REPUBLIC OF LIBERIA

MINISTRY OF PUBLIC WORKS

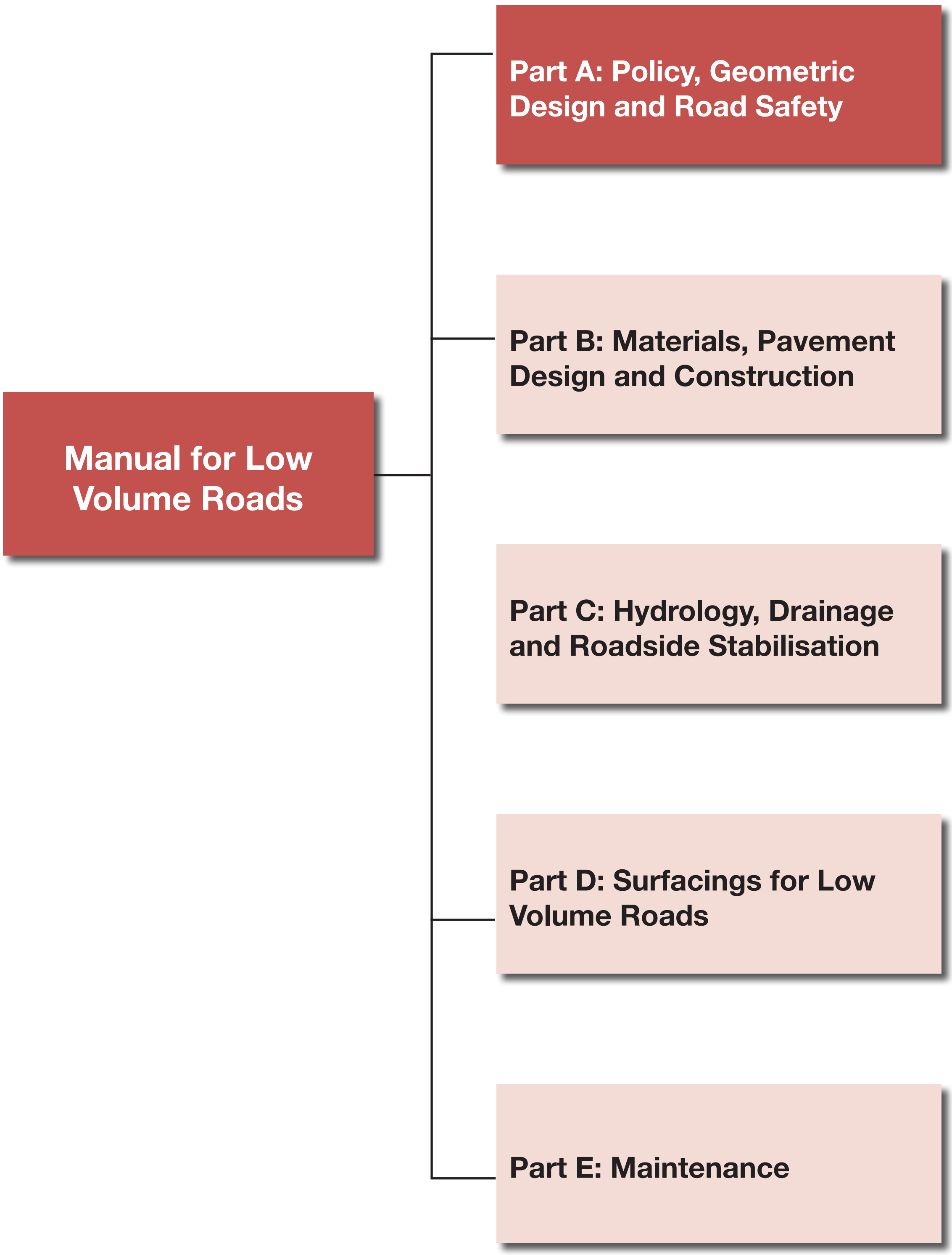
MANUAL FOR LOW VOLUME ROADS

PART A - POLICY, GEOMETRIC DESIGN AND ROAD SAFETY

2019

PART A

POLICY, GEOMETRIC DESIGN AND ROAD SAFETY



FOREWORD

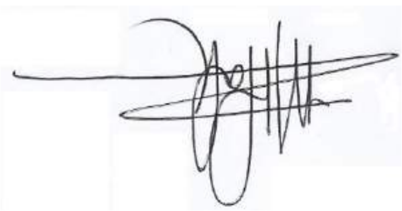
The development of the feeder road network in Liberia will contribute to poverty alleviation in rural areas by increasing the capacity of the rural poor to expand their livelihoods opportunities through improved access to markets. Improved roads will lead to greater availability of transport for rural communities and lower transport costs. Social interaction will improve in rural areas and the government will be able to strengthen the provision of basic services including health and education.

The Manual for Low Volume Roads builds on previous work done by the Liberia Government and development partners, notably the Liberia-Swedish Feeder Road Program. The Manual describes the basic standards to be adhered to in the provision and maintenance of rural roads. This includes standards for very low traffic roads linking small rural villages, as well as higher traffic rural roads that justify a paved road surface. By adopting the standards described by the manual, and closely following the detailed guidance provided, it is expected that savings will be made in construction costs. Roads will be more durable, resulting in lower maintenance requirements.

On behalf of the Government of Liberia I would like to thank UK Aid through the Department for International Development for its support to the manual preparation process. I would also like to thank the Project Management Unit of the Research for Community Access Partnership (ReCAP) and Civil Design Solutions for their role in managing the project.

Two project workshops were held during the development of the manual to enable stakeholders to contribute to the process. There was also a peer review process led by national and international experts.

I commend this manual to all individuals and agencies in Liberia that are responsible for the provision of low volume rural roads. I am confident that the manual will provide the essential information and guidance needed for the sustainable provision of roads, leading improved growth and wellbeing of our rural communities.



Honorable Minister Mobutu Vlah Nyenpan
Ministry of Public Works
Monrovia

PREFACE

The Manual for Low Volume Roads applies to the design, construction and maintenance of low volume roads, typically carrying less than 300 vehicles per day with four or more wheels and less than one million equivalent standard axles over the design life. The effective management of this important part of the national road network depends on adopting standards that meet the needs of road users yet are affordable to a developing economy such as Liberia.

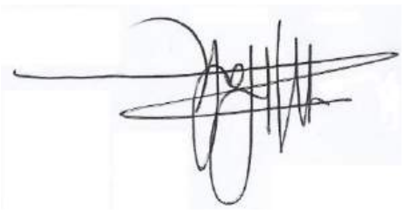
Part A of the Manual describes the background and philosophy of low volume road design in the context of rural road asset management. It provides guidance on route selection for rural roads and geometric standards for detailed design. Guidance is also provided on planning options and the implementation of Complementary Interventions to enhance the impact of road projects in local communities. Road safety is given particular importance in the manual, including guidance on safer design for motorcycles. The standards encourage the use of labor-based construction methods where appropriate, within the context of focusing on technical quality and value for money.

The design standards included in this manual are based on more than 40 years of research in Africa. Reference has been made wherever possible to existing standards in use in Liberia. The intention is to minimize whole life costs in the provision of roads yet provide agreed minimum levels of service for road users. The design standards set out in the manual shall be adhered to unless otherwise directed by the Ministry of Public Works.

Manual Updates

Significant changes to criteria, procedures or any other relevant issues related to new policies or revised laws of the land or that are mandated by the Government of Liberia will be incorporated into the manual from their date of effectiveness. Other minor changes that do not significantly affect the whole nature of the manual will be accumulated and made periodically. When changes are made and approved, new versions of the manual incorporating the revision will be issued.

All suggestions to improve the manual should be made in writing to the Minister of Public Works.



Honorable Minister Mobutu Vlah Nyenpan
Ministry of Public Works
Monrovia

ABBREVIATIONS, ACRONYMS AND INITIALISMS

>	:	Greater than
<	:	Less than
%	:	Percentage
$	:	United States Dollar
AADT	:	Annual Average Daily Traffic
AASHTO	:	American Association of State Highway and Transportation Officials
AC	:	Asphalt Concrete
AfCAP	:	Africa Community Access Partnership
AfT	:	Agenda for Transformation
AIDS	:	Acquired Immune Deficiency Syndrome
ALD	:	Average Least Dimension
ARRB	:	ARRB Group, formerly the Australian Road Research Board
ASTM	:	American Society for Testing and Materials
BC	:	Binder Course
CBO	:	Community Based Organization
CBR	:	California Bearing Ratio
CI	:	Complementary Interventions
DC	:	Design Class
DFID	:	UK Government's Department for International Development
DV	:	Design Vehicle
DEM	:	Digital Elevation Model
e.g.	:	For example (abbreviation for the Latin phrase exempli gratia)
EIA	:	Environmental Impact Assessment
EMP	:	Environmental Management Plan
EOD	:	Environmentally Optimized Design
ERA	:	Ethiopian Roads Authority
esa	:	Equivalent Standard Axles
ESIA	:	Environmental and Social Impact Assessment
FED	:	Final Engineering Design
g/m^2	:	Grams per square meter
GDP	:	Gross Domestic Product
GM	:	Grading Modulus
GVW	:	Gross Vehicle Weight
ha	:	Hectare
HDM 4	:	World Bank's Highway Development and Management Model Version 4
HIV	:	Human Immunodeficiency Virus
HVR	:	High Volume Road
i.e.	:	That is (abbreviation for the Latin phrase id est)
ILO	:	International Labor Organization
IMT	:	Intermediate Means of Transport
km	:	Kilometer
km^2	:	Square kilometer
km/h	:	Kilometers per hour
km/hr	:	Kilometers per hour
L-B	:	Labor-based (construction)
LOS	:	Level of Service

LSFRP	:	Liberia Swedish Feeder Road Program
LVR	:	Low Volume Road
LVSR	:	Low Volume Sealed Road
m	:	Meters
M	:	Million
m^2	:	Square meters
m^3	:	Cubic meters
mg/m^3	:	Milligram per cubic meter
mm	:	Millimeter
mm^2	:	Square millimeter
mm^3	:	Cubic millimeters
m/s	:	Meters per second
MPa	:	Megapascal
NGO	:	Non-Government Organization
nm	:	Nanometer
NMT	:	Non-Motorized Transport
ORN	:	Overseas Road Note
PCU	:	Passenger Car Unit
R	:	Radius
Ref	:	Reference
RS	:	Road Safety
RTS	:	Rural Transport Services
SADC	:	Southern African Development Community
SE	:	Super Elevation
SMEs	:	Small and Medium Enterprises
SRTM	:	Shuttle Radar Topography Mission
TBA	:	To Be Advised
ToR	:	Terms of Reference
TRL	:	Transport Research Laboratory
UK	:	United Kingdom
USA	:	United States of America
USD	:	United States Dollar
vpd	:	Vehicles per day
WC	:	Wearing Course

UNITS OF MEASUREMENT

The units of measurement used in this manual are based on International System (SI) units, with some exceptions. The basic units of measurement are summarized below.

Item	Unit	Symbol	Common Multiples
Length	meter	m	1000 meter (m) = 1 kilometer (km) 1 meter (m) = 100 centimeters (cm) 1 meter (m) = 1000 millimeters (mm)
Mass	kilogram	kg	1000 kg = 1 tonne (ton) 1 kg = 1000 grams (g)
Area	square meter	m^2	10,000 m^2 = 1 hectare (ha)
Volume (Solids)	cubic meter	m^3	1 m^3 = 10,000 cm^3
Volume (liquids)	liter	l	1000 liters (l) = 1 m^3 1 liter (l) = 1000 milliliter (ml)
Density	kilogram per cubic meter	kg/m^3	1000 kg/m^3 = 1 ton/m^3 1 kg/m^3 = 1000 g/cm^3
Force	Newton	N	1000 N = 1 kilonewton (kN) 1 N = 1 kgm/s^2
Pressure and stress	Newton per square meter	N/m^2	1 kN/m^2 = 1000 N/m^2
Speed	meter per second kilometer per hour	m/s km/h	
Temperature	degree Celsius	°C	

SI units may be converted to the Imperial System using the following factors.

Item	Measure and Unit		Conversion Factor and Unit	
Length	1	meter (m)	3.2808	Feet (ft)
	1	Meter (m)	39.3701	Inches (In)
	1	Meter (m)	1.0936	Yard (Y)
	1	Kilometer (km)	0.6214	Miles
Mass	1	Kilogram (kg)	2.2050	Pounds
Area	1	m^2	10.7639	Square ft
	1	m^2	1.1960	Square Yard
	1	Hectare (ha)	2.4711	Acres
Volume (Solids)	1	m^3	35.3147	Cubic feet
	1	m^3	1.3080	Cubic yards
Volume (liquids)	1	Liter (l)	0.2200	Gallons (UK)
	1	Liter (l)	0.2642	Gallons (USA)
Density	1	kg/m^3	0.0624	$Pounds/ft^3$
Force	1	Newton (N)	0.2248	Pounds - force
Speed	1	m/s	3.2808	ft/s
	1	km/h	0.6214	Miles/h

Source: LSFRP Design Manual, 2016.

GLOSSARY OF TECHNICAL TERMS

Annual Average Daily Traffic
The total of traffic on the road in one year (in both directions) divided by 365.

Base course
The upper layer of the road pavement.

Camber
The lateral slope of the cross-section of the carriageway and shoulder constructed to drain the rainwater from the carriageway to the side drains.

Carriageway
Paved or unpaved width of the road, excluding the shoulders, normally used by traffic.

Complementary Interventions
Actions that are implemented through a roads project which are targeted toward the communities that lie within the influence corridor of the road and are intended to optimize the benefits brought by the road and to extend the positive, and mitigate the negative, impacts of the project.

Crossfall
The difference in level measured traverse across the surface of the carriageway expressed as a percentage.

Cross-section (of a road)
Vertical section showing the profile of the road and the existing ground, usually at right angles to the centerline of the road.

Crown
Highest portion of the cross-section of a cambered roadway, normally on the centerline.

Curb/Kerb
Border of stone, concrete or other rigid material formed at the edge of the roadway or footway.

Cut
Excavation in the natural ground with graded slope to accommodate the road.

Cut slope
The constructed inclined soil surface in a cut.

Design Speed
The maximum safe speed that can be maintained over a specified section of road when conditions are so favorable that the design features of the road govern the speed.

Drain invert
The lowest surface of the internal cross-section of a drain.

Drain inside slope
The slope from the shoulder break point to the inside edge of the side drain invert.

Drain back slope (drain outside slope)
The outer slope of the side drain with an appropriate angle to prevent soil from sliding into the ditch.

Earth road
A road formed from the in situ soil material.

Embankment
Constructed fill material below the pavement or gravel surface raising the road above the surrounding natural ground level.

Embankment slope
The constructed, inclined surface on the side of the embankment.

Feeder Road
Lowest level of road in the classified road network hierarchy with the function of linking traffic to and from rural areas, either directly to adjacent urban centers, or to the collector road network.

Formation width
Full width of the road, including side drains, side cuts and embankments.

Gravel
A naturally-occurring, weathered rock within a specific particle size range.

Gravel road
Road with a gravel layer as a surfacing material.

Horizontal alignment
Arrangement of a road in plan view showing a series of straight lines connected by curves.

Labor-based construction
Economically efficient employment of as great a proportion of labor as is technically feasible throughout the construction process to produce the standard of construction as demanded by the specification and allowed by the available funding. Substitution of equipment with labor as the principal means of production.

Low Volume Road
Roads carrying up to about 300 vehicles (with 4 wheels) per day and less than 1 million equivalent standard axles over their design life.

Passability
Typically assessed in terms of the number of months a road is normally impassable, this relates to the ability of vehicles to travel along the road in light of its condition and the status of submersible cross-drainage structures.

Pavement
The part of a road designed to carry the weight of the traffic.

Paved road
A road that has a bitumen seal or a concrete riding surface

Roadway
Full width of the road, including shoulders and carriageway for use by traffic.

Road centerline
The longitudinal axis along the center of the road.

