a long section of straight road.
- There is an unexpected school crossing or rail level crossing.
- A drift or other structure is not clearly visible from a safe distance.
- The driver is approaching traffic-calming measures such as speed humps.

The approaches to bridges, culvert edges, masonry work and guardrails should be clearly indicated to improve visibility, especially at night. The railings of bridges also need special attention to guide drivers at night. The current road signs that are used in Afghanistan to deal with these matters include obstruction markers and reflector guideposts (see Table 12 of the Kabul Driver's Handbook).

4.6.3 Road Signs and Clear Zones

The recommended mounting heights and distances of road signs from the road edge are shown in Figure 4-15. Consistency in the provision of road signs according to these specifications is essential to ensure a safe road environment and to limit liability claims against the road authority. The standard mounting height is 2100 mm from the lowest edge of the sign plate to the road surface.



	Minimum (mm)	Desirable (mm)	Maximum (mm)
A	600	1500	2000
B	1200	1500	2000
C	600	2100	2500
D	750		
E			6000

Source: Adapted from Malawi Road Safety Manual

Figure 4-15: Mounting heights and roadside clearances for road signs

4.6.4 Road Markings

The Kabul Driver's Handbook covers the different road pavement markings and colors to be used, as illustrated in Figure 4-16. More details on the application of each road marking can be obtained from the Handbook.

Like road signs, road markings also provide an important road safety function. For example, they:

- Delineate the pavement centerline (where applied) and edges.
- Clarify the paths that vehicles should follow (in the case of paved rural LVRRs).
- Indicate the alignment of the road by the use of marker posts.

As regards the use of road markings on LVRRs, international research reveals the following:

- Centreline markings should only be applied when the width of the carriageway (sealed width in cases where shoulders are not provided) is ≥ 5.5 m.
- On narrower roads (< 5.5 m carriageway), centreline markings are not warranted as they do not contribute to improved road safety and, in addition, tend to encourage drivers to drive close to the edge of the sealed width which contributes to potential conflict with NMT users, early edge breaks and an increased maintenance burden.

- Edge line markings are desirable on all paved roads to guide the drivers, especially at night-time on unlit roads. However, they are costly to apply and maintain and, other than in isolated sections, may be unwarranted on the lower road classes (ADT < 200 vpd).
- Edge marker posts are desirable on isolated sections of the lower road classes (ADT < 100 vpd), where it would not be warranted to use any road markings to alert drivers to potentially hazardous situations (sharp bends, sub-standard road curvature, etc.).

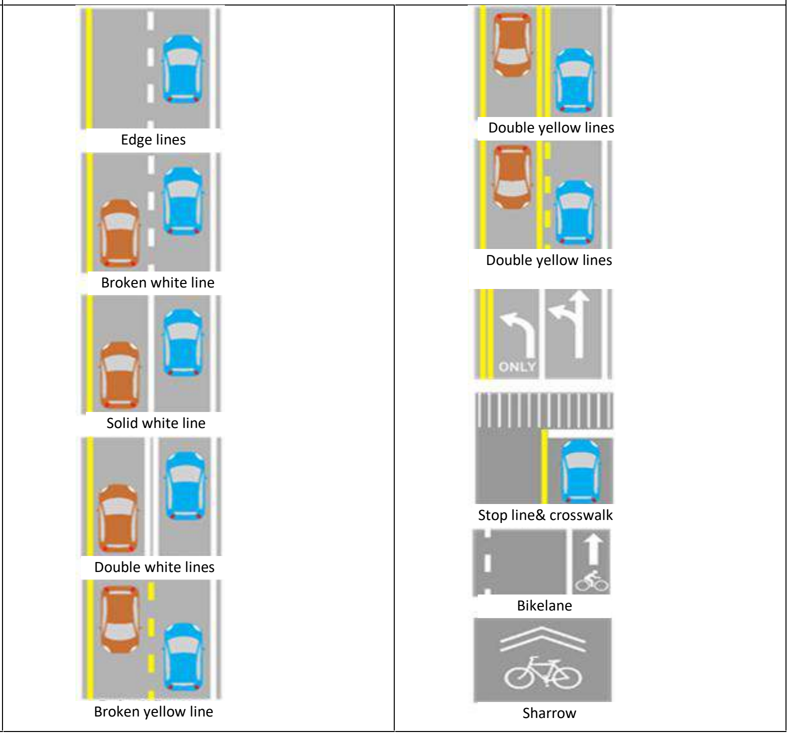
Road markings	Illustrations of road markings
• Edge Lines • White lane lines • Yellow lane lines • Turn Lanes • Pedestrian crosswalk • Bicycle Lanes	

Figure 4-16: Examples of road pavement markings

Based on the above, Figure 4-17 and Table 4-4 show the recommended use of road markings on the various LVRR classes considered in this Guideline.

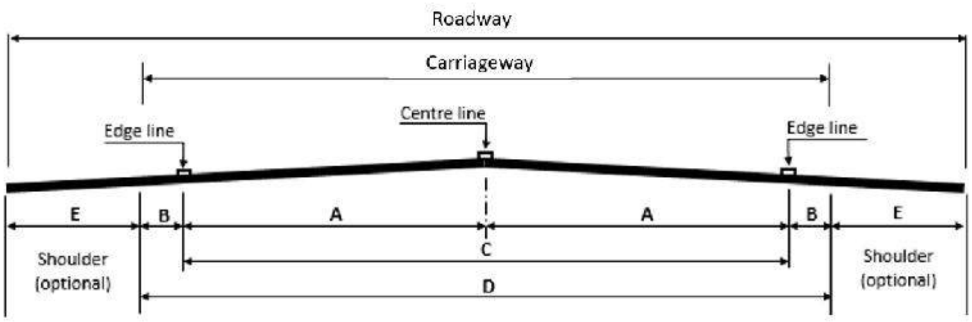


Figure 4-17: Road markings in relation to road width

Table 4-4: Recommended road marking scheme in relation to road width

LVRR class	Traffic vpd	Carriageway				E (optional)	Dashed centre-line	Dashed edge-line	Edge marker posts	Surface
		A	B	C	D					
LVRR 5	> 350	3.0	0.25	6.0	6.5	Varies	Yes[1]	Yes[1]		P
LVRR 4	250-350	2.75-3.0	0.25	5.5-6.0	6.0-6.5		Yes[1]	Yes[1]		P/UP
		2.5-2.75	0.25	5.0-5.5	5.5-6.0		No	Yes[1]		P/UP
LVRR 3	150-250	2.0-2.25	0.25	4.0-4.5	4.5-5.0		No	Yes[1]		P/UP
LVRR 2	50-150				3.5-4.5		No		Yes[2]	P/UP
LVRR 1	< 50				3.5		No		Yes[2]	UP

P = Paved, UP = Unpaved (gravel), D = Sealed width
Notes: 1. Total route 2. Isolated sections

Edge line road markings on a LVRR serve a dual purpose, namely:

- To encourage vehicles to travel within the central, narrow lane and only to move outside of the broken edge lines when approaching a vehicle traveling in the opposite direction. This will prolong the life of the pavement in general and contribute to a reduction in edge breaks and the associated maintenance burden.
- To indicate to the drivers that the area outside the edge lines is reserved primarily for pedestrians and bicycles.

Figure 4-18: Example of road marking on rural LVR
Source: (FHWA, 2016)

4.7 Road Safety at Work Sites

Good road safety practices must be ensured on all sites where road works are undertaken, be it simple routine maintenance operations or upgrading and construction activities. The *CAREC Road Safety Engineering Manual 2: Safer Road Works* covers safety at road works and the typical road signs that should be displayed to ensure safe operations. The road safety aspects to be considered include the following:

Road safety considerations during the repair, **construction or upgrading of LVRRs**:

In the safe management of any road construction project - whether it is repair, construction or upgrading - the key objectives are to:

- Maximize road safety for road users and workers at the site.
- Minimize the disruption and delay to road users because impatience leads to unsafe driver behavior.
- Ensure the cost of the temporary traffic control arrangements is commensurate with the overall project value.