Right-of-Way (Road Reserve)
Strip of land legally awarded to the Road Authority in which the road is or will be situated and where no other work or construction may take place without permission from the Road Authority.

Seal
A term frequently used instead of “reseal” or “surface treatment”. Also used in the context of “double seal” and “sand seal” where sand is used instead of stone.

Selected layer
Pavement layer of selected gravel materials used to bring the subgrade support up to the required structural standard for placing the sub-base or base course.

Shoulder
Paved or unpaved width of the road between the edge of the carriageway and the shoulder breakpoint which provides side support for the pavement and space for vehicles to stop off the road or pass in an emergency.

Shoulder breakpoint
The outside edge of the road shoulder where the side slope of the drain starts.

Site Investigation

Collection of essential information on the soil and rock characteristics, topography, land use, natural environment, and socio-political environment necessary for the location, design and construction of a road.

Sub-base

The layer in the road pavement below the base course.

Subgrade

The native material underneath a constructed road pavement.

Surface treatment

A general term incorporating chip seals, micro surfacing, fog sprays or tack coats.

Superelevation

Inward tilt or transverse inclination given to the cross-section of a carriageway throughout the length of a horizontal curve to reduce the effects of centrifugal forces on a moving vehicle.

Surfacing

The top layer of the road with which traffic makes direct contact.

Trafficability

This relates to the ease with which a vehicle is able to travel along a road that presents challenges on account of its condition, but nevertheless remains passable. This may be assessed in terms of the proportion of the road length over which the carriageway is in poor condition.

Unpaved road

Earth or gravel road.

Vertical alignment

Longitudinal section of a road indicating the surface levels of the completed road along the carriageway centerline.

Wearing course

The upper layer of a road pavement on which the traffic runs and is expected to wear under the action of traffic.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 Context and Scope of the Manual

1.1.1 Purpose of the Manual

This Manual for Low Volume Roads promotes the rational, appropriate, and affordable provision and maintenance of LVRs in Liberia. In doing so it aims to make cost effective and sustainable use of local resources. The Manual reflects local experience and advances in LVR technology gained in Liberia and elsewhere.

The Manual is fully adaptable for different clients and users. It has application for roads at a national and district level administered by the Ministry of Public Works and local authorities. The document caters for interventions that deal with individual critical areas on a road link (spot improvements) through to providing complete designs for new rural roads.

The Manual is intended for use by roads practitioners responsible for the design, construction and maintenance of low traffic earth, gravel or paved roads. It is appropriate for roads which are required to carry an average of up to about 300 vehicles per day (with four or more wheels) and less than 1.0 million equivalent standard axles (mesa) per traffic lane over their design life. It is divided into the following Parts:

- Part A: Policy, Geometric Design and Road Safety
- Part B: Materials, Pavement Design and Construction
- Part C: Hydrology, Drainage and Roadside Stabilization
- Part D: Surfacings for Low Volume Roads
- Part E: Maintenance

Part A provides guidance for SLRA staff, local authorities, Non-Governmental Organizations and local communities on how to:

- plan and prioritize road investments;
- identify and implement Complementary Interventions within road works contracts;
- select the optimal route for a road;
- determine appropriate geometric design standards in accordance with traffic using the road; and
- provide for the safety of road users.

1.1.2 Application of appropriate standards

Appropriate design standards for LVRs in Liberia are those that aim to optimize construction and maintenance costs and meet the requirement to:

- improve the economic and social well-being of rural communities and access to social and other services;
- lower road user costs and promote socio-economic development, poverty reduction, trade growth and wealth creation in rural areas;
- be accessible and relevant to the needs of different ethnic and other groups in society; and
- protect and manage non-renewable natural resources and reduce import dependency.

1.1.3 Clients for Low Volume Roads

The Client for the low volume road works could be the Ministry of Public Works, a local authority, Non-Governmental Organization or a community organization. Road works require a design, whether they are to be undertaken by a contractor, through an in-house capability or through a community contract. This design should meet national standards set for a particular type of road. The degree of sophistication of the design generally increases as the standard of the road increases. However, this does not mean that earth or gravel roads are any easier to design than a traditional low volume paved road. The opposite is often the case.

1.1.4 The Procurement Process and Project Cycle

Unless carried out in-house, the provision and maintenance of LVRs entails various instances of procurement, the process of creating and fulfilling contracts. Such contracts relate to the provision of the various services and goods needed to plan, appraise, design, supervise and execute the works while ensuring that related environmental and other safeguards are adhered to.

In the case of a specific project, these functions are broken down into step-by-step procedures that ensure that established good practice is followed at all stages of the Project Cycle. Figure A.1.1 illustrates how each of these procedures relates to each other and to the broader project cycle.

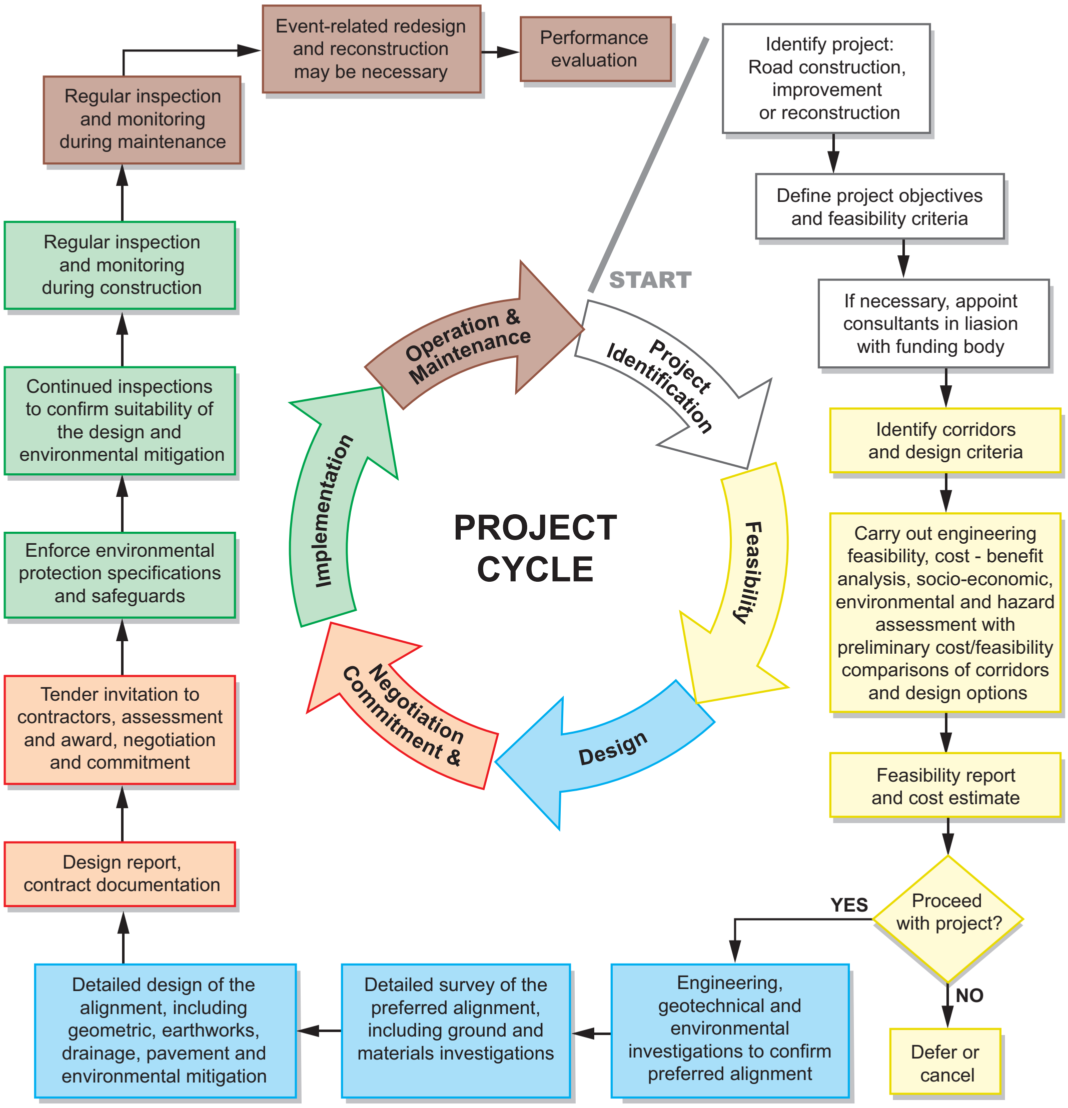


Figure A.1.1: Step-by-step breakdown of stages of the Project Cycle

Though not explicitly shown, there is implied associated lesson-learning at every stage, as Monitoring and Evaluation (M&E) functions identify scope for improvement.

1.1.5 The Design Process

The Road Design Engineer is normally supported by a team of individuals, with varying specialties, and equipped to deal with all aspects of the road design. The job of the design team is to provide a robust technical design (geometric, drainage and pavement), and to reflect this design in the Specifications, Drawings and the Bills of Quantities. The design team should include knowledge of the environmental and social development impacts of rural roads. The design process is summarized in Figure A.1.2.

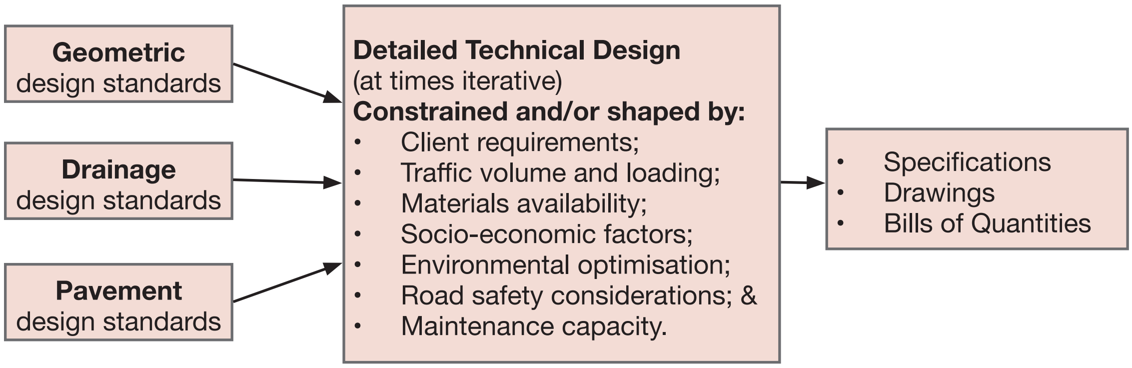


Figure A.1.2: Overview of the detailed design process

The general approach to the design is guided by the Client and builds on information and data collected during the project pre-feasibility and feasibility stages. The Client normally has a budget allocated for the works. The general location of the route is known, as well as the preferred approach to the works, for example labor or equipment based. The Client may have requirements on apportioning works and contract size, technical issues, social, environmental requirements and time constraints. The job of the road Design Engineer is to develop the project within and around these boundaries and limitations, whilst at the same time alerting the Client to issues and problems that may limit or require adjustment of expectations.

The approach to the design of LVRs follows the general principles of any good road design practice. There are, however, subtle but important differences from the traditional road design practice. This manual provides the Design Engineer with the requisite tools to achieve an optimized design based on the financial, technical and other constraints that define the project.

Optimizing a road design requires a multi-dimensional understanding of all of the project elements. In this respect, the design elements become context specific. The design team may need to work outside their normal areas of expertise in order to understand implications of their recommendations or decisions on all other elements of the design.

The successful design of LVRs relies on:

- A Client who is open and responsive to innovation;
- A full understanding by the Design Engineer of the road environment;
- An ability to work within the demands of the road environment and to turn these to a design advantage;
- Innovative and flexible thinking through the application of appropriate engineering solutions rather than following traditional thinking related to road design;
- Recognition and management of risk; and
- Prior certainty that the both the institutional and financial capacity is in place to guarantee effective and sustainable routine and periodic maintenance following construction.

The Design Engineer is required to provide a road that meets the level of service expected by road users and local communities. Design engineers are traditionally conservative and build in factors of safety that cater for their perceptions of risk. This approach does not necessarily encourage innovation, uses scarce or inappropriate resources, and may result in high financial costs for the Client and the country. There is often a temptation to upgrade roads to a level of service not justified by economics or by road user requirements. Such an approach absorbs available resources and prevents extension of access. It is the role of the Design Engineer to properly represent the Client's and country's interests.

The level of attention and engineering judgement required for optimal provision of LVRs is no different than that required for the provision of other roads. In many cases the required level of judgement is higher. The Design Engineer needs to draw on all of their engineering skills, judgement and local experience to develop appropriate designs without incurring unacceptable levels of risk.

1.2 Road Network Classification

All LVRs are an essential component of the rural road system and comprises of all feeder roads and a proportion of the secondary road system. Their importance and reach extends to all aspects of the economic and social development of rural communities and the country at large. In Liberia, rural roads are divided into three classes according to their function in the network. These are defined in accordance with the Ministry of Public Work's Geometric and Pavement Design Standards Manual (2017) as follows:

- **Primary roads**: Roads linking the major urban centers, County centers and main border posts.
- **Secondary roads**: Roads connecting adjacent Counties and linking main local centers to the primary road network.
- **Feeder roads**: These roads constitute the tertiary and other access roads. As tertiary roads, they provide additional connections within the County and Districts, accessing and linking to Secondary and Primary roads. Some Feeder roads provide access to one or more villages or settlements.

The Feeder and Secondary roads generally serve similar functions and accommodate shorter trips mainly feeding the Primary road or the major centers directly. Some Feeder roads are even more local in trip lengths providing access between villages or their local collection center. The level of service for these roads may be intermediate or low and therefore require intermediate or low design speeds.

LVRs are divided into four categories, or types, namely Type 1 to Type 4. The hierarchy of the various types of LVRs is based on traffic volume. Informal tracks are LVRs, but they don't conform to any basic engineering standards. This manual should be consulted when there is a need to upgrade a track to provide more reliable access by incorporating basic engineering standards.

Table A.1.1 shows the relationship between the definitive functional classification of roads in Liberia, the road categories, the desirable level of service (LOS), and range of annual average daily traffic volumes that they are designed to carry (AADT). The AADT in Table A.1.1 includes only motorized vehicles with 4 or more wheels.

Table A.1.1: Road classes in Liberia

<table>
<tr><th colspan="4">Rural Road Functional Classification</th><th>Road category</th><th>Desirable level of service</th><th>AADT (vpd)</th></tr>
<tr><td></td><td></td><td rowspan="3">PRIMARY</td><td rowspan="3">HIGH VOLUME</td><td rowspan="3">Refer to MoPW Geometric & Pavement Design Standards Manual</td><td>A</td><td>> 3,000</td></tr>
<tr><td></td><td></td><td rowspan="2">B</td><td>1,001 - 3,000</td></tr>
<tr><td></td><td rowspan="3">SECONDARY</td><td>301 - 1,000</td></tr>
<tr><td></td><td></td><td rowspan="4">LOW VOLUME</td><td>Type 4*</td><td rowspan="3">C</td><td>151 - 300</td></tr>
<tr><td rowspan="3">FEEDER</td><td></td><td>Type 3</td><td>51 - 150</td></tr>
<tr><td></td><td></td><td>Type 2</td><td>21 - 50</td></tr>
<tr><td></td><td></td><td>Type 1/Track</td><td>D</td><td>≤ 20</td></tr>
</table>

* If the traffic includes more than 80 large vehicles per day, the standards for high volume roads should be used.

The desirable LOS for roads is related to the road classification and is defined as follows:

Level A: This is the highest level of service. Traffic is free flowing, with the volumes and types of traffic easily accommodated. Safety is a high priority. Design speed is very important and takes precedence over topographic constraints.

Level B: Traffic may not flow smoothly in all situations. Safety is a high priority, but some safety controls may need to be enforced. Design speed is important, but topography may dictate some design changes and controls.

Level C: The efficiency of traffic movement and flow is not a limiting factor. Traffic will be accommodated, but some design controls may need to be applied, such as for speed, sight distance, access control and road carriageway configuration. Safety provisions are adapted to lower and variable speed scenarios. The topography will dictate alignment and the design speed.

Level D: Level of service is geared to the provision of basic access rather than efficiency. Design standards for water-crossings may allow temporary service interruption and some entire roads may even be closed at times (such as during and immediately following heavy rain) to protect the road from damage. Other design standards for geometrics, surfacing and safety reflect lower speed environments and access requirements.

For high volume roads it is seldom possible to achieve the desirable levels of service due to the high cost of construction. The highway designer is required to select an appropriate level of service based on acceptable levels of congestion and the available budget. Guidance is provided in the MoPW Geometric & Pavement Design Standards Manual (2017).

For LVRs the LOS is normally not linked to congestion because traffic volumes are low. The appropriate LOS is linked to the average speed of travel that the road users expect to achieve on the road. In some cases, a high functional classification and high level of service might be given to a road despite carrying a low volume of traffic. This might be for strategic reasons, for example a road providing access to an international border post, or an inter-regional route where a high average speed of travel is desirable. In these cases, the geometric standards applying to a higher volume road may be adopted. However, in most cases the appropriate standards and LOS for a road are determined by the traffic volume, with a lower LOS expected on low traffic roads.

1.3 Right-of-Way

Right-of-Way (or the road reserve) is provided to accommodate the ultimate planned roadway or to meet the future needs of expansion during the life of the road, including all cross-sectional elements and areas to enhance the safety, operation and appearance of the road. Right-of-way is dependent on the class of the road, the cross-sectional elements of the road, topography and other physical controls together with economic considerations. Right-of-Way (ROW) is a matter of National Ordinance and any applicable measures are to be determined by the Ministry of Public Works.

Reduced right-of-way widths may be adopted when these are found necessary for economic, financial, or environmental reasons to preserve valuable land, resources or existing development or when provision of the desirable width would incur unreasonably high costs.

Right-of-way widths are measured equally either side of the road center line. For example, a required right-of-way width of 30 m will be measured 15 m either side of the road center line. ROW widths typically applicable for the various types of LVRs are shown in Table A.1.2. In mountainous terrain, where large cuts and fills are required, the total width can exceed the right-of-way width.

Table A.1.2: Typical right-of-way widths

Road Class	Right of Way (m)	Reduced Right of Way (m)
Primary	50	30
Secondary	30	20
Feeder	15	15

Source: MoPW Geometric and Pavement Design Standards.2017

1.4 Definition of a Low Volume Road

A road is classified as “low volume” if:

- the daily traffic in the base year is less than 300 motorized vehicles with 4 or more wheels; and
- the cumulative number of equivalent standard axles is less than 1.0 million per traffic lane over the design life.

The most important aspect of such roads is that the performance of the road is more dependent on environmental influences than it is on traffic, as indicated in Figure A.1.3. The influence of the environment has very important ramifications on many aspects of the design of such roads.

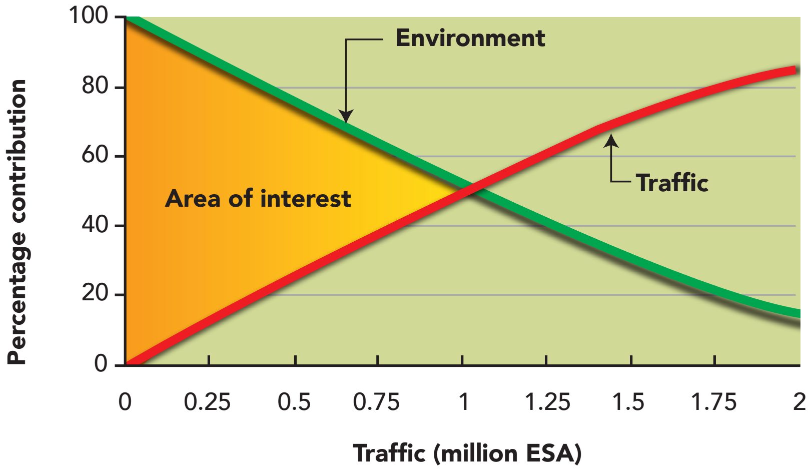


Figure A.1.3: The relative impact of environment and traffic on road performance

1.5 Sustainable Road Asset Management

1.5.1 The Road Preservation Pyramid

The design approach for LVRs is an integral part of the overall management of rural road assets by the responsible road agency. In addition to ensuring that the design developed is technically appropriate and affordable, the Design Engineer needs to bear in mind other factors affecting the sustainable provision of roads. These factors are represented by the building blocks of the Road Preservation Pyramid illustrated in Figure A.1.4.

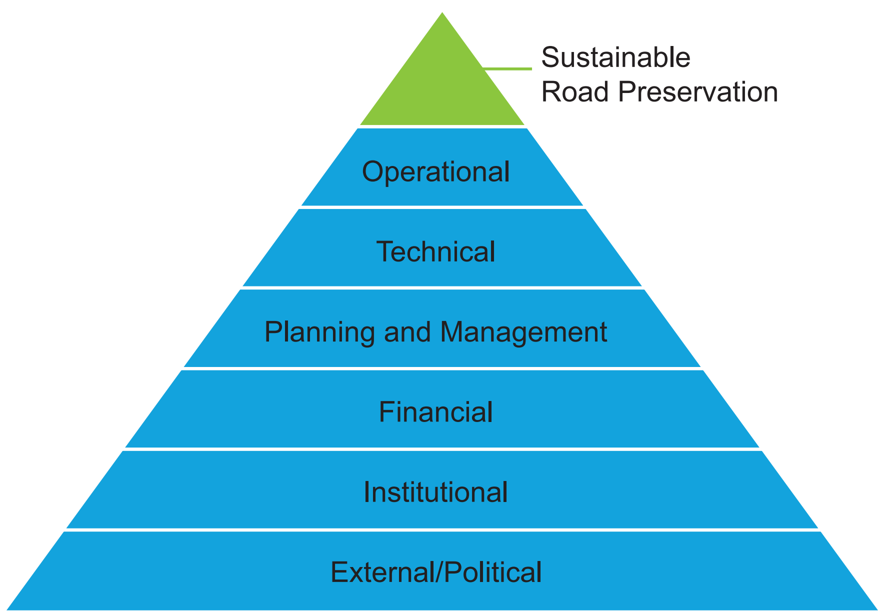


Figure A.1.4: The Road Preservation Pyramid

1.5.2 External factors

The "External" building block is the foundation of the Road Preservation Pyramid. It includes national policies for roads and stakeholder participation in road asset management. The demand for the sustainable provision of LVRs needs to be framed under a national policy driven by government and should be supported at the highest level. The cross-sectoral influence of LVRs and their role in underpinning other sectoral development strategies and poverty alleviation programs should be highlighted, quantified and understood by policy makers. Road agencies need to understand the needs and expectations of road users and communities by helping to identify local requirements, alternatives and solutions to problems.

Opportunities should be provided for all stakeholders, including those representing private sector interests, professional bodies, academia and civil society organizations, to contribute to and potentially influence the evaluation and development of the agency's procurement and asset management strategies. Accordingly, in keeping with applicable regulatory requirements and recognized good practice, data related to the road agency's programs, targets, projects and contracts should routinely be made available to the public in a consistent, reliable and readily accessible format. Where there is demonstrable interest from all stakeholder groups, consideration may be given to the formation of an independent and professional Multi-Stakeholder Group that would facilitate the joint analysis of such data, with a view to identifying constructive measures that would help improve performance.

Government policies for the provision and maintenance of LVRs should complement national plans, policies and strategies and should be responsive to wider needs and demands, including:

- The social and economic goals of poverty alleviation and development;
- Increasing rural accessibility; and
- Protection of the environment.

Specific government policies for the rural road sector should support:

- Sustainable funding for the maintenance of roads;
- Commercial management practices in the road sector;
- The inclusion of design, construction and maintenance approaches for LVRs in tertiary civil engineering training curricula;
- Targeted procurement practices that promote (where appropriate) the use of labor-based technology and the development of improved capacity within the domestic construction industry; and, ultimately
- Demonstrable Value for Money in the procurement and maintenance of LVRs, achieved through improvements in economy, efficiency and effectiveness.

Roads agencies should maintain dialogue with political and public stakeholders to highlight the advantages of design approaches and alternative, often unfamiliar, solutions selected for LVR provision. The language used for advocacy should be carefully chosen and should avoid negative connotations such as "low standard", "low cost" and "marginal", because these terms may give the impression that the proposed technical solution is not fit for purpose.

1.5.3 Current policy for roads

The Agenda for Transformation (AfT) is the Government of Liberia's five-year development strategy. It follows the three–year (2008-2011) Lift Liberia Poverty Reduction Strategy (PRS), which transitioned Liberia from post-conflict emergency reconstruction to economic recovery. The AfT is the first step toward achieving the goals set out in Liberia Rising 2030, Liberia's long-term vision of socio-economic transformation and development. One of the goals for Liberia Rising 2030 is to "ensure that Liberians nationwide have increased safe, reliable, accessible, affordable and efficient transport services". The strategic objectives include improving road connections between all regions of Liberia, opening more secondary and feeder roads, and keeping roads usable year round. Operational efficiency is to be improved through improved planning and procurement, strengthening the private road construction and maintenance sector and use of labor-intensive technologies that help reduce unemployment. Transport stakeholders and communities are expected to participate in road construction planning and monitoring to enhance accountability. Competitive private road construction and maintenance will be encouraged to reduce costs, and rural road development will be coordinated with agricultural development plans so that increased farm production can reach the markets. The sector strategy will also explore alternative technology for rural road development, such as concrete block construction.

Under the Agenda for Transformation the Ministry of Public Works will continue to lead on the roads and bridges. International development partners are expected to fund much of the required investment in roads and some of the maintenance, while the government budget and the Road Fund will cover an increasing share of maintenance costs.

Government policy, as described in the Agenda for Transformation, and national legislation dictate the underlying principles of LVR design. This includes, for example, environmental controls, road safety legislation, promotion of the use of labor-based technologies to encourage local participation and the development of domestic Small and Medium Enterprises. Authorities may choose to put emphasis on Complementary Interventions, as described in Chapter 3.

The Ministry of Transport was created by an Act of the National Legislature in 1987 to formulate and administer the transport, insurance and maritime regulations and policies of Liberia. These include the oversight responsibility for execution of policies relating to land, sea and air transport services operating within the country. (Source: MOT website).

1.5.4 Legal framework

The legislation governing the provision of roads in Liberia is summarized in Table A.1.3. Some key legislation enacted and under preparation as part of the institutional reform process in the roads sector.

Table A.1.3: Relevant legislation

Name of Legislation
Vehicle and Traffic Act (1972)
Ministry of Transport Act (1987)
Heavy Duty Vehicle Axle Load Regulations (2016)
Road Fund Act (2016)
Ministry of Transport Act (pending - new legislation)
Road Act (pending – new legislation)
Road Authority Act (pending – new legislation)

1.5.5 Institutional arrangements for roads

The institutional arrangements required for the sustainable management of roads include:

- the existence of appropriate asset management strategies supported by senior management of the road authority;
- an appropriate organizational structure with sufficient staff trained in the necessary core competencies for road management;
- ongoing training programs to address required asset management competencies
- performance indicators that can be used to measure the quality of the service the road agency provides.

1.5.6 Financial sustainability

The sustainable provision of low volume rural roads can be enhanced by ensuring that:

- roads are not upgraded to engineered standards unless both the funding and the institutional capacity are in place for routine and periodic maintenance requirements;
- designs are adopted that do not require excessive allocation of maintenance resources;
- annual valuation is carried out of road infrastructure assets;
- an effective costing framework is in place for determining unit costs of works;
- annual prioritized maintenance plans are prepared based on actual road condition data; and
- robust management systems are in place to account for the use of maintenance funds.

1.5.7 Technology choice

Good design of roads should be associated with good construction and maintenance. Therefore, workmanship and maintenance culture are important factors in achieving sustainable provision of LVRs. The technologies for the design, construction and maintenance of LVRs should:

- apply appropriate design standards and specifications that optimize the use of locally occurring materials and other resources;
- utilize intermediate equipment technology options and reduce reliance on heavy equipment imports;
- create employment opportunities;
- use types of contract that support the sustained development of viable domestic contractors and consultants; and
- ensure the economic viability of rural road investments.

The design of LVRs should seek to minimize negative impacts on communities and the environment by:

- careful design of drainage systems to avoid channeling of water which might result in excessive erosion;
- rehabilitation of material borrow-areas after construction;
- taking account of potential socio-cultural impacts on community cohesion; and
- optimizing resource management and promoting the recycling of non-renewable materials.

Road designs should be robust to the uncertainties and variability of climate and recognize the potential impacts of climate change.

Economic viability of LVRs

LVRs have direct social benefits and their economic viability does not only depend on the volume of vehicle traffic using the road. Economic appraisal for LVRs should therefore:

- employ economic appraisal tools that can quantify social, economic and environmental costs and benefits; and
- ensure that investment decisions for LVRs are based on an assessment of whole life costs.

In the case of very low volume roads where basic access is already provided, the next level of investment may only be justified by considering improved access as a public good, rather than on strict economic grounds. It thus becomes a matter of public policy whether the investment is made. Alternative investment options should be ranked using a Multi-Criteria Analysis, rather than in seeking to determine the economic viability of specific investments.

1.5.8 Management

Road agencies need to develop an appropriate asset management system that contains:

- Network definition (road and bridge inventory information);
- Network condition (roads and bridges);
- Network usage (traffic);
- Financial/cost information on works activities; and
- Storage, update, analysis and reporting of data collected.

For rural roads agencies this type of management system can be based on simple spreadsheets. The system must allow for the preparation of prioritized annual maintenance and investment plans based on level of service standards agreed with sector stakeholders.

1.5.9 Operations

Sustainable road preservation relies on efficient operations including planning and scheduling of maintenance works, procurement of service providers and compliance with technical standards. The road agency should implement forms of contract that are appropriate to the type of works with a clearly presented scope of works and specifications. Regular technical audits should be carried out on both road improvement and maintenance works. Strategic but non-core activities should be outsourced on a competitive basis to private companies.

1.5.10 Road Asset Management performance assessment

Road agencies should conduct regular assessments of their performance in road asset management. This can be done using the questionnaire developed under the ReCAP research project for "Economic Growth through Effective Road Asset Management" (GEM). The questionnaire assesses performance under each of the six building blocks of the Road Preservation Pyramid. The marking of the questionnaire results in the calculation of a single value that represents the performance of the road agency and its "maturity" in road asset management. This score is known as the Road Sector Sustainability Index (RSSI). The RSSI can be used to compare the performance of roads agencies within the same country or internationally. The questionnaire also allows roads agencies to identify weak areas in their road asset management which can be subsequently addressed to improve performance.

2. PLANNING

2.1 General approach

The planning phase of an LVR project is the foundation on which the subsequent implementation phases are based. It is an activity that considers a wide range of options with the objective of providing an optimal, sustainable solution, i.e. one which satisfies the multiple needs of stakeholders at minimum life-cycle costs. The planning process should take full account of government policies and strategies in the road transport sub-sector.

In order to make optimal use of scarce resources in the provision of new, or upgrading of existing LVRs, it is necessary to plan the road development activities in a comprehensive and coordinated manner. Such planning should be undertaken in a context sensitive manner in which all dimensions of sustainability are addressed. This places more weight on multi-disciplinary planning in which teams of planners, engineers, environmentalists, etc., work together with stakeholders in order to reach optimal solutions in the most cost-effective manner. Such an approach provides the best chance of achieving long-term sustainability of projects.

2.2 Stages in the planning process

The various stages/activities typically followed in the planning process are presented in Table A.2.1. In principle, the process comprises structured activities which start from the general and work towards the particular in relation to both data and project ideas.