Work Zone Traffic Management Plan (WTMP):

Although traffic volumes are fairly low on LVRRs, it is still important to develop a work zone traffic management plan (WTMP) for each work site. A WTMP is a drawing (or series of drawings) showing the traffic control devices proposed for use during the construction, upgrading or repair of a LVRR, together with a list of the programming of the works, stating the days and times the worksite will operate. Planning for safety at a worksite is time well spent. It is a necessary part of road works. There are some key decisions along the way, and by carefully considering each one, it is possible to design, implement, and manage a safe WTMP for a work site.

Developing a WTMP takes knowledge and experience. A WTMP cannot merely be "cut and pasted" from the Internet, or photocopied from a manual. Each site needs careful and detailed attention because no two worksites are the same. Factors such as vertical and horizontal geometry, LVRR class, traffic volumes, speeds, abutting development, and the duration of the project all add up to make each worksite unique. More information on the planning and implementation of a WTMP is covered in the CAREC Manual "Safer Road Works", as listed in the bibliography.

The main responsibilities of the different interest groups, as standard CAREC practice during road construction, maintenance or upgrading of LVRRs, are summarized in Table 4-5.

Table 4-5: Road safety responsibilities of different interest groups

Contractors &Supervisors	Workers	Road users
Their responsibility is to provide safe and convenient traveling conditions for the public and safe working conditions for their personnel.	Take responsibility for their own safety by looking out for danger and being observant.	Comply with all the regulatory requirements of the worksite, including the instructions and directions from any traffic controllers.
Ensure all personnel involved in traffic signage and traffic control are trained and aware of what is needed & of their responsibilities.	Wear the protective clothing provided for their safety.	Travel at a speed that is safe, given the road and traffic conditions.
Manage the site to avoid damage to private property.	Engage only in work practices that do not put themselves or any other person at risk.	

Special measures to be taken to ensure the safe passage of traffic during construction include:

- Adequate signage to warn drivers sufficiently in advance of the construction zone. The signs to be used during road construction works in CAREC countries are illustrated hereunder. The LVRR road class will dictate what road signs will be required so that the traffic control arrangements are commensurate with the overall project value.
- Deployment of flagmen/women and/or stop-go lights to provide a clear demarcation of the movement of vehicles.
- Temporary speed humps.
- Watering of unfinished works and detours to minimize dust emission.

The measures to be taken by the contractor are normally specified in the contract documents and must be adhered to.

Figure 4-19: Examples of road work signage

Source: CAREC Manual – Safer Road Works

4.8 Road Furniture

4.8.1 General

Road furniture is a generic term for various road-related assets within the road reserve, including bus laybys and shelters, guardrails, pedestrian barriers, traffic signals, traffic signage, rail crossings and other small structures such as pedestrian bridges across rivers or streams.

Road furniture plays an important role as part of a functional road system because it guides and protects all road users in the following ways:

- Guardrails and barriers prevent vehicles from driving onto sidewalks or straying off the road.
- Pedestrian barriers, on the other hand, prevent jaywalking and channelize pedestrians towards pedestrian crossings and intersections.
- Traffic signage and markings assist drivers by providing messages about the road layout ahead or potential danger spots such as railway level crossings.

- Narrow bridge structures and culverts also pose a danger to pedestrians and cyclists. This danger can be alleviated by the addition of a small walkway structure as an extension of the bridge deck.

4.8.2 Bus Laybys and Shelters

No public transport system serving rural villages currently exists in Afghanistan. Transport is provided mostly by three-wheelers and motorcycles. Should buses and minibuses start operating on LVRRs, bus laybys will have to be provided for safe passenger pick-up or drop-off. Figure 4-20 gives the typical layout of a right-hand drive bus bay layout that can accommodate two buses at a time.

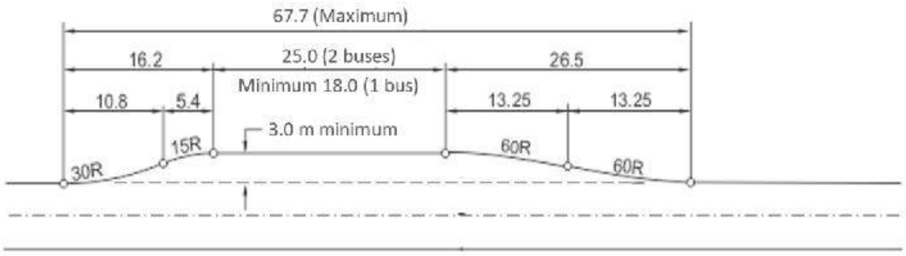


Figure 4-20: Typical bus layby
Source: AustRoads

Where possible, it is desirable to provide shelters for passengers waiting at bus stops. Some of the basic requirements are:

- They should be designed to accommodate the maximum number of passengers normally waiting, and to provide adequate protection from the weather, sun as well as rain.
- They should be well lit and ventilated, and approaching buses should be visible from inside the shelter.
- Where waiting times may be long, it may be desirable to provide seating.

4.8.3 Road Safety Barriers

Road safety barriers are expensive and seldom justified on LVRRs other than on hill roads. However, they may be required in highly dangerous situations, for example, on sharp bends that cannot be made safe by other means, for example where LVRRs cross major drainage channels or where sharp drop-offs next to the roadway are present, as illustrated in Figure 4-21.

The types of safety barriers and their application vary. The most commonly used are raised kerbed islands, wooden or steel posts, steel guardrails, masonry (parapet) walls and concrete barriers. Raised kerbed islands are generally applicable to paved roads and commonly used for segregating motorized and non-motorized traffic. Although wooden and steel posts are usually the cheapest forms of a barrier, they are often not the most effective. Steel guardrails are one of the most effective types of safety barrier and are most commonly used. They are usually cheaper to install compared to concrete barriers but, in the long-term, their repair and maintenance are often more expensive. Road signs or marker posts should be used to warn motorists of potential hazards. In high-risk areas, guard rails may be used to protect road users from a roadside hazard.

Figure 4-21: Masonry work providing an effective barrier on steep drop-offs

4.9 Street Lighting in Villages

4.9.1 General

Street lighting is generally neither warranted nor affordable on LVRRs. However, in villages, it would be preferable to provide street lighting along roads, which is an essential component to ensure a safe and secure road environment. Well-lit roads help both pedestrians and drivers to navigate easily and to alert them to possible obstacles and approaching vehicles. Crime is also lower in areas with good street lighting, which also has a positive effect on village life.

4.9.2 Renewable Energy Sources for Street Lighting

Only a small proportion of the rural population is connected to mains electricity. However, the Afghanistan Sustainable Energy for Rural Development (ASERD) program is tasked to assist rural areas in obtaining access to alternative sustainable energy source technologies such as solar and wind energy. Figure 4-22 illustrates the provision of solar-powered street lighting in Afghan villages.

Technical specifications for solar-powered street lighting can be obtained from the suppliers of solar lighting installations.

Figure 4-22: LED solar powered street lighting in Afghan villages

4.10 Rail Crossings

4.10.1 General

Afghanistan's central position in Asia and its rich mineral resources are generating traffic of bulk commodities over long distances and warrants developing a more extensive railway network. The Afghanistan Railway Authority oversees the maintenance and planning of future railway lines in the country.

People usually die in accidents involving road vehicles colliding with trains at level crossings. International statistics show that 98% of these fatalities are attributed to faults by the road vehicle driver. Road designers and road safety practitioners must, therefore, understand the basic design and road safety requirements to safeguard vehicle drivers where level rail crossings intersect LVRRs. This aspect is important because the upgrading and provision of new LVRRs will result in more of these roads intersecting existing or future railway lines. It is important that road designers and road safety practitioners understand the basic design and road safety requirements to safeguard rail crossings where they intersect LVRRs.

4.10.2 Requirements for Level Crossings

Figure 4-23 illustrates the typical layout of a level rail crossing. The measures normally implemented consist of the X-crossing sign, flashing lights, a boom gate, supplemented by road lighting. The requirements for LVRRs, however, will differ depending on the intensity of traffic volumes and rail operations.