Table A.2.1: Stages and activities in the planning process

Project Stage	Activity	Typical Tools	Output
Identification	Selection	Policy resource analysis Master Plans Local/regional plans	Long list of projects
Feasibility	Screening	Livelihoods analysis Integrated Rural Accessibility Planning	Shorter list of projects
	Appraisal	Cost-benefit analysis ▪ consumer surplus approach (e.g. Roads Economic Decision model - RED) ▪ producer surplus approach ▪ compound ranking ▪ Multi-Criteria Analysis (MCA)	Short list of projects
	Prioritisation	Budget considerations, ranking by economic or socio-economic criteria.	Final list of projects

The main features of the planning and appraisal processes for new road projects are as follows:

Selection: This is a multi-sectoral and multi-disciplinary process which should generate enough projects to ensure that no potentially worthwhile ones are excluded from consideration. The output is a long list of projects determined on the basis of an unconstrained policy resource analysis that satisfy national road transport policy.

Screening: Defines the constraints within which specific planning solutions must be found, i.e. a constrained policy resource analysis. The output is a shorter list of projects that justify further, more detailed, analysis.

Evaluation: Evaluates the shorter list of projects in more detail by subjecting them to a detailed cost-benefit appraisal for which various methods are available. The output is a final list of projects which satisfy a range of criteria - political, social, economic, environmental - at least cost.

Prioritization: Ranks the "best" projects in order of merit up to a cut-off point dictated by the budget available.

For existing roads which need to be rehabilitated or upgraded, it is not necessary to undertake the identification and feasibility phases but, rather, to concentrate on the design and commitment and negotiation phases that lead to implementation of the project.

2.3 Planning for Low Volume Roads

The procedures described in the planning and appraisal framework shown in Figure A.1.1 are common to any type of road project. However, there are aspects of it that are of particular significance in the planning and appraisal of LVRs that often do not emerge from conventional approaches. These are summarized in Table A.2.2.

Table A.2.2: Project cycle and related planning activities

Stage	Issues to be considered
Project Identification ▪ Project objectives	▪ Are the strategies being adopted supportive of government policy? (e.g. employment creation) ▪ Are they relevant to the current and future needs of beneficiaries? ▪ Are they cognizant of the multiple objectives and views of stakeholders? ▪ Have effective communication channels with stakeholders been created? ▪ Are they gender sensitive?
Feasibility ▪ Design criteria ▪ Cost-benefit analysis ▪ Socio-economic assessment ▪ Road safety assessment ▪ Environmental assessment ▪ Livelihoods	▪ Is there adequate participatory planning and consultation with public and private sector stakeholders? ▪ Do the design criteria take full account of the specificities of LVRs, including non-motorized traffic? ▪ Are appropriate evaluation tools being used? ▪ Has a base line environmental survey been undertaken? ▪ Has a road safety audit been incorporated in the project? ▪ Are there any geotechnical (ground-related) problems that might influence decision-making?
Design ▪ Design standards ▪ Pavement/surfacing design ▪ Earthworks and geotechnics	▪ Are the geometric, pavement design and surfacing standards technically appropriate? ▪ Are they environmentally sound? ▪ Are specifications and test methods appropriate to the local materials being used? ▪ Are there any ground-related problems that need to be considered, such as compressible or expansive soils and slope instability?
Commitment & negotiation ▪ Contract documentation	▪ Do designs accommodate construction by labor-based methods where appropriate? ▪ Do they include environmental protection measures? ▪ Have tender documents been prepared and contract strategies adopted that facilitate the involvement of small contractors working in potentially remote locations?
Implementation ▪ Construction ▪ Inspection and monitoring ▪ Environmental mitigation	▪ Have labor-based rather than equipment based methods of construction been adopted where feasible? ▪ Are environmental mitigation measures contained in the contracts? Are they enforceable? ▪ Have specific measures been included in the contract to cater for health and safety matters such as HIV/AIDS? ▪ Has the construction schedule considered the weather conditions with respect to the different activities, e.g. earthworks, unbound pavement materials, cement concrete and bituminous works with respect to dry and rainy seasons?
Operations & maintenance ▪ Performance evaluation ▪ Maintenance operations	▪ Have the various indicators of socio-economic well-being been monitored and evaluated? ▪ Are there adequate arrangements for community participation in road maintenance? ▪ What are the lessons for the future?

2.4 Planning tools

There are several tools that may be used to undertake rural accessibility planning. They include:

- Policy Analysis;
- Regional Development Plans;

- Livelihoods Framework;
- Integrated Planning Techniques;
- Multi-Criteria Analysis; and
- Network-Based Planning.

Policy analysis

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

Regional Development Plans

Regional development plans are used to determine priorities for future investments in infrastructure. These plans are not transport specific but relate to all sectors and help to identify investment requirements and priorities over a defined period. It is at this stage that road projects for rehabilitation and upgrading will first be identified.

During the preparation of a regional development plan it is important that transport planners liaise closely with other sectors. In the rural context, priorities normally include education, health and agriculture. It is also important that extensive consultation is undertaken with local communities and political leaders.

Livelihoods Framework

"Livelihoods Analysis" is a useful approach to adopt in order to identify the ways in which any particular investment intervention will impact, benefit or disadvantage the local community. A rural livelihoods analysis provides a framework for understanding how any proposed changes will affect personal or community livelihoods in the longer term. It focuses directly on how the local community uses and develops its social, human, financial, natural and physical asset structure.

Integrated planning techniques

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

Integrated Rural Accessibility Planning (IRAP) has been developed by the International Labor Organization (ILO) and has been used in several countries of the world, including Malawi and Tanzania. The approach integrates rural households' mobility needs, the siting of essential social and economic services, and the provision of appropriate transport infrastructure. Communities are involved at all stages of the planning procedure. It is based on a thorough but easy to execute data collection system that seeks to rank the difficulty with which communities access various facilities.

In the IRAP approach, an Accessibility Indicator (AI) is calculated for various facilities in each community as follows:

$$AI = N \times (T - Tm) \times F$$

N = number of households

T = average travel time to a facility

Tm = target travel time

F = frequency of travel

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

Multi-Criteria Analysis

Multi-Criteria Analysis provides a means of prioritizing investments in rural roads through the consideration of the current condition of each road link and its economic and social importance. For rural roads such data typically include:

- traffic on the road;
- the population served by the road;
- agricultural output of the area served by the road; and
- existing social facilities such as schools and clinics along the road.

The condition of each road link is assessed, and a score allocated. This is known as a "Condition Index". Roads in poor condition have a high Condition Index. Priority factors are then determined for traffic, population, agriculture and social facilities, with weightings applied to each factor depending on their importance. A "Priority Score" for each road link can be then calculated by multiplying the Condition Index by the traffic, agriculture, social and population priority factors. The equation is as follows:

$$\text{Priority Score} = \text{Condition Index} \times TF \times AF \times SF \times PF$$

TF = Traffic factor

AF = Agriculture production factor

SF = Social facilities factor

PF = Population factor.

The result of this analysis is that roads in poor condition but with high social and economic importance are selected first for maintenance or improvement interventions.

The Priority Score for each road link should be determined on the basis of weights and points allocated to each factor in a participatory and transparent manner. This will ensure that the outcome is accepted by all stakeholders.

In the case of new roads, MCA can be applied to inform the process of route selection. This is described in detail Chapter 3, which includes a case study and worked example.

Network-Based Planning

Investments in LVRs have traditionally been evaluated on a link by link basis with less consideration given to the connectivity or accessibility contributions of links to the entire network. Network-based planning enables contributions from the various links to be considered in such a way that the travel needs of the people or the community in an area are met to the maximum extent possible in a collective way at the lowest development cost.

Network-based planning is particularly useful where a "core road network" needs to be identified in situations where funding is available to maintain only part of the total road network. Such a network often includes roads of different classes that are an essential part of the total network so that links are maintained between all the communities throughout the country. This network can be reviewed periodically and will expand or contract depending on local circumstances.

Models such as HDM-4 can be used for network-based planning purposes. However, the necessary data required is often not available at local level, making such models inappropriate. Thus, procedures that involve a high level of stakeholder consultation and a multi-criteria analysis are likely to be more effective for rural network planning purposes.

Stakeholder consultations

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

- Establishing background information on the project from all possible sources;
- Identifying viable alternatives for the project;
- Taking on board the views of stakeholders at all stages of the project; and
- Reaching a consensus on the preferred choice of project(s).

Decisions on transport planning and prioritization are often taken without considering the transport requirements of the people being affected by the investment. Insufficient consultation can lead to the inappropriate use of resources not only in terms of their usefulness to rural communities but also in terms of their impact on social and cultural traditions. To rectify this shortcoming, it should be ensured that:

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

Types of stakeholders

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

- rural communities;
- farmers groups;
- market traders; and
- transport operators and road users.

It is important to ensure that women's needs are heard and addressed as part of the stakeholder consultations indicated above.

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

- Ministry of Public Works;
- District Councils; and
- Local and national political leaders.

Consultation techniques

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

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

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

3. COMPLEMENTARY INTERVENTIONS

3.1 Context and application

This Chapter describes some concepts and practical issues relating to the planning, design and implementation of potential Complementary Interventions (CIs) on LVR projects.

CIs are:

- actions that can, if desired, be included in and implemented through the roads project or the road works contract;
- targeted toward the communities that lie within the influence corridor of the road and are affected by the road itself, by road users or by the road works; and
- intended to optimize the benefits brought by the road and to enhance the positive impacts. While the contract should already provide for mitigation of any negative impacts of road projects on local communities, CIs could potentially go further.

Such interventions are neither:

- mandatory (they are included at the discretion of the client); nor
- designed to remove or replace the standard responsibilities of the contractor, client or other authorities or institutions.

The concept of CIs is motivated by opportunity. Put simply, they take advantage of the road project to build in aspects that will enhance the social and environmental wellbeing of affected communities. Their relatively small scale means that their inclusion would not normally result in a disruption of the main contracted works program.

The opportunity to take advantage of CIs will only be available during the period of the works when the contractor is on site. Any CI-related activities requiring access to Contractor's physical, human and financial resources that may not normally be readily available in the project area must be planned accordingly.

When a decision is taken to include a CI, this will have a cost consequence. This is normally borne by the client, though other arrangements could potentially be made. The extent to which the client wishes to include CIs within a project would be communicated to the design engineer through his or her terms of reference, or through a site instruction. This can be reflected in the bill of quantities.

CIs are demand driven, reflecting the needs expressed by local communities. Appropriate responses to these needs will already to some extent be reflected in development plans drawn up at the District and National level. Whether or not this is the case, the process of identifying potential opportunities for CIs will, during the feasibility stage, entail close consultation with relevant authorities, as well as with affected communities where appropriate. If CIs are to be included in the works, the relevant administrations must have agreed in principle the extent, type and approach for any inclusion of actions and initiatives (Appendix A.4). In some cases, there may also be a requirement for the beneficiary community to contribute, whether financial or in kind.

With an outline framework agreed at the feasibility stage, the task of the design engineer is to reflect these desires and agreements in the works bidding documents and the eventual contract.

Following an outline description of the concept of CIs, examples are provided of the types of intervention that may be provided, and an explanation given as to how the detailed design and bidding documents should be used to clearly define the requirements for implementation, measurement, and monitoring.

CIs can be grouped into three categories:

Category I) Management Interventions. These are simple actions that enhance the positive impact of the road project itself and are well within the normal skills of the road contractor. They may build on or extend the normal socio-environmental and safety obligations of the contractor.

Category II) Opportunity Interventions. These are actions that are beyond the scope of traditional road projects but are within the technical and management skills of the road works contractor.

Category III) Enhancement Interventions. These are actions that utilize the provisions of the contract but extend beyond the normal skills and experience of a road works contractor. These actions would normally be implemented by other parties with the relevant skills.

Figure A.3.1: Installation of a water pump as a Complementary Intervention

One of the main advantages of including CIs through a contractor already mobilized for a road project is that they can be completed more quickly, more efficiently and at a lower cost than if implemented separately. This can improve the economic rate of return on the road investment while enhancing the prospects for local socio-economic growth, employment and empowerment.

3.2 Planning, identification and implementation of CIs

The identification and development of CIs should consider:

- current national, district and sector policies;
- legal instruments; international conventions and treaties;
- guidelines and procedures relating to public consultation/participation; and
- local development planning and implementation.

3.2.1 Planning

CIs need to be considered early in the project cycle and be an integral part of project planning, from project identification to feasibility study. It is important that the client works closely with key stakeholders, including those who identify the need for the project and local government representatives in the project area. Together they are well placed to develop an outline plan for the inclusion of complementary interventions in the road project/program. This should be to a sufficient level of detail to facilitate their ready further development during the feasibility study and detailed design stages.

The outline plan and budget for CIs, and an assessment of the potential short-term effects and longer-term impacts, should be included in the economic analysis of road projects. This is because, despite entailing additional initial investments, they may result in a net improvement in the economic rate of return of the road investment.

Key issues for consideration during the planning, feasibility and preliminary design stages of a project are described more fully in Appendix A.4.

Figure A.3.2: Community participation in the planning process

When approaching the design of complementary interventions, it is necessary to consider actions that:

- are demand driven;
- are agreed in principle by all of the relevant local and other authorities;
- will have a high level of participation and involvement from the local authorities and communities during implementation; and
- are matched with and complement actions within existing local plans, such as District Development plans.

A high level of consultation with affected communities will also be needed during the detailed design of CIs. The design engineer will work through the client to ensure that the correct local procedures are adopted and that all necessary formalities are followed. Decisions, prioritization methods and approvals for planned initiatives would be introduced by the client and achieved through the client's interaction with the existing and appropriate local level structures. The client may require the design consultant to assist with the identification and prioritization process. Where this occurs the design engineer will need to communicate with local authorities and communities. If identification and prioritization are within the design consultant's mandate these should be carried out under the client's guidance using established participatory processes.

Table A.3.1: Principles of participation

Participation Considerations
In promoting consultations and participation the following should be noted: ■ Beneficiaries should not be viewed as a passive element. They should be active participants. ■ Situations should be avoided that override existing and legitimate decision-making processes and structures. ■ Due care and attention should be given to group decision-making processes that may reinforce existing power structures at the expense or exclusion of vulnerable groups.

Though Liberia has a decentralization policy and structure in place, challenges remain in operationalizing it to enhance true grassroots participation in decision-making, while ensuring associated transparency and accountability.

In developing their own detailed methodology for identification and selection of complementary activities for each LVR project, the design consultant should draw on and relevant participatory methodologies used by the MPW and other sectors. Where the Environmental Protection Agency (EPA) of Liberia requires an Environmental and Social Impact Assessment (ESIA) to be carried out, the associated community consultation can serve as a ready vehicle for identifying potential CIs.

The design engineer should also be familiar with existing local and regional development plans, potential sources of complementary financing or resources that may be allocated to the complementary activities, willingness of local communities to make other contributions, work by local NGOs and CBOs.

The consultant, with guidance from the client and key stakeholders, may be required to help establish and provide support to a 'Complementary Intervention Oversight Committee' at the different levels. These would become the main contact points for the design consultant and may assist in the community consultation and participatory decision-making processes. If the establishment of a separate committee is not required, a main contact point within the existing local administration would need to be nominated or identified through the client.

The participatory process will require a multi-disciplinary design team to ensure appropriate consideration of technical and financial aspects of the proposals identified, to develop appropriate designs and implementation mechanisms that meet the expressed needs of the communities, and to ensure adequate coverage in the construction contracts.

3.2.2 Identification and selection of CIs

In theory, CIs may include almost anything that can be implemented through a road works contract and which contributes to the socio-economic, environmental or safety of communities affected by the road. As summarized above, they are divided into three categories to help clarify the different types of activities and how they relate to the traditional role of the road works contractor or works contract.

Category I - Management interventions

The works contractor will already have clear-cut environmental, safety and employment obligations set out under the provisions of the works contract. These would be captured within the relevant design and implementation management documents. These include the ESIA and Environmental Management Plan (EMP). Management interventions add to and extend the normal obligations of the contractor. These could include interventions such as:

- items relating to improving road and resident access;
- reinstatement/improvement of areas used temporarily during construction; and/or
- provision of facilities and services disrupted by construction activities.

Such activities would be included as Bill of Quantity items (Measured Works) in the contract. In the case of small-scale activities, they could be included within other items. In some circumstances the contractor may elect to undertake the activity as a goodwill gesture.

Category II – Opportunity interventions

Opportunity interventions go beyond the normal scope of a road works contract but are within the technical and management skills of a road works contractor. Opportunity interventions would typically include:

- support for provision or repair of community infrastructure, such as a clearance of a market area; and
- provision of materials, labor or supplies for small community works, such as the rehabilitation or repair of community facilities (community buildings, hand pumps, irrigation infrastructure and the like);

Provision by the contractor of technical training to local government administrations and staff is also possible. The scope of such training could include:

- vehicle maintenance, financial management, road construction and maintenance; and
- building and/or sanitation management.

Similar technical support could also be provided to local enterprises and cooperatives. Such activities would be included as Bill of Quantity Items (Measured Works) in the contract or could be established through a separate or parallel agreement between the contractor and the Local Government Administrations or with the community.

Category III – Enhancement interventions

Enhancement interventions extend beyond the skills and experience of a normal road contractor and would require specific arrangements through the contract with other skilled parties. Such parties may include local government offices, NGOs, private sector organizations, community-based organizations and cooperative societies that are better placed and skilled to implement the proposed interventions. The role of the contractor would be to manage the activity through the contract and provide physical support or, if necessary or appropriate, provide financing to the organization implementing the activity. This would be included within the scope of monthly reporting, and associated payments sought through monthly Interim Payment Certificates. Verification of activities would be undertaken by the supervising consultant or client. Examples of Category III activities include:

- awareness raising and education campaigns;
- establishment of new or improved livelihoods options;
- building of facilities;
- life skills training; and
- provision of supplies and training to local service providers.

Such activities would be included as provisional sums in the contract.

CIs can cover a range of themes; for example, road safety, road corridor environment, road transport services, and community development. Appendix A.5 provides further details of complementary interventions, set out by category and theme.

3.3 Contract provisions to support Complementary Interventions

The successful implementation of CIs requires clearly defined requirements and adequate provisions to be included in contract documents and at all stages of the project. The following sections describe how the different contracts (for project design and supervision services and works) may be used to address CIs.

3.3.1 Design services contract

During project planning, the client will need to determine the approximate budget and scope of the project, including the budget and scope for CIs. This then needs to be reflected in the Request for Proposals (RFP), in particular the Terms of Reference, for consulting services for the detailed design. The RFP should specifically include appropriate inputs of key personnel with the requisite skills to meet the requirements of the client with regards CIs.

The client may require the consultant to undertake some participatory process to assist with the development of the CI package. With regards to Category III interventions, it would generally be more efficient and appropriate for the client to undertake the identification and preliminary selection using the existing government structures and plans.

The development of Category I and II intervention packages are relatively straightforward as they fall within the skill area of a multi-disciplinary design team. However, the RFP still needs to be well developed and thought out (see Table A.3.2). The feasibility study will have developed the preliminary options and budget/cost estimates for the CIs. The detailed design will require preparation of the finalized list of CIs, detailed designs and engineer's cost estimates.

Table A.3.2: References to CIs in the Request for Proposals

The RFP should include:
▪ Clearly defined and appropriate inputs for key personnel to be involved in developing CIs; ▪ Reference to this Chapter or alternative guidance on identifying, selecting and designing CIs; ▪ A requirement to organize a mobilization workshop that draws all stakeholders together on site; ▪ A requirement to review participatory decision-making practices and develop a project specific methodology that best reflects local decision-making structures (formal and informal); ▪ Clearly defined duties and responsibilities of the parties to the contract and any external organizations with respect to development of the CIs; ▪ A requirement to review national, regional and local development plans in the development of CIs; ▪ A requirement to include CIs in any further economic analysis; ▪ A requirement to consult with local government and community representatives to enable them to participate effectively in the decision-making process when developing CIs; ▪ A requirement to clearly define and specify requirements for CIs in the preparation of bidding documents.
The RFP may require the consultant to provide guidance on:
▪ How to decide which potential CIs will result in the most effective or efficient use of resources and how this can be measured; ▪ How to ensure that the contractor does not become overburdened by CIs, that the proposed interventions are suitable to the scope of works, and that the necessary skills and experience are brought to bear by the contractor.

The client may require the consultant to undertake some participatory process to assist with the development of the CI package. With regards to Category III interventions, it would generally be more efficient and appropriate for the client to undertake the identification and preliminary selection using the existing government structures and plans.

3.3.2 Works Contract

For the purposes of including Complementary Interventions within works bidding documents, the key documents requiring attention are:

Instructions to Bidders (ITB) and the Bid Data Sheet (BDS): For an LVR project the client should include an additional item that will draw the attention of the bidder to any requirements for CIs.

Standard Technical Specifications: These are defined on a project by project basis in Liberia and may include reference to some activities that could potentially constitute CIs. Other CIs should be included in the Particular Specification.

Particular Specifications: This is where any detailed technical requirements and specifications, and implementation mechanisms specific to the designed set of CIs should be clearly defined for the project.

Bills of Quantities or Schedules of Rates: This should be linked by item number to the Standard Specifications and to the Particular Specifications; and is where the schedule of activities and estimated quantities for the CIs are set out for the bidder to price.

Drawings: Some standard detailed drawings, such as for the provision of side access, may be applied directly. Supplementary drawings, linked with the Particular Specifications, may also be required where new or special complementary approaches are included. Where trail bridges are included within the contract as a CI, a separate volume of associated drawings will be required. For Category III interventions reference should also be made to any standard drawings used by line ministries for infrastructure under their control.

Conditions of Contract: This includes standard provisions for execution of the contract and unless amended in the Conditions of Particular Application, these will apply. In some cases, modification of some clauses may be required to reflect the desired approach and will need due consideration. For example, where there is a targeted procurement policy to support small and medium enterprises and small-scale contractors then due consideration should be given to the clauses referring to Performance Security, Performance Program, Insurances, Cash Flow, Plant, Equipment & Workmanship, Payments, Retention and Advances, Price Adjustment and currency restrictions.

Conditions of Particular Application: This is where any Provisions in the General Conditions of Contract may be amended, as required, to make them more appropriate. This may apply to some of the CIs envisaged. Where assets are involved, the document should be clear on the responsibilities for asset transfer. Due consideration should also be given to strengthening clauses aimed at promoting sub-contracting/assignment; local employment and conditions (particularly for women); rights and insurances; and for strengthening CIs.

Important documents which are not part of the Works Contract are User Guides. These are guidelines to the design Consultant or the client organization on the preparation of the Works Bidding documents and include reference to provision of CIs.

The main issues for a contractor are to fully understand the scope of the works, including the CIs, and to be clear about associated mechanisms for measurement and payment. The primary interest for the client is to achieve the objectives of the intervention, to achieve value for money, and for these interventions not to require a disproportionate amount of supervision or monitoring.

Table A.3.3: Works Bidding Documents and Contract Documents

Document	General notes for guidance
Instructions to Bidders (ITB) and the Bid Data Sheet (BDS)	The ITB is generally a standard document which may vary depending on the procedures of different clients. For an LVR project, the client should include an additional item that will draw the attention of the bidder to the LVR design approach. The BDS is linked to the ITB and provides specific project information.
Standard Specifications	These will define the scope of the technical requirements of the contract, including the type and quality of materials and equipment, the standards of workmanship. The General Specifications for Road and Bridge Works includes the works to be undertaken, general obligations information on the format of Bill Items for the Bill of Quantities, on item coverage and the method of payment.
Particular Specifications	This is where any detailed technical requirements and specifications, and implementation mechanisms specific for the project, should be clearly defined. Particular technical specifications add further detail to complement or replace those stated in the Standard Technical Specifications. The particular technical specification should also include any specifications and limitations on the freedom of choice for the contracting company related to the execution of works.

Document	General notes for guidance
Bill of Quantities	This should be linked by item number to the Standard Technical Specifications and to the Particular Specifications; and is where the schedule of activities and estimated quantities are set out for the bidder to price.
Drawings	Some standard detailed drawings may be applied directly for LVR works (e.g. cross-sections, standard culvert design and road signs). Supplementary drawings, linked with the Particular Specifications, may also be required where new, innovative or special approaches are included.
Conditions of Contract	This includes standard clauses or provisions for contracting requirements, obligations and legal commitments which, unless amended in the Conditions of Particular Application, will apply for the project. In some cases, modification of some clauses will need due consideration and modification may be required to reflect the desired approach for the LVR works (see below).
Conditions of Particular Application	This is where any Provisions in the General Conditions of Contract may be amended as required, to make them more appropriate to non-standard project requirements, including complementary interventions.
User Guides	These documents will provide detailed guidelines to the design consultant on the preparation of the works bidding documents.

3.3.3 Options for inclusion of CIs in works contracts – measurement and payment

Many CIs involve provision of work items, activities or services beyond the usual core activities associated with a traditional road works contract.

Bill of Quantity items (measured works)

Where the scope and detailed design of a CI is well defined and within the scope of activities normally expected of a road contractor (i.e. Category I and II interventions), the preferred option would be to include these activities as items within the Bill of Quantities for the contractor to price. This approach would apply to any extension. An example of typical entries is provided in Table A.3.4.

Table A.3.4: Example Bill of Quantities entries

No	Item Description	Unit	Quantity	Rate	Amount
1*	Clear and prepare hard standing for market, in accordance with Specification Ref: (……….) and Drawing: (……….)	m^2	500		
2*	Rehabilitate school block in accordance with Specification Ref: (……….) and Drawing: (……….)	Item	1		

** Item No. relates to item in Standard Specifications or Particular Specification. Shaded area for bidder to price.*

Provisional Sums

In cases where the intervention is not fully developed and agreed then it is probably better to describe the activity briefly and to include a 'Provisional Sum' item in the Bill of Quantities. Such cases could include the enhancement of a borrow pit to a small dam or fishpond, or provision of training that falls outside the scope of activity normally expected of the contractor in some category II and III interventions.

What information is known could be included in the Particular Specifications or Drawings, with a requirement for the Contractor and/or Supervision Consultant to further develop and define the intervention later. Generally, the Provisional Sum Item is only one or two lines included in the Bill of Quantities. A 'cost estimate' is inserted by the Client to cover the cost of these items.

The provisional sum is an estimated cost for the intervention based on the information available at the time of bidding document preparation. The actual cost of the intervention may change, with the final design and price for the intervention being agreed between the parties to the contract once all the necessary information is known.

Provisional Sums are flexible and are used ‘at the discretion’ of the Engineer.

When using provisional sums, provision must be made for the administration and management of these funds by the contractor, in the form of a % fee or adjustment to the provisional sum item.

An example of Provisional Sum entries in the Bill of Quantities is shown in Table A.3.5.

Table A.3.5: Example of Provisional Sum entries

No	Item Description	Unit	Quantity	Rate	Amount
1*	Provision of road maintenance training to District staff	PS			125,000
	Allow percentage for administrative fee on provisional sum, item (....)	%	1		
2*	Provision of construction supplies to District Administration	PS			75,000
	Allow percentage for administrative fee on provisional sum, item (....)	%	1		

** Item No. relates to item in Standard Specifications or Particular Specification.*

Output related items

Output related approaches are most applicable for procurement of supplies or services. Measurement and payment will normally include stages and be linked with outputs or ‘deliverables’ (e.g. an activity report following a training program). If the Terms of Reference are complete for such an intervention then bill items can be included for the contractor to price, as in the example in Table A.3.6. If such information is not available to the contractor, then the intervention should be included as a Provisional Sum item and an estimated cost included in the Bill of Quantities by the client.

Table A.3.6: Lump Sum item for completed output related to PS

No	Item Description	Unit	Quantity	Rate	Amount
1*	Provide training materials and deliver training on community and schools road safety education in accordance with Terms of Reference	Lump Sum	1		

**Item No. relates to item in Standard Technical Specifications or Particular Specification. Shaded area for bidder to price*

Any items for supplies or services that are outsourced to appropriate implementation partners will require a detailed Terms of Reference to be developed and included in the sub-contract agreement. Such sub-contractors may be nominated by the client or selected by the contractor as a ‘domestic’ sub-contractor, subject to client approval. These ToR will need to clearly define the scope of work, identify the beneficiaries to be reached and set out the detailed specifications if the sub-contract is for supplies. For a service sub-contract, the projected person.month inputs and minimum staff requirements may be included. The ToR should also include a payment schedule based either on inputs or, where possible, linked to deliverable.

Schedule of rates

This is a form of pricing mechanism that is used where the activities or procurement items are known, but the quantities are not (See Table A.3.7). The schedule lists the items to be provided giving the unit of measure but not the quantities, or if quantities are included it is made clear that such quantities are nominal. The bidder will then submit a rate (rate only) against each item in the schedule.

Table A.3.7: Example of schedule of rates where quantities are unknown

No	Item Description	Unit	Quantity	Rate	Amount
1*	Provide animal drawn carts in accordance with Specification Ref: (……….) and Drawing: (……….)	No	1		Rate Only

**Item No. relates to item in Standard Technical Specifications or Particular Specification. Shaded area for bidder to price*

If standard unit rates are known, then they can be inserted by the design engineer (See Table A.3.8) and will then normally form the basis of a nominated sub- contract. This could be used, for example, for the provision of school furniture from a nominated supplier, or a national procurement office, whose rates have already been agreed with the Ministry of Education. If such fixed rates are to be used, they will generally include for contractor overheads and profit.

Table A.3.8: Example of schedule of rates where quantities are known

No	Item Description	Unit	Quantity (Nominal)	Rate	Amount
1*	Provide school desks in accordance with Specification Ref: (……….) and Drawing: (……….)	No	50	100	5000.00

**Item No. relates to item in Standard Technical Specifications or Particular Specification*

Dayworks

The dayworks schedule is intended for the pricing and payment for small scale 'incidental works' and should not be relied on as a mechanism for the measurement and payment of CIs.

3.3.4 The Works Contract evaluation

Although the CIs component of a road project may be a relatively small part of the construction budget, it must be included within the evaluation of the bid process. The aim should be to ensure that the contractor understands the CI requirements and has consulted with the relevant partners to provide considered and accurate price estimates.

3.4 Supervision Consultant's Contract

The Request for Proposals (RFP), in particular the Terms of Reference, for consultancy services for construction supervision need to reflect the role of the Engineer in supervising the works and administering payments for the CIs.

As with the main engineering design, the supervision consultant will be required to review the agreed list and detailed designs of the CI, and to consult with the necessary stakeholders to ensure that priorities remain unchanged and that the interventions are still appropriate to the needs of the beneficiary communities.

The RFP also needs to take into account the need to further develop and negotiate detailed agreements for some of the interventions as the construction works progress, such as in the case of interventions relating to the reinstatement of temporary works areas. The Employer may also need to be involved in monitoring grievances and dispute resolution, should the need arise. In such cases, the Engineer shall provide the required assistance.

The supervision and monitoring of CIs may require specialist skills beyond those available within the normal engineering supervision team. The RFP should reflect this, and should include:

- clearly defined and appropriate roles for key personnel to be involved in monitoring and supervising CIs;
- reference to this Chapter of the low volume design manual or alternative guidance on designing and monitoring CIs;

- clearly defined duties and responsibilities of the parties to the contract and any external organizations with respect to development and implementation of the CIs;
- a requirement to consult with and provide appropriate training to implementation partners to assist them in fulfilling any obligations as defined in agreements / sub-contracts for CIs; and
- a requirement to include CIs in their progress meeting agendas and progress reports.

3.5 Targeted Procurement

3.5.1 Targeted procurement as a quasi-complementary intervention

Because the commercial considerations of a contractor are not necessarily well-aligned with the results of higher level socio-economic appraisal, or with other policy imperatives of government, the client may decide to adopt a "targeted procurement" approach. This is a process used to create a demand for the services or goods, or to secure the participation, of targeted enterprises and targeted labor in contracts in response to the objectives of a secondary procurement policy. Examples of targeted procurement could potentially entail the client stipulating requirements, targets, or rewards for:

- the employment of local labor; and/or
- the employment of women, and others from disadvantaged groups; and/or
- the engagement of small contractors.