Figure 4-23: : Typical rail level crossing on a road in northern Afghanistan

The current signage for level rail crossings in Afghanistan is covered in the Kabul Drivers' Handbook. The road signs recommended to be provided at LVRRs are:

- Paved LVRRs
  - A stop line must be marked on the road to indicate to the drivers where to stop.
  - An advance Danger Warning Sign (Sign 34) and a Priority Stop Sign (Sign 2), supplemented by Priority Sign 7 (single or double line sign).
- Unpaved LVRRs
  - Priority Sign 7 (Kabul/Afghanistan Drivers' Handbook) as illustrated in Figure 4-24.

W403 – Single track W404 – Double track or more

Figure 4-24: Warning signage for level crossings

4.11 Culverts and Bridges

4.11.1 General

Culverts are commonly used both as cross-drains to relieve drainage of ditches at the roadside, and to pass water under a road at natural drainage and stream crossings. A culvert may be a bridge-like structure designed to allow vehicle or pedestrian traffic to cross over the waterway while allowing adequate passage for the water. The design of culverts needs special attention from a road safety perspective to ensure that it is safe for both motorized and non-motorized traffic to pass. Figure 4-23 (left side) shows an unsafely designed culvert that could endanger road users. The visibility of the culvert in Figure 4-23can be enhanced by placing obstruction markers (see Table 12 of Kabul Drivers' Handbook) on all the culvert edges facing traffic and providing edge lines on both approaches.

Bridges or culverts provided on LVRRs invariably have restricted carriageway widths, and the space available for pedestrians and cyclists to cross safely in the presence of vehicles, motorcycles and farm vehicles is often restricted and risky as illustrated in Figure 4-25. Furthermore, although vehicle volumes on LVRRs are fairly low, vehicle accidents can take place when drivers from opposing directions do not observe basic traffic rules.

Narrow road culverts or bridge edges should be fitted with reflective plates on both approaches, as shown in the Kabul (Afghanistan) Drivers' Handbook. These are listed as Traffic Control Devices:

- Sign 7 - Reflector guideposts (right side of the road)
- Sign 8 - Reflector guideposts (left side of the road).

Figure 4-25: Road safety challenges at culverts and narrow bridge structures

4.11.2 Road Safety Requirements on Bridge Structures

The following road safety measures should be considered at bridge crossings:

- Provision of railings and a dedicated crossing space (preferably a raised walkway) for pedestrians to cross when vehicles are also using the bridge. These measures might not be warranted on the lower classes of LVRRs where vehicle volumes are low but will apply to LVRR Classes 4 & 5 and in villages where larger volumes of pedestrians can be expected.
- In the case of one-lane bridges, properly signed approach and safe waiting areas with clear sightlines across the bridge should be provided at both ends.
- Provision of warning signs and delineation is recommended where a bridge is narrower than the approaching road.
- Provision of bollards or railings on both sides of the structure, as illustrated in Figure 4-26, are important road safety features to guide vehicles across the structures. Bollards or bridge edges should be fitted with reflective material to delineate the approach for night-time driving.

Figure 4-26: Examples of protected bridge approach and bridge railings

4.12 Road Safety on Hill Roads

4.12.1 General

The approach to road safety on hill roads is generally similar, in principle, to that in flat or rolling terrain, as described in *Chapter 2 – Approach to Road Safety.* However, there is one major difference - the severity of climatic and environmental conditions (e.g., torrential rains, mud slides, falling rocks, avalanches, blizzards, etc.) - that affect hill roads to a much greater extent.

The typical causes of accidents on hill roads, especially in adverse and inclement weather conditions, are as follows:

- Traveling over sharp curves of a sub-standard radius in conditions of inadequate sight distance, which require frequent acceleration and deceleration of the vehicle.
- Negotiating curves at varying speeds due to varying degrees of curvature and the need to apply brakes when entering a curve and to accelerate when leaving the curve.

- Alternating entry from a major valley into a side valley, crossing of streams by narrow bridges, causeways, etc.
- Steep and alternating up and down grades.

In view of the above, there is greater driver stress in negotiating hill roads and hence, greater scope for driver errors. Thus, special attention needs to be given to several road safety factors as discussed below.

4.12.2 Geometric Design Deficiencies

Any deficiencies in the geometric design of hill roads compromise road safety, the extent of which will depend on the severity of the inadequacy. Particular measures are required in the following situations, at least for the higher traffic classes, i.e., LVRR3, LVRR4 and LVRR5.

Narrow/sharp curves with inadequate sight distance

This common deficiency on hill roads may lead to head-on collisions. At such locations, the following measures are recommended:

- A double solid line should be painted to prohibit overtaking, together with reflective studs along the centreline for visibility at night.
- "Overtaking Prohibited", "Compulsory Sound Horn" and speed limit signs shall be erected on each side of the curve in accordance with the Kabul Drivers' Handbook.
- Adequate widening, transition curves, where possible, and sight distances are mandatory.
- All blind curves must have two lanes which should be divided by stone or concrete studs.

Vertical curves and grades

On hill roads, steep grades contribute, to a large extent, to accidents due to factors such as inadequate sight distances, overtaking of slow-moving traffic, and vehicles whose brakes have failed. In such situations, the following measures are recommended:

- Adequate widening of lanes, as illustrated in Figure 4-27.
- Marking of a continuous centreline.
- Providing reflective studs prohibiting overtaking.

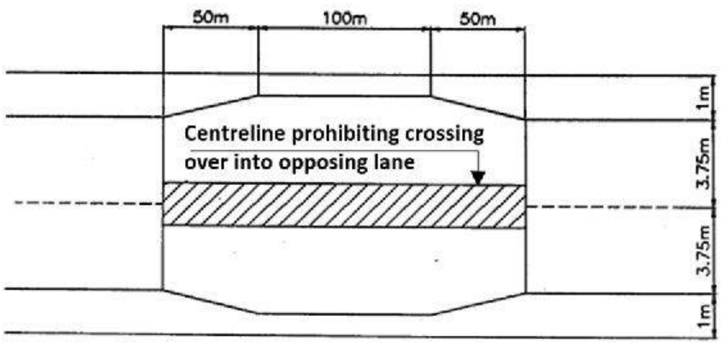


Figure 4-27: Widening of roadway

Bridge approaches

The existence of a bridge with a curved approach combined with a down gradient, due to the tight geometry on a hill road, results in a serious accident-prone location where vehicles may topple over the bridge. Wherever possible, such situations should be avoided and, instead, the bridge structure should follow the general flow of the alignment. Complementary road safety measures would include the following:

- Use of reflective cautionary signs and road delineators.
- Use of speed control measures, such as rumble strips.
- Use of guard rails to deflect out of control vehicles.

4.12.3 Miscellaneous Issues

High altitude/snow fall areas

In areas of high altitude with snowfall in winter, detailed studies should be carried out of sections prone to snow drifts and avalanches to identify and design adequate mitigating measures. Having identified the area, a warning system should be developed first, and then long-term engineering measures planned. The engineering measures available include:

- Use snow fences.
- Construction of snow-sheds to allow the passage of snow drifts over the road.
- Placement of snow markers on both sides of the road.
- In very dangerous areas, the construction of tunnels, if economically justified.

Rockfall, shooting boulders and unstable areas

The above is basically due to unstable upper slopes. Measures to improve safety at such locations include:

- Posting appropriate warning signs to caution the traffic.
- Stabilizing the upper slope by improving drainage, other erosion control measures and treatment of rock face.
- Planting of the upper slopes with a belt of trees to stop boulders short of the road.
- Providing extra wide hill side shoulders with deep drains to catch falling debris and carry it away as the water flows.
- Providing a shelter, similar to a snow shelter, to allow the boulders to roll over the road.
- Providing deflection walls and buffer zones to divert boulders and impound them.
- Placing a wire net screen buffer to catch the boulders and subsequently dispose of them suitably.

Vehicles falling into a valley

Vehicles rolling off the road into a valley are a significant safety problem on hill roads. In areas prone to this type of accident, i.e., blind curves, sharp curves and deep vertical cuts, etc., strong parapet walls, as illustrated below, or guard rails/cables fixed to deep piles, should be provided.

Figure 4-28: Typical road safety issues in hill road environments

Ice on roads

In many locations on hill roads in high altitude areas, water flowing over the road surface freezes into ice sheets, which make the roadway slippery, causing accidents by skidding. In such locations, the following measures should be adopted:

- Imposing speed limits.
- Installing appropriate warning signs, such as "Slippery Road" and providing additional informatory signs advising the use of tire chains.
- Improving drainage by providing steep hill side cross fall draining water towards the hill side. This measure will also help to some extent to prevent skidding/running of vehicles to the valley side.
- Providing impact resistance railing or parapet walls on the valley side.
- Using appropriate de-icing chemicals, such as calcium, magnesium, potassium, or sodium chloride, which work by lowering the freezing point of water and creating a brine with the heat of solvation helping to melt the snow and ice.

Avalanches

Avalanches are generally caused by large amounts of snow moving quickly down a mountain, typically on slopes of 30 to 45 degrees, and generally following the most direct route before settling into the valleys below. The kinetic energy thus released can be very destructive with the avalanche sweeping away, crushing, or burying everything in its path.

Avalanches can be divided into two categories according to the type and condition of the snow involved. These are dry snow or "dust" avalanches, and wet snow or "ground" avalanches. The former is dangerous because of the shock waves they set off, and the latter because of the sheer volume, due to the added moisture in the wet snow, flattening everything in its path as the avalanche rolls downhill, often at high speeds, and sometimes carrying away sections of subsoil.

Avalanche control is a specialized subject that is beyond the scope of this Guideline. Nonetheless, a broad overview of the measures that may be considered for dealing with avalanches is presented in this section, and specialist texts on the topic are included in the bibliography, such as the IRC SP48 Hill Road Manual.

Control structures: Three types of structures may be considered depending on their intended function. These are:

(1) Structures in the formation zone which prevent avalanches. These include:

- Snow rakes (see Figure 4-29)
- Snow nets
- Snow bridges
- Avalanche fences
- Terraces

Figure 4-29: Illustration of typical snow rake

In addition to the above structures, drift control structures should also be installed in the formation zone. These structures make use of wind force and prevent the formation of great mounds of snow and cornices, and include the following:

- Jet roofs
- Wind baffles
- Snow fences

(2) Structures in the avalanche path which deflect the avalanches. These include:

- Galleries
- Guide walls
- Diversion dams
- Avalanche ramps
- Avalanche wedges

(3) Structures in the run out zone which reduce the damaging effect of the avalanches. These structures are massive in construction and are used to shorten the run out zone or give direct protection to an installation by obstructing the force of the moving avalanches. These structures include:

- Masonry catch dams
- Retaining walls
- Wedges and mounds.

Roadside hazards

Roadside trees, poles, projecting rocks, parapets, etc., are all potential sources of accidents. These should be painted in accordance with the appropriate clauses of the Kabul Drivers' Handbook to reduce such hazards and to provide suitable adequate delineation. All stone/tree hindrances, in case these cannot be removed, should be white-washed, which is necessary for safe night driving.

4.13 Road Safety in Desert Areas

4.13.1 General

Parts of southern Afghanistan are covered by low-lying desert terrain, typically comprising sand dunes. Apart from the normal road safety measures that are usually implemented to make LVRRs safe, sand desert areas also require specific road safety considerations to ensure that these LVRRs are accessible and safe at all times.

Dust storms and wind regularly blow sand onto paved road surfaces, causing road blockages or rendering them unsafe for motorists (Figure 4-30). This could result in decreased sight distance, losing control of vehicles, sideway skidding, multiple vehicle accidents, or single-vehicle rollover accidents. Roads practitioners should, therefore, understand the basic principles involved in sand movement onto LVRRs and the low-cost road safety measures that are available to reduce the advancement of sand onto the surfaces of LVRRs. Regular maintenance procedures should also be carried out on road sections where sand cover is regularly experienced.

Figure 4-30: Road safety risk caused by sand on roadway

4.13.2 Road Safety Countermeasures

There are a number of widely accepted countermeasures available to manage sand movement along roads, including LVRRs in desert areas. These include:

- Ditching: digging a cut perpendicular to sand drift direction.
- Trenching: dune destruction using mechanical equipment.
- Sand drift fencing, the specifications of which are illustrated in Figure 4-31.
- Sand removal from roadside area (mechanically or manual labor)
- Reduce sand transport by terrain smoothing.
- Sand stabilization techniques using flexible weed fencing to control the movement of sand, but this requires constant maintenance.
- The application of arboriculture, as discussed in Section 4.5.2 of this chapter.
- The constant removal of drifting sand on sections of LVRRs where it is a regular phenomenon.

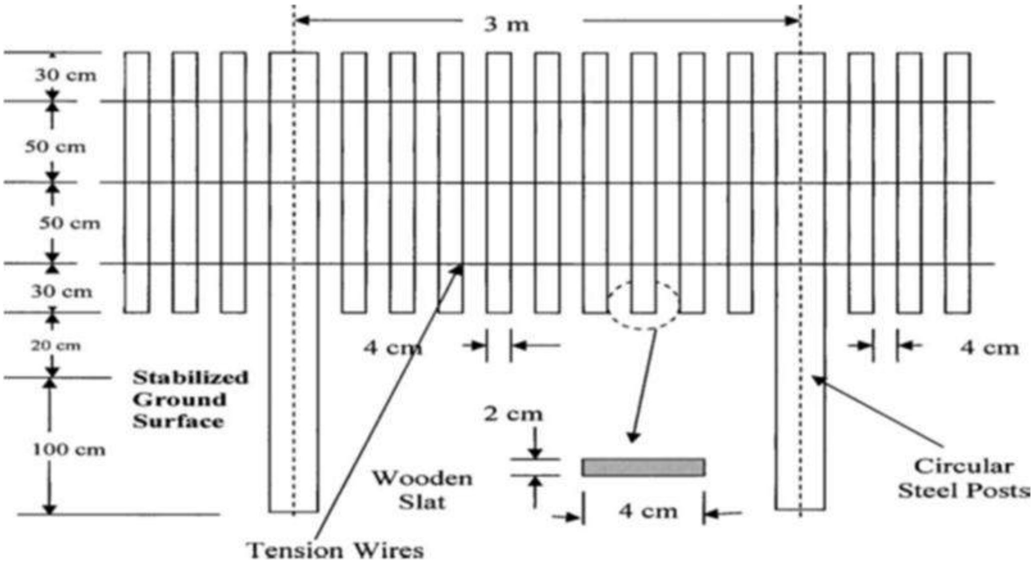


Figure 4-31: Technical details of a sand drift fence

5 Education and Traffic Law Enforcement

5.1 General

In many countries, road safety responsibilities are fragmented and uncoordinated. This is especially relevant when it comes to the 3Es in road safety (Engineering, Enforcement and Education). Strong inter-relationships exist between these elements, and deficiencies in one of them can be compensated for by the strengthening of the other two elements. The 'Safe Systems' Approach, as mentioned earlier in Chapter 2 of this Part, is the desired road safety tool to achieve the necessary coordination between the different road safety elements.

5.2 Improving Road Safety Awareness

5.2.1 General

Various generations have been lacking education because of internal conflict in Afghanistan. Important initiatives have been implemented, however, to correct this imbalance to promote child and adult education in rural areas to reduce the backlog in education. Road safety awareness in rural areas is a major concern and can be improved through a number of measures of which education, publicity campaigns and traffic law enforcement that have been proven to yield favorable results.

5.2.2 Education

Public schools

Road safety education and community participation are important tools to raise awareness of problems and behavior related to traffic and road safety. It involves teaching children, who are often the most vulnerable group, by developing:

- Knowledge and understanding of road traffic.
- Behavioral skills necessary to survive in the presence of road traffic.
- Understanding of their responsibility for keeping themselves safe.
- Knowledge of the causes and consequences of road accidents.
- A responsible attitude to their safety and the safety of others.

Village or community-based schools

The program intends to expand educational opportunities to children in rural areas of Afghanistan that lack access to formal governmental schools. The program was designed to minimize the distance children must travel to go to school by starting schools directly in the children's villages. Within the classroom, students are exposed to the same government curriculum that students in public schools encounter. These facilities are an important opportunity to provide road safety awareness to children in rural villages.