The issue of employment and skills-development opportunities arising directly from the main works contract is not strictly speaking a complementary intervention as such, because it in inherent in, rather than being additional to, the main contract. However, it is included in this Chapter of the LVR Manual on account of its resonance with features of CIs in terms of its potential short-term effect, and longer-term impact, on the socio-economic outcomes of a road contact, whether for new construction, rehabilitation, or maintenance.

3.5.2 Choice of technology

Road works potentially provide an opportunity for temporary employment of local labor in the case of rehabilitation or new construction, and longer-term employment in the case of maintenance. The choice of technology, and of the associated management system adopted, is determined in part by the availability and cost of resources, in part by the capacity and outlook of contractors, and in part by applicable procurement policies. It is important in this regard to be clear about the difference between:

"Labor-intensive" practices that, by using labor rather than machines wherever possible, seek to maximize employment opportunities;

"Labor-based" practices that, by using labor when it is more cost-effective than machines, seek to optimize both value for money and socio-economic outcomes; and

"Community-managed" practices that tend to be labor-intensive, focused on meeting expressed needs at the community level, and implemented through community contracts.

Through feasibility studies, governments evaluate the optimum labor content of a works contract in economic rather than financial terms. Particularly in remote rural areas with high unemployment, this tends to favor the adoption of labor-based technology for many activities. By contrast, contractors typically evaluate the options in terms of financial costs and management requirements. Because labor-based operations are necessarily relatively management-intensive, this means, for instance, that most contractors would rather deploy one grader than 120 laborers, even though the latter option could potentially result in better outcomes in terms of technical quality, value for money, skills development and socio-economic impact. Hence the decision by some clients to adopt a targeted procurement approach to encourage labor-based technology where there is a proven socio-economic case for doing so.

Such requirements or incentives would typically be reflected in both the procurement guidelines and the works contracts. Potential contractual mechanisms could include, for example, minimum targets for the percentage of laborers on specific activities employed from local communities. Payment for the relevant activities could reflect the extent to which the employment targets have been met. This should also be a topic for review at monthly site meetings.

More simply, an overall target could be set in terms of person-days worked either as a total or percentage of the total by local people. Again, payments could then reflect the extent to which the target has been met.

When developing such clauses, or enhancing existing clauses, the following issues should be given due consideration:

- Boundaries for defining local labor – e.g. living within a designated number of kilometers from the project road; or living within certain administrative areas;
- Availability of skilled and semi-skilled labor within the project area, and within sections of the road project, taking account of seasonal variations;
- General health and physical condition of the locally available labor (especially in areas where there is significant out-migration for work, drought, food insecurity or endemic health issues);
- Social, religious or traditional barriers that may prevent some social groups from accessing labor opportunities and how these might be overcome;
- Incentives or penalties to be used to encourage the contractor to meet local employment targets; and
- Measurement, monitoring and recording mechanisms to accurately report on local employment.

The client will guide the design engineer on any special emphasis with regards the approach to be adopted. When a targeted procurement approach has been decided upon, the design consultant will need to carry out a labor survey during the detailed design stage to develop appropriate local employment contract clauses and targets that are realistically capable of being achieved along the project corridor.

Figure A.3.3: Labor-based technology on an LVR

Beyond the immediate works contract, the principles of CIs can be used to enhance access to employment opportunities for the wider community, particularly in cases where unemployment or under-employment are local issues. Such activities could include:

- crushing and screening rock for aggregate or hand screening gravels;
- making gabion baskets;
- seedling and sapling planting and subsequent maintenance; and
- cooking, cleaning, and managing work sites and camps.

3.5.3 Encouraging participation of marginalized groups

Every society has groups that are, for whatever reason, disadvantaged or excluded from participation in employment. Often these groups can benefit most from temporary employment in road works projects.

Typically excluded groups include:

- women in general and especially mothers with young children;
- the physically or mentally disadvantaged;

- ethnic or religious minorities; and
- those infected or affected by HIV/AIDS.

It must be recognized that the labor required on the road site usually requires physically hard work and construction sites can be relatively dangerous places. It is not, therefore, appropriate to require contractors to employ physically or mentally disadvantaged people, though there are some jobs, for example at the works camp, that could be appropriate

It should be possible for the design engineer to develop an understanding of the barriers to participation in employment by women and minority groups and find ways to help them access employment, without causing conflict or concern amongst the wider community. In many areas the barriers to women's participation in road works are caused by their own need to collect water, firewood, animal fodder and look after the home and children.

Figure A.3.4: Participation of women in road works on LVRs

Measures that can be easily introduced to help women overcome barriers to participation in road works include:

- Allowing women to form work groups and share the workload between them. This provides for flexible working hours for individual women and protection in numbers. This also allows them to share childcare responsibilities through a rotating crèche or similar;
- Ensuring women work in areas where they feel safe and secure. Due consideration should be given to issues of isolation (e.g. distance from other work groups), appropriate areas or facilities for nature calls and distance from home/crèche; and
- Removal of time constraints preventing women from accessing employment opportunities. This can be done by, for example, providing firewood or alternative fuel or potable water through the contract. This would require the contractor to bring fuel or potable water to site for distribution. In some cases, this could also be used as part of payment for work done (by men as well as women). Importantly, it should only be part payment.

3.5.4 Labor standards

There are already existing legal and national policy requirements relating to employment of temporary workers defined in the National Employment Policy Strategy and implementation Plan. Under the works contract, these requirements are inherent in the over-riding requirement for parties to comply with all applicable laws. Nevertheless, in the interests of clarity and accountability, and compliance with international labor standards, some of which have been ratified by Liberia, it is considered good practice to explicitly include key provisions within works contracts.

Table A.3.9: Contract clauses reflecting labor standards

In general, contract clauses should include provisions that ensure:
■ Minimum wage rates per unit of time or unit of work are adhered to; ■ Equal pay for equal work; ■ Equal access to employment opportunities (considering local traditions, with respect to male / female jobs, for example); ■ Effective monitoring and recording of work done and wages paid (transparency); ■ Health and safety of employees and affected communities (due attention to sanitation, waste disposal, disease control and prevention, first aid and emergency health care, accident management and reporting); ■ Safe and appropriate temporary accommodation and recreational facilities; ■ Effective grievance procedures for temporary employees; ■ Limitations on use of child labor (according to local laws, regulations and customary practices); ■ Use of ILO guidelines and regulation if it is an internationally funded contract.

3.5.5 Supporting small scale contractors

Targeted procurement often seeks to promote the development of local small scale and emergent contractors and enterprises, as part of a strategy to stimulate entrepreneurship, skills development, and local employment. This can be achieved in two ways:

Utilizing bidding documents aimed at SMEs

Smaller scale works contracts are more forgiving to the emergent contractor and protect the client from high levels of financial risk.

When contracting work to small scale contractors, small enterprises or community-based organizations that are not so used to undertaking road related works, the following issues need to be considered and a position agreed with the client:

- Emergent contractors may lack contract experience. The client and supervisor will need to be forgiving in some instances where full compliance with normal contract provisions could have a negative impact on bidding, the performance of the contract or the existence of the contractor.
- Ensuring the requirements of the contract, allocation of responsibilities, technical and performance standards, payment terms and conditions are clearly understood by the tenderer/contractor. The project could include elements of contract management and supervision support, technical assistance and/or management training.
- Cash flow: It is unlikely that small sub-contractors will have enough cash or resources to start the activity without some form of advance payment (in cash or in kind) and it is likely that they would need more frequent payments, possibly every two weeks rather than monthly.
- Advances: The advance amount, repayment conditions, and regular payments need to be defined in a payment schedule in the agreement. Advance guarantees used on larger contracts may not be appropriate or even possible for small scale works.
- Performance guarantees and bonds: It is mandatory to include performance guarantees for the works. Where small scale enterprises are sub-contracted, the main contractor guarantees will cater for the SME. Where SME are contracted directly, the provisions set out in the respective model tender/contract documents should be responsive to the size of the contract/contractor and to local constraints.
- Performance Program: The period of the works should also take account of the likely size of the contractor, the choice of technology, and the resources that can realistically be deployed and effectively managed.

Utilizing sub-contracting clauses

By requiring the main contractor to engage the services of small scale enterprises, risk is carried by the main contractor who has qualified and met the minimum criteria set by the client. The client may set a minimum percentage or type of works that should be sub-contracted to small scale enterprises.

In doing so the client needs to recognize the risk that is carried by the contractor and to ensure that the performance program and payment clauses recognize that the works contract has a capacity building component.

3.6 Management, monitoring and enforcement

In general, the CI aspects of the contract should be managed monitored and enforced using the normal provisions of the contract documents.

CIs should be included in the contractor's detailed work plan and the payment schedule. Progress and performance should be reported through the monthly site meetings and progress reports. It may be appropriate to prepare specific reports for local communities and their leaders on the progress of CIs in their area. The frequency of such reports would depend on the nature and scale of CIs being implemented in that area, which should be determined during the detailed design stage and uses provisions made in the reporting sections of the works and supervision contracts.

While it is the Contractor's responsibility to manage and implement the CIs according to the contract, it is the Engineer's responsibility to ensure CIs are monitored regularly and to verify that technical and performance standards are being consistently met by the contractor.

Monitoring and enforcement should be closely linked to the Contractor's payments. It is essential that measurement and payment for CIs and any incentives or penalties are clearly defined in the works contract.

Payment for sections of the road should only be fully paid once all aspects of the contract have been completed in that section. This includes completion of environmental mitigation measures and the CIs, to the required standards. This should be reflected in the payment schedule. When processing payment requests for CIs it can be helpful to make use of forms that make provision for retaining a certain amount from the contractor's payment to ensure that enough funds are available to the client to complete the mitigation measures/CIs should the contractor fail to do so.

Where the CIs involve small scale contractors or community groups, it may be appropriate to include an element of community-based monitoring. In such cases a mechanism should be established by which the affected communities are clearly informed about what is to be done and by whom, and to monitor implementation by all parties to the CI agreements. This can be done through formal monitoring groups, or by putting up information on a notice board that allows all members of the community to see what should be happening.

It is important to be clear that the role of community monitoring should never be to make technical judgements, but rather to ask questions related to any apparent discrepancies between what has been agreed, and what they observe. It may be necessary in this regard for basic training to be provided, and simple protocols established for community monitoring and subsequent reporting back to the supervision consultant's team.

4. PRINCIPLES OF ROUTE SELECTION

4.1 Introduction

The 2012 National Transport Master Plan focuses attention on the need to improve Liberia's road transport infrastructure as a pre-condition for economic growth. The same conclusion was reached by the African Development Bank and the USAID Millennium Challenge Commission, both of which cited poor road access as a limiting factor in the country's development. The 2014-2015 Ebola crisis illustrated how important reliable rural access is to the effective provision of health care. Although much of this concern focuses on the existing road network, there is a need to expand rural access through the construction of new road links into the rural interior of the country. The problems associated with the management and maintenance of the existing road network in a country with extreme rainfall, sometimes difficult terrain and poor subgrade soils, are only too clear, and it is important that new routes are selected in such a way that all relevant factors are given sufficient consideration.

Route selection for new roads 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 alignment within the corridor.

4.2 Route corridor identification

A route corridor is defined as the linear 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.

In Liberia the data resources available for identifying a corridor include:

- published 1:50,000 scale topographical maps;
- geological maps at 1:250,000 scale published by the US Geological Survey;
- information held by the Environmental Protection Agency and the Forest Development Authority in Monrovia concerning areas of conservation status;
- satellite imagery to assist in the mapping of land use, drainage systems and topographical constraints, as well as the location of villages, towns and other infrastructure;
- site reconnaissance and site investigations;
- local information; and
- national and regional development plans.

4.3 Alignment identification

Road authorities are usually required to identify at least three possible alignment options within the corridor which:

- connect the stated start and end points via any specified intermediate points;
- maximize connectivity with the existing road network;
- avoid environmentally sensitive areas;
- 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.

The preferred route option 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. The criteria used to select the preferred alignment may vary from project to project, but some typical criteria, or factors, are given in Table A.4.1. It should be noted that construction cost will be controlled by 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 LVRs especially, it is advisable not to consider route options that will require expensive and complex engineering solutions.

Table A.4.1: Typical route selection criteria

Selection criteria
Minimum route length
Minimum construction cost
Minimum maintenance cost (where persistent geo-hazards 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, including the need to avoid cemeteries and sacred sites
Socio-economic benefits to be accrued
Minimal unfavorable geological conditions and slope geo-hazards
Sufficient freeboard above flood levels, i.e. coastal and riverine
Construction materials availability

4.4 Route selection in Liberia

Through the Environmental Protection Agency Act of 2002, the Environmental Protection Agency (EPA) of Liberia is the authority responsible for granting licenses for infrastructure development. The Wildlife and National Parks Act (1988), the Environmental Protection and Management Law of the Republic of Liberia (2002) and the National Biodiversity Strategy and Action Plan (2004) are important background documents, but any new infrastructure project of significance, such as the construction of a new road, requires consultation with the EPA to establish the requirements for granting a license. This places a significant control on route selection.

Environmental issues

Liberia is home to some of the most critical habitats of biodiversity in the world. The Nimba Mountains (Figure A.4.1), shared jointly by Liberia, Ivory Coast and Guinea, are of internal significance and World Heritage status on account of their critical habitat for rare and endangered floral and faunal species. Loss of biodiversity is one of the main outcomes of road construction into forested areas, not only through the physical effects of road construction itself, but also because of the access these roads provide for hunting, slash and burn and other land use pressures.

Figure A.4.1: The Nimba Mountains of North East Liberia

Figure A.4.2: Riverine environments are common-place in Liberia

The remainder of the country is covered by forest, savannah, grassland and cultivation in a terrain formed by highlands, plains and coastal lowlands (Figure A.4.2). Lakes and swamps prevail in many areas and the ecology and habitats of many of these areas are vulnerable to the effects of infrastructure development and land use change. The cultural heritage of many parts of the country is also diverse and social impacts associated with development can be significant.

Terrain, soils and hydrology

Liberia can be divided into broad topographic zones that progress inland from the coast through coastal belt, rolling hills and dissected plateau and mountainous interior. Much of the coastal belt comprises estuaries, coastal plains, lagoons and mangrove swamps. Some of these areas may prove problematic for road construction in terms of soft ground, high water table and flooding. If LVRs are to be constructed in these areas, route selection will need to take careful consideration of environmental, flooding, water management and soil engineering issues. The EPA will have clear views on which areas are to be avoided on environmental grounds, but these views will have to be supported and strengthened through project-specific environmental assessment to identify the environmental constraints that might apply in detail. Flooding will be a serious engineering concern in many areas, as will the suitability of subgrade soils, and especially the compressibility of alluvial silts and clays. Bridge locations need to be carefully chosen, in terms of minimum span, flood and scour hazard. The further downstream, i.e. towards the coastline, that river crossings are considered, the more expensive they are likely to become. For LVRs it will be preferable to avoid the most problematic areas altogether, even if it means significantly extended road alignments to facilitate necessary detours.

The rolling and dissected terrain poses relatively minor problems for route selection and road alignment. The mountainous interior, however, does pose significant problems in terms of the choice of alignments for new roads. The mountain ranges of Liberia are aligned very approximately NE-SW and road construction can be especially problematic along alignments that cross this topographic grain. Steep terrain not only constrains the choice of vertical and horizontal alignment, but it also necessitates large cut and fill volumes, and sometimes the need for retaining structures to support slopes above and below road alignments. With the climate regime of Liberia dominated by prolonged and heavy rainfall, erosion and slope instability can be significant problems on unprotected cut and fill slopes (Part C, Chapter 6) and these issues must be considered when selecting alignments for new roads.

Another important consideration with route selection in mountainous terrain is the relationship between topography and topographic complexity and geometric standard. Where the terrain is especially severe, it may be necessary to relax geometric standards to avoid escalating land take and construction costs and reduce environmental impacts. Another issue relates to the ease with which future road improvement and widening schemes can be applied. In mountainous terrain this can prove quite difficult, both in terms of temporary access for traffic and the difficulty in widening the formation width due to constraining topography above and below the road.