Figure 5-1: Road safety education at public schools

Local adult education

Many rural adult Afghans lack basic skills such as literacy and road safety awareness because of decades of conflict and are at risk when traveling along roads or when visiting larger centers or towns. The Afghan National Association for Adult Education (ANAFAE) is an umbrella organization to foster the development of local adult education centers. The Association is a national forum for the promotion of strategies and programs of adult education with a particular focus on literacy learning, basic education, further vocational training, and continuing civic education, including road safety and security.

Figure 5-2: Adult education in rural areas

Experience shows that the following measures make road safety education for communities in rural areas more effective and engaging, when:

- It is based on an understanding of a community's needs and concerns.
- It is realistic and relevant to the lives of communities.
- It recognizes what make particular individuals at risk, whether as an individual, part of the community or a peer group.
- It is a partnership between the community and the government.
- It is positive and rewards safe behavior.

Education of drivers of motorcycles and three-wheelers

Motorcycles and three-wheelers are involved in many accidents on rural roads. The Kabul Drivers' Handbook specifies the vehicle categories for which driver's licenses should be acquired, including motorcycles (Category A). All applicants for a new driving license are required to attend the driver training courses either in public or private driving schools. The training courses aim to familiarize the new drivers with the rules of driving and all the traffic signs. Many motorcycle drivers in rural areas, however, have not been subjected to driver training courses to sensitize them about road safety awareness and road signs. These aspects should, therefore, be incorporated in rural adult educational programs and publicity campaigns.

5.2.3 Publicity campaigns

Publicity campaigns are an important way to help improve road safety. They can be used to increase awareness of road safety issues (including existing issues as well as new traffic laws), increase awareness about the penalties for breaking road rules and try to change peoples' attitudes to road safety issues. However, publicity campaigns alone will not make people change their behavior. When trying to change behavior, it is also necessary to educate people about why they need to change. This can be part of the publicity or part of a wider education program. It is also necessary to combine publicity and education with the enforcement of penalties.

The key characteristics of community road safety education are:

- Reliance on the involvement of the community so that measures are identified, initiated and supported at the local level.
- Involvement of schools, teachers and children.
- Inclusion of all demographic groups (e.g., young, elderly, economically active, unemployed, physically impaired, etc.), including persons that do not reside permanently within the community (e.g., truck drivers, motorcyclist, etc.).

Effective publicity campaigns require careful thought and planning. The International Road Assessment Programme (iRAP) states that publicity campaigns must consider seven elements that should be covered when planning a campaign, as follows:

- Behavior to target
- Audience to target
- Appeals to motivate the audience
- Message content
- Audience activation
- Media selection
- Campaign timing.

5.3 Traffic Law Enforcement

Currently, the Afghan Road Traffic Act is in the process of promulgation. Generally, traffic law enforcement is meant to achieve the safe and efficient movement of all road users, including non-motorized traffic (NMT). 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 behavior and safety. However, the objective should be to improve the behavior (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, rather, to improve safety. The role of traffic law enforcement is essential to ensure that road users are behaving correctly in the road environment. In addition, it has been proven, in practice, that the physical and noticeable presence of traffic law enforcement officers on the roads and streets has a major beneficial effect on road user behavior. Coupled to an authoritative but friendly admonition for minor transgressions, it goes a long way to instill trust, influence behavior and improve road safety in general. However, clamping down on serious transgressions remains essential.

The following aspects of traffic law enforcement will generally ensure that road users comply with traffic laws:

- Its ability to create a meaningful deterrent threat to road users.
- Increasing penalty severity and the quick and efficient administration of punishment.
- Increasing the actual level of enforcement activity.
- The use of periodic, short-term intensive enforcement operations (blitzes).
- The use of automated enforcement devices, such as camera surveillance.
- The use of publicity to support enforcement operations.
- The use of legal sanctions, such as license suspension and revocation procedures.
- The use of point demerit schemes.

Specific law enforcement actions on LVRRs to improve road safety include the checking for vehicle roadworthiness, driver fitness and licensing, overloading, reckless driving, dangerous overtaking; and speeding on rural roads, in villages and on mountainous roads.

In essence, traffic law enforcement requires a judicial approach of visibility, education, admonition and punishment.

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Appendix A Glossary of Terms

Glossary of Terms

A

AADT Annual Average Daily Traffic is calculated by counting the number of vehicles passing a roadside observation point in a year and dividing this number by 365. The number given is the sum of both directions.

Abutment An end support of a bridge or similar structure. These are often designed

Access 1 The driveway by which vehicles and/or pedestrians enter and/or leave property adjacent to a road.

Access 2 To come to or reach a destination.

Access Control The condition whereby the road agency either partially or fully controls the right of abutting landowners to direct access to and from a public street or road.

Adverse Cross Fall A slope on a curved pavement that generates forces detracting from the ability of a vehicle to maintain a circular path.

Alignment The geometric form of the centreline (or other reference line) of a carriageway in both the horizontal and vertical directions.

Alignment Co-ordination (Co-ordinated Alignment) A road design technique in which various rules are applied to ensure that the combination of horizontal and vertical alignment is both safe and aesthetically pleasing.

Aquaplaning Full dynamic aquaplaning occurs when a tyre is completely separated from the road surface by a film of water.

Arterial Highway designed to move relatively large volumes of traffic at high speeds over long distances. Typically, arterials offer little or no access to abutting properties.

Auxiliary Lane A portion of the carriageway adjoining the through traffic lanes for speed change, or for others purposes supplementary to the through traffic movement.

Average Daily Traffic (ADT) Total volume of traffic during a given time period in whole days, greater than one day but less than one year, divided by the number of days in the period.

Average Recurrence Interval (ARI) The Average Recurrence interval (ARI) is the average interval of interval time during which an event will be equalled or exceeded once. It should be based on a lengthy period of records of the event. Statistically, it is the inverse of the Average Exceedance Probability. The term replaces the recurrence interval.

Average Running Speed The distance summation for all vehicles divided by the running time summation for all vehicles. Also referred to as space mean speed whereas time mean speed is simply the average of all recorded speeds.

Axis of Rotation The line about which the pavement is rotated to super-elevate the roadway. This line normally maintains the highway profile.

B

Barrier An obstruction placed to prevent vehicle access to a particular area.

Barrier Kerb A kerb with a profile and height sufficient to prevent or discourage vehicles moving off the carriageway.

Barrier Sight Distance The limiting sight distance below which overtaking is legally prohibited.

Bicycle or Motorcycle Taxi The use of a bicycle or motorcycle to transport people for gain.

Black Spot A site on a road where accidents happen at regular intervals.

Braking Distance The distance required for the braking system of a vehicle to bring the vehicle to a stop from the operating speed.

Bridge A structure erected with a deck for carrying traffic over or under an obstruction and with a clear span of six metres or more. Where the clear span is less than six metres, reference is to a culvert.

Broken-back Curve Two curves in the same direction with a tangent shorter than 500 metres long connecting them.

Bus Bay An auxiliary lane of limited length at a bus stop or terminus, usually indented into the shoulder or verge.

Bus Stop An area in which one or more buses load and unload passengers. It consists of one or more loading areas and may be on line or off line.

C

Camber The slope from a high point (typically at the centre line of the highway) across the lanes of a highway. Negative camber refers to a central low point, usually with a view to drainage of a small urban street or alley.

Capacity The maximum number of vehicles that can pass a point on a highway or in a designated lane in one hour without the density being so great as to cause unreasonable delay or restrict the driver's freedom to manoeuvre under prevailing roadway and traffic conditions.

Carriageway The lanes of the cross-section. The carriageway excludes the shoulders.

Catch Drain A surface channel constructed along the high side of a road or embankment, outside the batter to intercept surface water.

Catchment Area The area that will contribute to the discharge of a stream after rainfall at the point under consideration.

Catchwater Drain Located above a cut face to ensure that stormwater does not flow down the cut face causing erosion and deposition of silt on the roadway.

Centre Line The basic line that defines the axis or alignment of the centre of a road or other works.

Channel Grading Where side channels are designed to gradients that differ from those of the road centre line, typically on either side of the highest points on crest curves and the lowest points on sag curves where the centre line gradient is less than 0.5 percent.

Channelization The use of pavement markings or islands to direct traffic through an intersection.

Channelized Intersection An intersection provided with channelized islands.

Clear Zone An area adjacent to the traffic lane that should be kept free from features potentially hazardous to errant vehicles.

Clearance The space between a stationary and/or moving object.

Clearance Profile Describes the space that is exclusively reserved for the provision of the road or street. It defines the minimum height of the soffit of any structure passing over the road and the closest approach of any lateral obstacle to the cross-section.

Climbing Lane A special case of an overtaking lane located on a rising grade, allowing faster vehicles to pass trucks and other vehicles.

Coefficient of Run-off The ratio of the amount of water that runs off a catchment area to the amount that falls on the catchment.

Collector A road characterised by a roughly even distribution of its access and mobility functions.

Commercial Vehicle A vehicle having at least one axle with dual wheels and/or having more than two axles.

Complete Street A street that accommodates all street users, allow for the safe movement of people and goods, giving priority to the most efficient modes of transport, respond to the neighbourhood character, create a vibrant public realm, contribute to a healthy and sustainable environment and create harmonious streetscapes in a cost-effective way.

Compound Curve A curve consisting of two or more arcs of different radii curving in the same direction and having a common tangent point or being joined by a transition curve.

Context-Sensitive Design (CSD) Is defined as a project development process, which includes geometric design, and attempts to address safety and efficiency while being responsive to, the street or road's natural and human environment. It addresses the need for a more systematic and all-encompassing approach in project development which recognizes the interdependency of all stages in the process. In short, the term CSD refers as much to an approach or process as it does to an actual outcome.

Criterion A yardstick according to which some or other quality of the road can be measured. Guideline values are specific numerical values of the criterion. For example, delay is a criterion of congestion.

Critical Length of Grade The maximum length of a specific upgrade on which a loaded truck can operate without an unreasonable reduction in speed. Very often, a speed reduction of 15 km/h or more is considered "unreasonable".

Cross-section The transverse elements of the longitudinal elements**.**

Crossfall The slope, measured at right angles to the alignment, of the surface of any part of a carriageway.

Crosswalk A demarcated area or lane designated for the use of pedestrians across a road or street.

Crown The highest point on the cross section of a carriageway with two-way cross fall.

Crown Run-off (Also referred to as tangent runout) The rotation of the outer lane of a two- lane road from zero cross fall to normal camber (NC).

Culvert A structure, usually for conveying water under a roadway or parallel to a street.

Curvilinear Alignment The alignment is a continuous curve with constant, gradual and smooth changes of direction.

Cut Section of street or road below natural ground level. Sometimes referred to in other documents as a cutting or excavation.

Cycle Lane A portion of the roadway which has been designated by road markings, striping and signing as being exclusively for the use of cyclists.

Cycleway A facility provided for cyclist movement and segregated from vehicular traffic by a kerb, or provided for on a separate right-of-way.

D

Deceleration Lane An auxiliary lane provided to allow vehicles to decrease speed.

Decision Sight Distance Sometimes referred to as anticipatory sight distance, allows for circumstances where complex decisions are required or unusual manoeuvres have to be carried out. As such, it is significantly longer than Stopping Sight Distance

Depressed Median A median lower in elevation than the carriageway and so designed to carry a portion of the stormwater falling on the road.

Design Domain The range of values of a design criterion that are applicable to a given design, e.g. lane widths of more than 3.3 metres.

Design Hour The hour in which the condition is designed for, typically the anticipated flow is expected to occur. This is often the thirtieth highest hour of flow in the design year, or the peak hour traffic determined by modelling.

Design Hourly Volume (DHV) The hourly traffic volume selected for design purposes.

Design Life The period during which the quality of a structure (e.g. riding quality of pavement) is expected to remain acceptable.

Design Period A period considered appropriate to the function of the road. It is used to determine the total traffic for which the pavement is designed and does not concern the geometric design.

Design Speed A speed fixed for the design and correlation of those geometric features of a street or road, that influence vehicle operation. Design speed should not be less than the operating speed.

Design Traffic The volume of traffic in the design year in equivalent vehicles, used for determining the required lane configurations of a street or road, normally taken as the design hourly volume.

Design Vehicle A hypothetical road vehicle whose mass, dimensions and operating characteristics are used to determine geometric requirements.

Design Year The last year of the design life of the road or any other facility, often taken as twenty years although, for costly structures such as major bridges, a longer period is usually adopted.

Directional Distribution (split) The percentages of the total flow moving in opposing directions, e.g. 50:50, 70:30, with the direction of interest being quoted first.

Discharge The volumetric rate of water flow.

Divided Road (divided carriageway) A road with a separate carriageway for each direction of travel created by placing some physical obstruction, such as a median or barrier, between the opposing traffic directions.

Drainage Natural or artificial means for the interception and removal of surface or subsurface water.

Driveway A road providing access from a public road to a street or road usually located on an abutting property.

E

Eighty-fifth Percentile Speed The speed below which 85 per cent of the vehicles travel on a given road

F

Footway Separate pedestrian facility.

Frangible Term is used to describe roadside furniture designed to collapse on impact. The severity of potential injuries to the occupants of an impacting vehicle is reduced, compared to those that could occur if the furniture was unyielding.

Freeway Highest level of arterial characterised by full control of access and high design speeds. (Class 1 road)

Frontage Road A road adjacent and parallel to but separated from the highway for service to abutting properties and for control of access. Sometimes also referred to as a service road.

G

Gap The elapsed time between the back of one vehicle passing a point on the road or highway and the nose of the following vehicle passing the same point. A lag is the unexpired portion of a gap, i.e. the elapsed time between the arrival of a vehicle on the minor leg of an intersection and the nose of the next vehicle on the major road crossing the path of the entering vehicle.

Grade The straight portion if the grade line between two successive vertical curves.

Grade Separation The separations of road, rail or other traffic so that crossing movements, which would otherwise conflict, are at different elevations.

Gradient The slope of the grade between two adjacent Vertical Points of Intersection (VPI), typically expressed in percentage form as the vertical rise or fall in metres/100 metres. In the direction of increasing stake value, upgrades are taken as positive and downgrades as negative.

Guardrail A rail erected to restrain vehicles that are out of control. It could also take the form of a set of vertical strung and anchored cables.

Guideline A design value establishing an approximate threshold, which should be met if considered practical. It is a recommended value whereas a standard is a prescriptive value allowing for no exceptions.

H

High Occupancy Vehicle Lane (HOV) A lane designated for the exclusive use of buses and other vehicles carrying more than two passengers. The actual number varies between authorities.

High-speed Typically where speeds of 80 km/h or faster are being considered.

Horizontal Curve A curve in the plan or horizontal alignment of a carriageway.

Horizontal Sight Distance The sight distance determined by lateral obstructions alongside the road and measured at the centre of the inside lane.

Human Factors Design This represents a paradigm shift from a Newtonian physics approach to design to a more complex process of the modelling of driver behaviour. In short, the design is now also predicated on what the driver’s capabilities are and wishes to do as opposed to only what the vehicle can do.

I

Intensity of Rainfall The rainfall in a unit of time.

Intersection A place at which two or more roads intersect at grade or with grade separation.

Intersection (at-grade) An intersection where carriageways cross at a common level.

Intersection Angle 1 An angle between two successive straights on the centreline of a carriageway.

Intersection Angle 2 The angles between the centrelines of two intersecting carriageways.

Intersection Leg Any one of the carriageways radiating from and forming part of an intersection.

Intersection Sight Distance The sight distance required within the quadrants if an intersection to safely allow turning and crossing movements.

K

Kerb Concrete, often precast, or hewn stone element adjacent to the carriageway and used for drainage control, delineation of the pavement edge or protection of the edge of surfacing. Usually applied only in urban areas.

Kerb Clearances A distance by which the kerb should be set back in order to maintain the maximum capacity of the traffic lane.

Kerb Ramp The treatment at intersections for gradually lowering the elevation of sidewalks to the elevation of the street surface.

K-Value The length required for a 1% change of grade on a parabolic vertical curve.

L

Lane (Traffic) A portion of the paved carriageway marked out by kerbs, painted lines or barriers, which carries a single line of vehicles in one direction.