While large parts of the country are underlain by free-draining lateritic soils that offer reasonably acceptable subgrade strength, there are areas, especially in the southeast, where materials and ground conditions are problematic (Part B, Chapters 3 and 4). While it may not be possible to avoid these areas in their entirety, alignments should be optimized through the selection of routes on higher ground, thus avoiding poor drainage and poor subgrade conditions. Where there is no choice but to cross these areas, it will be necessary to ensure that adequate provision is made in the cost estimate to accommodate sufficient engineering mitigation for route comparison purposes. Table A.4.2 contains some of the more important generic recommendations for route selection.

Table A.4.2: Some generic recommendations for route selection

Principles of route selection
1. The route should be as direct as possible and make maximum use of existing tracks (within the bounds of the geometric standards for the particular class of road) between the towns or villages to be linked, thereby minimizing road user transport costs and probably minimizing construction and maintenance costs as well.
2. The route should not be so close to public facilities that it causes unnecessary disturbance. Cultural sites such as cemeteries, places of worship, archaeological and historical monuments should be specifically protected. Although a road is designed to facilitate access to hospitals, schools and so on, it should be located at a reasonable distance away for safety and to reduce noise.
3. Where the proposed location interferes with utility lines (e.g. overhead transmission cables and water supply lines), the decision between changing the proposed route and moving the utility line should be based on a study of the feasibility and the relative economics.
4. The route should, as much as possible, be located along edges of properties rather than through them to minimize interference to agriculture and other activities and to avoid the need for frequent crossing of the road by the local people.
5. The location should be such as to avoid unnecessary and expensive destruction of trees and forests.
6. The route should be ‘integrated’ with the surrounding landscape as far as possible. Normally, it is necessary to study the environmental impact of the road and ensure that its adverse effects are kept to the minimum.
7. Where possible, marshy and low-lying areas and places having poor drainage and weak materials should be avoided.
8. When feasible, the preferred alignment should be one that permits a balancing of cut and fill to minimize borrow, spoil and haul.
9. Ideally, the route should be as close as possible to sources of borrow materials and should minimize haulage of materials over long distances.
10. Where the route follows the corridor of a railway line or river, frequent crossings of the railway or river should be avoided.
11. Problematic and erosion-susceptible soils should also be avoided as much as possible.
12. Areas liable to flooding and areas likely to be unstable due to toe-erosion by rivers should be avoided.
13. Where possible, the route should be located such that the road reserve can be wide enough to allow future upgrading to a wider carriageway.
14. High fills should be avoided, and special attention should be paid to the compaction of all fills.
15. Cross-sections should be designed such that mass haul is minimized and cut and fill are balanced, where the topography permits.
16. Needless rise and fall should be avoided.
17. Wherever possible, unstable slopes and areas having frequent landslide and erosion problems should be avoided.

4.5 Multi-Criteria Analysis

4.5.1 Role of Multi-Criteria Analysis

Depending upon location in the country, a range of factors needs to be covered. Most of these are included in Table A.4.1. Some will be more important than others, depending upon regional and site-specific circumstances. Maximum use should be made of desk study data sources, including published topographical and geological mapping, satellite imagery and aerial photographs. Digital elevation data can be downloaded from internet sources and these can assist in route selection and alignment design, especially in steep terrain.

Fieldwork, however, is normally the greatest source of data necessary for route selection. Reconnaissance surveys allow the key factors and controls to be identified. Drone surveys can provide useful supplementary terrain interpretation, especially when supplied with the software capable of deriving digital topographic mapping data. Geological and hydrological studies allow difficult ground and flood-prone areas to be identified while environmental and social surveys help identify and evaluate the various benefits and impacts associated with each route option.

In some cases, the choice of route option and alignment might be obvious, especially where environmental, topographical and geohazard factors play only minor roles in decision-making. However, 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. 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-quantitative way, and then combines scores to reach an overall preferred route. It is usual to apply a weighting to each 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 impinge on an area of forest.

Route selection for LVRs in Liberia may not need to adopt the MCA approach if it is clear from the outset which option is preferred, whether on length, cost or environmental grounds. However, the MCA approach requires the decision-maker to examine all relevant criteria and constraints and to adopt a process of stakeholder engagement in determining which factors are more important than others in arriving at the final route selection. The MCA approach is therefore a useful way of ensuring that all factors are considered for new road construction and where road improvement projects require realignments to be made.

The following steps are required in the application of MCA for route selection:

1. List all criteria that are relevant to route selection. These will include engineering, social, environmental, economic and planning considerations.
2. Determine how each criterion is to be assessed.
3. Rank each option according to each criterion.
4. Apply a weighting to each criterion according to its perceived importance.
5. Multiply rank x weighting for each criterion for each option and sum for each option to determine preferred route.

4.5.2 List of criteria

Table A.4.3 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 to ensure that the list of criteria is fully-inclusive of all concerns.

4.5.3 Methods of assessment

Table A.4.3 indicates how each criterion might be assessed. The method of assessment should be as objective as possible, maximizing quantification, and subject to stakeholder consultation to ensure that all parties are satisfied with the method adopted.

Table A.4.3: Common criteria for consideration in MCA and route selection in general

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 habitats and could air pollution and noise affect public health?	Yes, no, number of locations, ecological and public health severity
Environmental Economic Planning	Ecology - are there any areas of important biodiversity (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 particularly prone to erosion?	Length
	Viability	Qualitative, NPV, EIRR, Cost-Benefit Analysis
	Sustainability - Does the route satisfy regional and local sustainable development goals?	Yes, no, not applicable

4.5.4 Identifying the preferred option

In order to identify the preferred option through the use of MCA, it is necessary to carry out the following simple calculation:

- Rank each option for each criterion. The worst option is usually given the highest rank (e.g. where there are three options, the longest length is given a rank of 3) then other options are assigned a score on a pro-rata basis.
- For each option, multiply each criterion rank by its importance weighting.
- Sum all products of rank and weighting for each option.
- The option with the lowest sum is the preferred one.

For example, take the case where there are three route options: A, B and C. For ease of explanation only three criteria are considered: length, estimated cost and number of families to be rehoused. Length is considered the least important as this is an LVR and travel times are not an issue. Cost is more important than length, but the number of families to be relocated is considered by far the most important criterion. The weightings for these criteria are therefore assigned accordingly:

- Length: 1;
- Cost: 3; and
- Number of families to be relocated: 6.

This weighting is not linear and can only be finalized through collective discussion and agreement with local communities. Table A.4.4 shows the MCA carried out for this case. Option A has the lowest sum of Rank x Weighting and is the preferred option.

Table A.4.4: Hypothetical MCA application for illustration purposes

Route Option	Criterion			Rank (pro-rata'd)			Rank x Weighting			Sum (R x W)
	Length (km)	Cost ($)	Families relocated	Length	Cost	Families relocated	Length	Cost	Families relocated	
A	50	1.2 M	1	3	3	1/7 x 3 = 0.43	3 x 1 = 3	3 x 3 = 9	0.43 x 6 = 2.6	14.6
B	40	0.9 M	5	40/50 x 3 = 2.4	0.9/1.2 x 3 = 2.25	5/7 x 3 = 2.14	2.4 x 1 = 2.4	2.25 x 3 = 6.8	2.14 x 6 = 12.8	22.0
C	35	0.75 M	7	35/50 x 3 = 2.1	0.75/1.2 x 3 = 1.88	= 3	2.1 x 1 = 2.1	1.88 x 3 = 5.6	3 x 6 = 18	25.7

4.5.5 MCA Case Study

To illustrate the MCA approach, an example is taken from the Nimba Mountains in Liberia. MCA was used to help select the preferred route for a new haul road between mine sites. Given the significance of the Nimba Mountains for floral and faunal biodiversity, environmental considerations were considered among the most important. The following methodology was adopted:

- The project area was mapped in detail by environmental and biological specialists and a map was produced that delineated areas of high biodiversity (Level 1) that should be avoided entirely, and areas of intermediate biodiversity (Level 2) that should be avoided to the greatest extent possible. LiDAR was specially-commissioned, and a DEM was produced with 2 m contour intervals.
- Five route options were developed by manually plotting their approximate center lines onto paper contour maps taking account of maximum allowable gradient and minimum permissible curve radius. These routes were then digitized, and highway design software was used to develop each route into a preliminary design. Earthworks quantities were calculated for each option, based on cross-sections at 20 m intervals.
- A range of relevant engineering factors (cost; length; mass haul; geohazards; conflict with other mine facilities), environmental factors (Level 1 and 2 environmental areas affected; excess cut to be spoiled; need for borrow pits; number of stream crossings affected) and social factors (farmland

to be acquired; number of dwellings affected; number of cultural heritage sites affected) were identified (Table A.4.5).

- Each factor was quantified for each route option and the route option with the worst-case condition, for example greatest Level 1 land take, greatest cost, longest length, was assigned a rank of 5. The other route options were then assigned ranks proportionally according to their value for each factor. Each factor was given a weighting according to its perceived importance. For example, the total land take in Level 1 environmental areas was given the maximum weighting of 10, while cost and route length were given weightings of 6 and 5 respectively.
- By multiplying the rank and the weighting for each factor and then summing the total, an aggregate score is obtained for each route option and the route with the lowest score is the preferred option. From Table A.4.5, Option 2A has the lowest aggregate score, and was therefore the preferred option.

Table A.4.5: MCA Case Study - ranks, weightings and scores used in route selection

ENGINEERING

Factor	Route	Rank	Weighting	Score
Cost	1	3.7	6	22.3
	2 -	4.2	6	24.9
	2A	3.7	6	22.4
	3	5	6	30
	3A	4.8	6	28.8
Length	1	3.5	5	17.4
	2	3.4	5	17
	2A	3.4	5	17.2
	3	5	5	25
	3A	5	5	25
Compaction issues	1	3.5	2	6.9
	2	2.3	2	4.7
	2A	2.6	2	5.3
	3	5	2	10
	3A	4.1	2	8.2
Mass haul	1	3.5	2	6.9
	2	2.3	2	4.7
	2A	2.6	2	5.3
	3	5	2	10
	3A	4.1	2	8.2
Geohazards	1	5	5	25
	2	5	5	25
	2A	5	5	25
	3	3	5	15
	3A	3	5	15
Mine facilities crossed	1	0	5	0
	2	0.1	5	0.4
	2A	0.1	5	0.3
	3	5	5	25
	3A	3.6	5	17.9

ENVIRONMENTAL

Factor	Route	Rank	Weighting	Score
Level 1 Areas	1	5	10	50
	2	1.4	10	14.3
	2A	0.9	10	8.6
	3	1.3	10	13.3
	3A	0.8	10	8.2
Level 2 Areas	1	2.8	5	13.8
	2	2.9	5	14.3
	2A	2.7	5	13.7
	3	4.9	5	24.6
	3A	5	5	25
Length Above or Through Level 1	1	5	5	25
	2	3.3	5	16.5
	2A	2.1	5	10.5
	3	2	5	9.8
	3A	2	5	9.8
Excess of Cut to be Spoiled	1	3.8	5	18.9
	2	4.9	5	24.7
	2A	4.4	5	22.2
	3	4.2	5	21.2
	3A	5	5	25
Need for Borrow Areas	1	0	4	0
	2	0	4	0
	2A	0	4	0
	3	0	4	0
	3A	0	4	0
Number of Stream Crossings	1	4.3	3	12.9
	2	2.5	3	7.4
	2A	2.5	3	7.4
	3	5	3	15
	3A	5	3	15
Total Length of Route	1	3.5	3	10.4
	2	3.4	3	10.2
	2A	3.4	3	10.3
	3	5	3	15
	3A	5	3	15

SOCIAL IMPACT

Factor	Route	Rank	Weighting	Score
Areas of Farm-land Removed	1	3.4	6	20.6
	2	3.9	6	23.6
	2A	3.9	6	23.6
	3	5	6	30
	3A	5	6	30
Temporary dwellings Removed	1	3	2	6
	2	0	2	0
	2A	0	2	0
	3	0	2	0
	3A	0	2	0
Cultural Heritage Sites Affected	1	0	8	0
	2	0	8	0
	2A	0	8	0
	3	0	8	0
	3A	0	8	0

Route	Total of scores (Engineering Factors)	Total of scores (Environmental Factors)	Total of scores (Social Impact Factors)	TOTAL OF ALL SCORES	OVERALL RANKING
1	78.54	131.15	26.58	236	4
2	76.61	87.33	23.58	188	2
2A	75.41	72.57	23.58	172	1
3	115	98.85	30	244	5
3A	103.01	98	30	231	3

Analysis carried out by URS, now AECOM Ltd for ArcelorMittal Liberia Ltd (AML).

5. TRAFFIC

5.1 Introduction

Determination of the amount and type of traffic is one of the most important factors in the design of LVR geometric features such as road widths and alignments as well as the design of the road pavement structure itself. The effect of traffic on the choice of road pavement is covered in Part B of the Manual.

The types of traffic using LVRs in Liberia vary significantly and include both motorized and non-motorized traffic involving a wide spectrum of road users from pedestrians to motorcycle taxis to large commercial vehicles. Appropriate traffic surveys are required to provide the information necessary for both geometric and pavement design. Traffic counts for LVRs should include motorized and non-motorized traffic including pedestrians.

5.2 Traffic counts

The estimate of the initial traffic volumes, both motorized and non-motorized, should be the Average Annual Daily Traffic volume (AADT) currently using the route. This is determined from traffic count surveys. A typical traffic count survey form is included in Appendix A.1. Traffic counts may include:

- seven consecutive days counts, including at least one (1) market day;
- twelve hour volume counts during the daytime including peak periods (usually 6am to 6pm);
- separate counts taken for all seasons of the year, but avoiding unusual events such as market days, public holidays, ceremonies or severe weather;
- In the case for proposed paved roads the categorization of vehicles into groups or classes; and
- separate counts undertaken for both directions of travel.

Where there is no information available on a factor to convert 12-hour traffic counts to 24-hour average daily traffic volume (ADT), an hourly factor of 1.33 can be applied i.e.

$$ADT = \text{12-hour count} \times 1.33$$

Other survey methods used to determine traffic volumes and loading for pavement design purposes are covered in Part B of the Manual.

5.3 Estimating design traffic

Design traffic volume (AADT) used for geometric design purposes is generally determined as being the projected future traffic volume expected to be using the facility halfway through its design life or design period. The design period to be used for LVRs is generally 15 years thus 7 years is used for estimating design traffic volumes for geometric design purposes.

The process by which the design traffic volumes and hence the traffic class is determined for geometric design purposes is illustrated in Figure A.5.1.

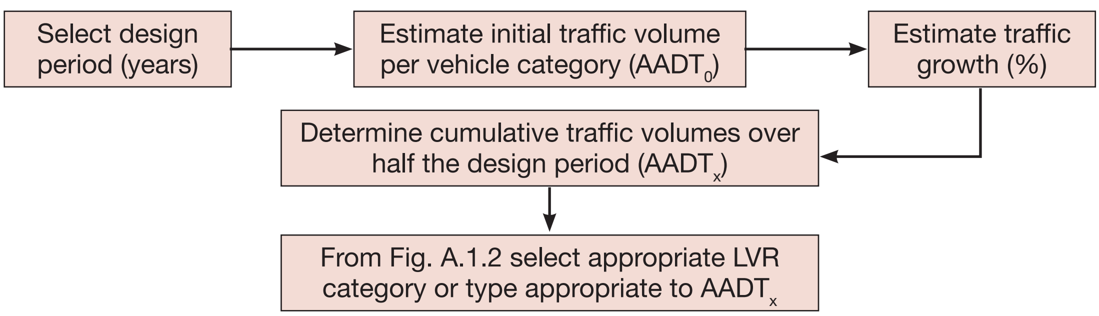


Figure A.5.1: Procedure to determine design traffic class

The following steps are followed to determine the cumulative number of vehicles over the design period of the road:

- Determine the initial traffic volume in *both directions* ($AADT_0$) using the results of a traffic survey and any other recent traffic count information that is available. For paved roads, the corresponding daily *one-directional* traffic volumes for each type of vehicle is required e.g. car, bus, types of truck, and truck- trailers.
- In the case of existing unpaved roads of poor standard which are to be either rehabilitated, upgraded or paved, there can be a rapid increase in traffic. This will typically include diverted traffic as well as some new traffic above and beyond a normal steady growth rate. The diverted traffic depends on the characteristics of the local road network and often the trade-off between a faster more comfortable ride and additional distance. Estimates of this effect are best derived from local experience in similar circumstances.
- Estimate the annual traffic growth rate in terms of percentage (%).
- Determine the projected future traffic volume in *both directions* for the mid-life year of the road ($AADT_x$). This can be determined by using Equation 1 or by selecting the value from Table A.5.1 based on a mid-life of 7 years.

$$AADT^x = AADT_0\,(1+i)^x \qquad \text{Equation 1}$$

Where "i" = annual traffic growth rate expressed as a decimal fraction.