Lane Separator A separator provided between lanes carrying traffic in the same direction to discourage or prevent lane changing, or to separate a portion of a speed change lane from through lanes.

Lateral Friction The force which, when generated between the tyre and the road surface assists a vehicle to maintain a circular path.

Lay-by A place at the side of a road where a vehicle can stop for a short time without interrupting other traffic.

Level of Service (LOS) A qualitative concept, from LOS A to LOS F, which characterises acceptable degrees of congestion as perceived by drivers. Capacity is defined as being at LOS E.

Line of Sight The direct line of uninterrupted view between a driver and an object of specified height above the carriageway in the lane of travel.

Longitudinal Friction The friction between vehicle tyres and the road pavement measured in the longitudinal direction.

Low Speed Typically where speeds of 70 km/h or slower are being considered.

M

Median A strip of road, not normally intended for use by traffic, which separates carriageways for traffic in opposite directions.

Median Island A short length of median serving a localised purpose in an otherwise undivided road.

Median Lane The traffic lane nearest the median.

Median Opening An at-grade opening in the median to allow vehicles to cross from a roadway to the adjacent roadway on a divided road.

Minimum Turning Path The path of a designated point on a vehicle making its sharpest turn.

Minimum Turning Radius The radius of the minimum turning path of the outside of the outer front tyre of a vehicle.

Modelling A mathematical process to replicate traffic movements by computation

Modal Transfer Station The public facility at which passengers change from one mode of transport to another, e.g. rail to bus, passenger car to rail.

Movement Networks Movement networks comprise public right of ways, incorporating roads and streets as well as footways and cycleways which provide in a continuous and friendly manner for all human travelling needs. Movement networks recognises the multi-faceted nature of local residential streets, morphing into public transport orientated wider area movement facilities operating at higher speeds for the efficient transport of people and goods.

Mountable kerb A kerb designed so that it can be driven across.

Mountainous Terrain Longitudinal and transverse natural slopes are severe and changes in elevation abrupt. Many trucks operate at crawl speeds over substantial distances.

N

Non-motorized transport All road users that are not using motorized transport, including pedestrians, cyclists and animal-drawn carts**.**

Non-Mountable Kerb A kerb so designed to discourage being driven across

Normal Cross Section The cross section of the carriageway where it is not affected by superelevation or widening.

Normal Crown (NC) The typical cross-section on a tangent section of a two-lane road undivided road.

O

O-D Survey Origin-Destination survey. This is a survey carried out to study the patterns and movements of road users so as to guide a road planner/designer on who and what to cater for.

Off-tracking The radial off-set between the path traced by the centre of the front axle and the centre of the effective rear axle on a turning vehicle.

One-way Road A road or street on which all vehicular traffic travels in the same direction.

Operating Speed Refer: Speed.

Outer Separator The portion of road separating a through carriageway from a service road or frontage road.

Overpass A grade separation where the subject road passes over an intersecting road, and/or pedestrian crossing and/or animal crossing.

Overtaking The manoeuvre in which a vehicle moves from a position behind to a position in front of another vehicle travelling in the same direction.

Overtaking Distance The distance required for one vehicle to overtake another vehicle.

Overtaking Lane An auxiliary lane provided to allow for slower vehicles to be overtaken. It is lined-marked so that all traffic is initially directed into the left-hand lane, with the inner lane being used to overtake.

Overtaking Zone A section of road on which at least 70 per cent of drivers will carry out overtaking manoeuvres subject to availability of adequate gaps in the opposing direction.

P

Passenger Car Equivalents(units) (PCE or PCU) A measure of the impedance offered by a vehicle to the passenger cars in the traffic stream. Usually quoted as the number of passenger cars required to offer a similar level of impedance to the other cars in the stream.

Passing The manoeuvre by which a vehicle moves from a position behind to in front of another vehicle, which is stationary or travelling at crawl speeds.

Passing Sight Distance The total length of visibility, measured from an eye height of 1,05 metres to an object height of 1,3 metres, necessary for a passenger car to overtake a slower moving vehicle. It is measured from the point at which the initial acceleration commences to the point where the overtaking vehicle is once again back in its own lane.

PC (Point of Curvature) Beginning of horizontal curve, often referred to as the BC.

PI (Point of Intersection) Point of intersection of two tangents.

PRC (Point of Reverse Curvature) Point where a curve in one direction is immediately followed by a curve in the opposite direction.

Property Line The boundary between a road reserve and the adjacent land.

PT (Point of Tangency) End of horizontal curve, often referred to as BC or EC.

PVC (Point of Vertical Curvature) The point at which a grade ends and the vertical curve begins, often also referred to as BVC.

PVI (Point of Vertical Intersection) The point where the extension of two grades intersect. The initials are sometimes referred to as VPI.

PVT (Point of Vertical Tangency) The point at which the vertical curve ends and the grade begins. Also referred to as EVC.

R

Rainfall Intensity The rate of rainfall (mm/h).

Rate of Rotation The rate of rotation required to achieve a suitable distance to uniformly rotate the cross fall from normal to full superelevation.

Reaction Distance The distance travelled during the reaction time.

Reaction Time The time between the driver’s reception of stimulus and taking appropriate action.

Re-alignment An alteration to the control line of a road that may affect only its vertical alignment but, more usually, alters its horizontal alignment. A method of widening a road reservation.

Relative Gradient The slope of the edge of the carriageway relative to the grade line.

Renewable energy lighting sources: The provision of street lighting in villages or along LVRs through the use of solar energy or wind energy driven devices.

Residual Median The remnant area of the median adjacent to right turn lanes.

Reverse Camber (RC) A superelevated section of roadway sloped across the entire carriageway at a rate equal to the normal camber.

Reverse Curve A section of road alignment consisting of two arcs curving in opposite directions and having a common tangent point or being joined by a short transition curve.

Road Accident An incident in which a single vehicle or two or more vehicles are involved in an accident that could include human injury or death.

Road Furniture A generic term used for various road-related assets within the road reserve, including bus laybys and shelters, guardrails, pedestrian barriers, traffic signals, traffic signage, rail crossings and other small structures such as pedestrian bridges across rivers or streams.

Roadway A route trafficable by motor vehicles; in law, the public right-of-way between boundaries of adjoining property. The roadway includes the carriageway and the shoulders.

Road (Street) Furniture A general term covering all signs, streetlights and protective devices for the control, guidance and safety of traffic, and the convenience of road users.

Road Prism The lateral extent of the earthworks.

Road Reserve Also referred to as Right-of-way. The strip of land acquired by the road authority for the provision of a road.

Road Safety Audit A structured and multidisciplinary process leading to a report on the crash potential and safety performance of a length of road or highway, which report may or may not include suggested remedial measures.

Road Safety Inspection Road Safety Inspections (RSIs) to be carried out on an ongoing basis once a road is fully operational to ensure the safe performance of the road.

Roadside A general term denoting the area beyond the shoulder breakpoints.

Roadside Safety Barrier A device erected parallel to the road to retain vehicles that are out of control.

Rolling Terrain The natural slopes consistently rise above and fall below the road grade with, occasionally, steep slopes presenting some restrictions on highway alignment. On general, rolling terrain generates steeper gradients, causing truck speeds to be lower than those of passenger cars.

Roundabout An intersection designed on the principle of gap acceptance and where all traffic travels in one direction around a central island.

Run-off That part of the water precipitation onto a catchment which flows as surface discharge from the catchment area past a particular point.

S

Sag Curve A concave vertical curve in the longitudinal profile of a road.

Safe Systems: An approach to build a road transport system that tolerates human error and minimises casualties following road accidents.

Section Operating Speed The 85th percentile speed of cars traversing a section of road alignment.

Semi-Mountable Kerb A kerb designed so that it can be driven across in emergency or on special occasions without damage to the vehicle.

Servitude A servitude is a registered right that a person has over the immovable property of another. It allows the holder of the servitude to do something with the other person’s property, which may infringe upon the rights of the owner of that property.

Shared Path A paved area particularly designed (with appropriate dimensions, alignment and signing) for the movement of cyclists and pedestrians.

Shoulder Usable area immediately adjacent to the traffic lanes provided for emergency stopping, recovery of errant vehicles and lateral support of the road pavement structure.

Shoulder Breakpoint The hypothetical point at which the slope of the shoulder intersects the line of the fill slope. Sometimes referred to as the hinge point.

Side friction (f) The resistance to centrifugal force keeping a vehicle in a circular path. The designated maximum side friction (max) represents a threshold of driver discomfort and not the point of an impending skid.

Sidewalk The portion of the street cross-section reserved for the use of pedestrians.

Sideways Friction The resistance to the sideways motion of the tyre of a vehicle on a road surface.

Sight Distance

- **Approach Sight Distance (ASD)** The distance required for a driver to perceive marking or hazards on the road surface and to stop.
- **Car Stopping Sight Distance (SSD)** The distance required for a car driver to perceive an object on the road and to stop before striking it.
- **Entering Sight Distance (ESD)** ESD is the sight distance required for minor road drivers to enter a major road via a left or right turn, such that traffic on the major road is unimpeded.
- **Manoeuvre Sight Distance** The distance required for an alert car driver to perceive an object on the road and to take evasive action.
- **Minimum Gap Sight Distance (MGSD)** The minimum sight distance based on the gap necessary to perform a particular movement.
- **Overtaking Sight Distance** The sight distance required for a driver to initiate and safely complete an overtaking manoeuvre.
- **Railway Crossing Sight** Triangle The clear area required for a truck driver to perceive a train approaching an uncontrolled railway crossing and to stop the truck.
- **Safe Intersection Sight Distance (SISD)** The distance required for a driver in a major road to observe a vehicle entering from a side road, and to stop before colliding with it.
- **Sight Distance Through Underpass** The distance required for a truck driver to see beneath a bridge located across the main road, to perceive any hazard on the road ahead, and to stop.
- **Sight Triangle** The area in the quadrants of an intersection that must be kept clear to ensure adequate sight distance between the opposing legs of the intersection
- **Stopping Sight Distance** The sight distance required by an average driver, travelling at a given speed, to react and stop.
- **Truck Stopping Sight Distance** The distance required for a truck driver to perceive an object on the road and to stop before striking it.

Simple Curve A curve of constant radius without entering or exiting transitions.

Skid Resistance The frictional relationship between a pavement surface and vehicle tyres during braking or cornering manoeuvres. Normally measured on wet surfaces, it varies with the speed and the value of ‘slip’ adopted.

Slope

- The inclination of a surface with respect to the horizontal, expressed as rise or fall in a certain longitudinal distance.
- An inclined surface.

Speed

- **Operating Speed** The speed at which 85 percent of car drivers will travel slower and 15 percent will travel faster.
- **Operating Speed of Trucks** The 85th percentile speed of trucks measured at a time when traffic volumes are low.
- **Section Operating Speed** The value at which vehicle speeds on a series of curves tend to stabilise and is related to the range of radii on the curves.

Speed-change Lane A subdivision of auxiliary lanes, which cover those lanes used primarily for the acceleration or deceleration of vehicles. It is usual to refer to the lane by its actual purpose (such as deceleration lane).

Speed Profile The graphical representation of the 85th percentile speed achieved along the length of the highway segment by the design vehicle.

Standard A design value that may not be transgressed, e.g. an irreducible minimum or an absolute maximum. On the sense of geometric design, not to be construed as an indicator of quality, i.e. an ideal to be strived for.

Standard Axle A single axle with dual wheels loaded to a total mass of 8.16 tonnes.

Superelevation A slope on a curved pavement selected so as to enhance forces assisting a vehicle to maintain a circular path.

Superelevation Run-off (Also referred to as superelevation development) The process of rotating the outside lane from zero crossfall to reverse camber (RC), thereafter rotating both lanes to the full superelevation selected for the curve.

Sustainable Safety A safe road traffic system that aims to prevent deaths, injuries and damage to vehicles and property by systematically reducing the underlying risks of the entire traffic system.

Swept Path The area bounded by lines traced by the extremities of the bodywork of a vehicle while turning.

Swept Width The radial distance between the innermost and outermost turning paths of a vehicle.

T

Table Drain The side drain of a road adjacent to the sidewalk or shoulder, having its invert lower than the pavement base and being part of the formation.

Tangent The straight portion of a highway between two horizontal curves.

Tangent Run-off See crown runoff.

Tangent Run-out The length of roadway required to accomplish the change in crossfall from a normal crown section to a flat crossfall at the same rate as the superelevation runoff.

Terrain Topography of the land.

- **Level Terrain** Is that condition where road sight distance, as governed by both horizontal and vertical restrictions, are generally long or could be made to be so without construction difficulty or major expense**.**
- **Undulating Terrain** Is that condition where road sight distance is occasionally governed by both horizontal and vertical restrictions with some construction difficulty and major expense but with only minor speed reduction.
- **Rolling Terrain** Is that condition where the natural slopes consistently rise above and fall below the road grade and where occasional steep slopes offer some restriction to normal horizontal and vertical roadway alignment. The steeper grades cause trucks to reduce speed below those of passenger cars.
- **Mountainous Terrain** Is that condition where longitudinal and transverse changes in the elevation of the ground with respect to the road are abrupt and where benching and side hill excavation are frequently required to obtain acceptable horizontal and vertical alignment. Mountainous terrain causes some trucks to operate at crawl speeds.

Time of Concentration The shortest time necessary for all points on a catchment area to contribute simultaneously to run-on at a specified point.

Traffic A generic term covering all vehicles, people, and animals using a road.

Traffic calming Speed reducing measures implemented to force drivers to reduce speed at unsafe road conditions.

Traffic Composition The percentage of vehicles other than passenger cars in the traffic stream e.g. 10 per cent trucks, 5 per cent articulated vehicles (semi-trailers) etc.

Traffic Control Signal A device that, by means of changing coloured lights, regulates the movement of traffic.

Traffic Island A defined area, usually at an intersection, from which vehicular traffic is excluded. It is used to control vehicular movements and as a pedestrian refuge.

Traffic Lane A portion of the paved carriageway marked out by kerbs, painted lines or barriers, which carries a single line of vehicles in one constant direction.

Traffic segregation The vertical or horizontal separation of motorized and non-motorized road users.

Traffic Sign A sign to regulate traffic and warn or guide drivers.

Transition Length for increasing or decreasing the number of lanes.

Transition Curve A curve of varying radius used to model the path of a vehicle as it enters or leaves a curve of constant radius used for the purpose of easing the change in direction.

Transition Length for Alignment The distance within which the alignment is changed in approach from straight to a horizontal curve of constant radius.

Transition Length for Crossfall The distance required rotating the pavement crossfall from normal to that appropriate to the curve. Also called superelevation development length.

Transition Length for Widening The distance over which the pavement width is changed from normal to that appropriate to the curve.

Turning Lane An auxiliary lane reserved for turning traffic.

Turning Roadway Channelized turn lane at an at-grade intersection.

Turning Template A graphic representation of a design vehicle's turning path for various angles of turn. If the template includes the paths of the outer front and inner rear points of the vehicle, reference is to the swept path of the vehicle.

Typical Cross Section A cross section of a street showing typical dimensional details, utility services and street furniture locations.

U

Underpass A grade separation where the subject road passes under an intersecting road, pedestrian crossing or railway.

Urban Road or Street Characterised by adjacent property development, traffic volumes in keeping with the nature of the adjacent development, moving at relatively low speeds and pronounced peak or tidal flows. Usually within an urban area but may also be a link traversing an unbuilt up area between two adjacent urban areas, hence displaying urban operational characteristics.

V

Value Engineering A management technique in which intensive study of a project seeks to achieve the best functional balance between cost, reliability and performance.

Verge That portion of the road reserve outside the road prism

Vertical Alignment The longitudinal profile along the design line of a road.

Vertical Curve A curve (generally parabolic) in the longitudinal profile of a carriageway to provide for a change of grade at a specified vertical acceleration.

W

Walkway A facility provided for pedestrian movement and segregated from vehicular traffic by a kerb, or provided for on a separate right-of-way.

Warrant A guideline value indicating whether or not a facility should be provided. For example, a warrant for signalisation of an intersection would include the traffic volumes that should be exceeded before signalisation is considered as a traffic control option.