"x" = number of years to mid-life of the design period.

Worked example:

The design traffic volume ($AADT_x$) required for an LVR with a selected design period of 15 years, an initial $AADT_0$ of 100 vehicles, and estimated traffic growth rate of 5% is determined as follows:

$AADT_7 = 100 \times (1 + 0.05)^7 = 141$ cumulative vehicles.

Table A.5.1 may be used to obtain the same result.

Table A.5.1: Mid-life (7 years) AADT for various initial AADTs and various growth rates

Initial $AADT_0$ (vpd)	$AADT_7$ (vpd)										
	Traffic Growth Rate (%)										
	2	3	4	5	6	7	8	9	10	12	15
15	17	18	20	21	23	24	26	27	29	33	40
25	29	31	33	35	38	40	43	46	49	55	67
50	57	61	66	70	75	80	86	91	97	111	133
75	86	92	99	106	113	120	129	137	146	166	200
100	115	123	132	141	150	161	171	183	195	221	266
125	144	154	164	176	188	201	214	229	244	276	333
150	172	184	197	211	226	241	257	274	292	332	399
175	201	215	230	246	263	281	300	320	341	387	466
200	230	246	263	281	301	321	343	366	390	442	532
225	258	277	296	317	338	361	386	411	438	497	599
250	287	307	329	352	376	401	428	457	487	553	665
275	316	338	362	387	413	442	471	503	536	608	732
300	345	369	395	422	451	482	514	548	585	663	798

5.4 Traffic volume and traffic growth

Roads need to provide good service for many years, so the traffic level used in the design process must take account of traffic growth. In general, it is expected that roads that do not have 'through' traffic (essentially feeder roads) will have lower traffic growth rates than the higher classes of road. However, each situation should be treated on its own merits taking into account any expected future developments.

For the purpose of geometric design, it is the daily traffic that is important. The approach recommended for estimating the traffic for geometric design purposes is based on the estimated traffic level at the middle of the design life period and this therefore requires an estimate of the traffic growth rate. This method eliminates the risk of under-design that may occur if the initial traffic is used and the risk of over-design if projected traffic at the end of the design life is used.

Normally a general growth rate is assumed or is provided by government, based on a combination of criteria including actual traffic counts, and the rate of growth in the number of registered vehicles in operation. However, local development plans may indicate higher growth rates in some places.

Where there is no existing road, estimating the initial traffic is difficult and estimating future traffic even more so. However, in many cases where a new road is proposed there is likely to be pedestrian and other non-motorized traffic and therefore some information on the likely vehicular traffic after the road is constructed.

In some cases, an economic evaluation may have been carried out to justify the road in the first place. This will have provided an estimate of the amount of goods transported by pedestrians and bicycles and the likely amount that will be carried by vehicles. In the unlikely event that there is no information available, the lowest class of engineered road (Type 1) should be designed. Historical growth rates of similar roads in any specific area should be considered as a proxy if available.

Four categories are defined for LVRs, Type 1, 2, 3 and 4, and each is applicable over a specific traffic range. These ranges are quite wide and little difficulty should normally be experienced in assigning a suitable standard to a new road project. Where the expected traffic is near to a traffic boundary, the higher category of LVR should be adopted.

5.5 The Design Vehicle

For geometric design purposes the physical dimensions of vehicles are important. A truck requires more space than a motorcycle or a car, whether or not the truck is loaded.

The way that vehicle size influences the geometric design of LVRs and HVRs is fundamentally different. When the volume of traffic is high, the road space occupied by different types of vehicle is an essential element in designing for capacity (i.e. the number of vehicles that the road can carry in a unit of time - vehicles per hour or per day). For example, at the highest traffic levels, when congestion becomes important, traffic volume dictates how many traffic lanes need to be provided.

For LVRs the volume of traffic is sufficiently low that congestion issues do not arise from traffic volume. Congestion can, however, result from the disparity in speed between the variety of vehicles and other road users which the road serves. The key issue here is traffic composition rather than traffic capacity. Nevertheless, it is the size of the largest vehicles that uses the road that dictates many aspects of geometric design. Such vehicles must be able to pass each other safely and to negotiate all aspects of the horizontal and vertical alignment. Trucks of different sizes are usually used to determine different standards; the driver of a large 6-axle truck would not expect to be able to drive on roads of the lowest standards.

In some countries the truck population in rural areas is predominantly composed of one or two types and sizes of vehicle. This makes it relatively easy to select a typical vehicle for setting geometric standards. Conversely, some countries have a wide variety of truck sizes. This makes it more difficult to select a suitable truck size for geometric design purposes.

In view of the low density of roads in Liberia and, hence, lack of alternative routes, together with the limited choice of vehicle for many transporters, it is prudent to be conservative in choosing the design vehicle for each class of road so that the maximum number of vehicle types can use the road. Four distinctive design vehicles and their characteristics used to develop the various design standards for the LVR categories are shown in Table A.5.2.

Table A.5.2: Design vehicle characteristics

LVR Category	Design vehicle	Height (m)	Width (m)	Length (m)	Front overhang (m)	Rear overhang (m)	Wheel Base (m)	Minimum design turning radius (m)
Type 1	Passenger car	1.3	2.1	5.8	0.9	1.5	3.3	7.3
Type 2	Single unit bus	3.2	2.4	12.2	2.1	4.0	6.1	11.9
Type 3	Single unit truck (11 m long)	3.8	2.5	11.0	1.5	3.0	6.5	12.8
Type 4	Truck and semi- trailer	4.1	2.4	13.9	0.9	1.4	11.6	12.2

Source: Modified from MoPW Geometric and Pavement Design Standards. 2017

5.6 Traffic composition – proportion of heavy vehicles

The density of roads in Liberia is quite low and one of the consequences of this is that the proportion of heavy vehicles in the traffic stream on LVRs may be quite high. Each of the LVR categories includes a modification to cater for this:

- For Type 1 roads, if the number of large vehicles, defined as 3-axled (or more) trucks, exceeds 10 then a Type 2 should be used.
- For Type 2 roads, if the number of large vehicles is greater than 20, a Type 3 should be used.
- For Type 3 roads, if the number of large vehicles exceeds 30, a Type 4 should be used.

If the number of large vehicles exceeds 80 then the design standards for high volume road classes (as defined in Section A.1.2) should be used.

Recommendations regarding the influence of heavy vehicles on design standards can be found below each of the geometric design summary tables in Appendix A.2.

5.7 Traffic composition - use of Passenger Car Units

In order to quantify traffic for normal capacity design the concept of equivalent Passenger Car Units (PCUs) is often used. For example, a typical medium goods carrying vehicle requires about 2.5 times as much road space as a typical car in flat terrain, hence it is equivalent to 2.5 PCUs.

The PCU concept was not originally intended for use in the geometric design of LVRs but is useful where traffic congestion is likely to be a problem. However, in parts of Liberia the high volume of non-motorized traffic can have a negative impact on the ease at which motorized vehicular traffic can operate. Slow moving motorized vehicles also can create congestion.

In situations where the number of slow moving vehicles, both motorized and non-motorized, is significant, the road standard should be improved to reduce congestion and retain the level of service appropriate to the traffic level of the motorized vehicles. This is best achieved by widening the shoulders. Where there is a high volume of non-motorized transport and two- and three-wheeled motorized vehicles, defined as exceeding 300 PCUs per day, this can be expected to have a negative impact on traffic flow and road shoulder widening is recommended. The PCU concept is also useful for identifying the need for additional facilities or safety features where the numbers of pedestrians and slow-moving vehicles are high. PCU conversion factors recommended for Liberia are shown in Table A.5.3.

Table A.5.3: PCU conversion factors

Vehicle Type	PCU value		
	Flat	Rolling	Mountainous
Pedestrian	0.1	0.1	0.1
Bicycle	0.2	0.2	NA
Motorcycle	0.25	0.25	0.5
3-wheel vehicle (ke-ke)	0.5	0.5	1.0
Passenger car	1.0	1.0	1.5
Light goods vehicle	1.0	1.5	3.0
Bus	2.0	4.0	6.0
Medium goods vehicle	2.5	5.0	10.0
Heavy goods vehicle	3.5	8.0	20.0

Source: MoPW Feeder Roads Design Manual and Specifications. 2016

Worked example:

A traffic count on an existing LVR to be upgraded in flat terrain revealed that 80 bicycles, 50 motorcycles, 10 passenger cars, 2 buses, and 8 medium goods vehicles are expected to use the road in year 7. The passenger car unit equivalent (PCU) required for the design is determined as follows:

> Non-motorized transport, 2- and 3-wheeled motorized vehicle design PCU = [(80 x 0.2) + (50 x 0.25)] = 29 PCUs per day.
>
> Motorized traffic (4-wheels and more) design PCU = [(10 x 1.0) + (2 x 2.0) + (8 x 2.5)] = 34 PCUs per day.

6. GEOMETRIC DESIGN

6.1 Introduction

Geometric design is the process whereby the layout of the road through the terrain is designed to meet the needs of all the road users. The geometric standards are intended to meet two important objectives, namely: to provide acceptable levels of safety and comfort for drivers by provision of adequate sight distances, coefficients of friction and road space for maneuvers, while also minimizing earthworks to reduce construction costs.

Geometric design covers the determination of road width, crossfall, horizontal and vertical alignments and sight lines, and the transverse profile or cross-section. The cross-sectional profile includes the design of the side drainage ditches, embankment heights, and side slopes, and is a vital part of geometric design for LVRs. The cross-section essentially adapts the pavement to the road environment and is part of the drainage design. For example, wide paved shoulders and high camber or crossfall can significantly improve the operating environment for the pavement layers by minimizing the ingress of surface water. Sub-surface water is a problem in low-lying flood-prone areas and in road cuttings. The height of embankment and the depth and type of drainage ditch have significant effects.

6.2 Design standards and their application

6.2.1 Purpose of national standards

A national 'standard' is not a specification, although it could be and often is, incorporated into specifications and contract documents. Rather, a standard defines a specific level of quality that should be achieved at all times, and nationwide. Amongst other things this ensures consistency across the country. For geometric standards, this means that road users know exactly what to expect, so that, for example, drivers are not 'surprised' by unexpected changes in standard. The standards should be a guarantee of a particular level of service, which is important for reasons of safety.

6.2.2 Functions and characteristics of roads

The functions and characteristics of a road network determine the principles and approach to the design of roads in the network. Conventionally, the adoption of design speed for various terrain types is the major determinants for establishing geometric design parameters. However, for low volume rural roads, design speed may be both a determinant and result of design standards.

In networks where roads function to provide increased capacity and efficiency or where the level of service is high, increased and uniform speeds and uninterrupted traffic is desirable, a design speed approach is used.

In a road network where the function is to provide access to land and properties, a basic access approach is used. Such roads include rural feeder and secondary roads with low traffic. The purpose of these roads is to provide all-weather accessibility rather than operational efficiency. Traffic mix is still an important factor, and in Liberia it includes motorized transport, motorcycles and cyclists. Safety is an important consideration. For roads with more than 50 vehicles per day, the increased number of large vehicles justifies the use of a higher standard.

6.2.3 Basic Access approach

In the basic access approach, the geometric layout should allow the largest vehicle which normally uses the road to operate. For low trafficked roads, small trucks are usually the largest vehicles. The average daily traffic volume will also guide the designer in selecting the geometric standards of the road.

The standards used are also dependent upon the terrain. The designer must consider the implication of the selected alignment standards with the construction and future maintenance costs. With a wide cross-section, the cost of construction and future maintenance will be high. On the other hand, if a gentle gradient is chosen in hilly areas, the cost of construction may be high, but the cost of future maintenance may be reduced for earth and gravel roads. It is necessary to choose geometric standards appropriate to the prevailing socio-economic conditions and financial constraints.

For very low volume roads simple design criteria involving a 'design by eye' approach with basic survey instruments like levels, ranging rods, profile boards and boning rods may be used to set out the horizontal and vertical alignment.

LVR design usually starts with the basic access approach by selecting an appropriate cross-section based on traffic composition. The designer then determines the likely speed that the choice of design cross-section will attract. The likely speed is used to define the horizontal and vertical alignment standards bearing in mind road safety concerns. Traffic composition and volume assist in determining other alignment standards.

6.2.4 Conventional Design Speed approach

Conventional design aims to provide a constant level of service over a specific road or road segments where a consistent speed environment needs to be provided. The approach is therefore governed by speed selection. In principle, most roads are constrained to minimum parameter values over certain sections. Road costs and benefits are optimized by using different design speeds.

Care must be exercised to ensure that the selection of design speed and other standards take into consideration the design controls specified in Section 6.3. The road surface type and environmental factors have an influence in deciding geometric standards as they affect the design life of the road.

6.2.5 LVR design scenarios

There are three design situations for LVRs, namely:

- Upgrading from a lower class of road to a higher class;
- Designing a road to replace an existing track; and
- Designing a completely new road where none existed before.

Upgrading an existing road

The basic alignments will already exist, but the standards of the existing road are normally applicable to a road of lower class as opposed to the higher standard intended with the upgrade. The existing road alignment will need to be checked for compliance in terms of the new standard and may require a wider cross-section, higher design speeds, and therefore larger horizontal and vertical curvature standards. Handheld GPS equipment may be used to establish the existing horizontal alignment on site. In flat and rolling terrain, larger horizontal curve radii are usually achieved by means of minor realignments at the curves themselves. Larger vertical curve lengths are usually more difficult to achieve but, depending on the terrain, can often be attained by additional fill rather than deeper cutting. In more severe mountainous terrain, it may be necessary to make substantial realignments to avoid deep cuts. For example, following a contour more closely can serve to avoid a steep hill with inadequate sight distances over a crest.

Challenges occur in mountainous terrain when substantial widening is required. Under these circumstances it is not always possible to meet the standards of the new road class and therefore adequate warning signs need to be employed to alert drivers to the lower standards. Traffic calming measures should also be considered to reduce speed.

In general, however, the main improvements, apart from overall widening, are essentially spot improvements and do not require sophisticated design methods.

An alternative strategy for rehabilitating an old existing LVR or upgrading a track is to accept much of the existing alignment. This does not include areas where road safety may be an issue, and for which specifically engineered measures, such as appropriate traffic calming or road widening at blind crest curves may be required. Accepting the existing alignment may result in variable cross-section widths and travel speeds but will not incur significant earthworks costs. For such a strategy to be acceptable there are a number of qualifying conditions:

- 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 not familiar with the characteristics of the alignment; and
- Problem areas such as very tight curves, or steep grades, or other potentially hazardous locations are addressed by sound engineering solutions.

A design-by-eye approach may be adopted for such a strategy, but considerable experience and skill is needed to carry it out. The design-by-eye approach should only be used under the guidance and supervision of an experienced Engineer. In mountainous terrain the design-by-eye approach has an important role to play because an experienced Engineer is required to first identify where a route corridor should be located before the alignment can be designed within it using conventional approaches. Design-by-eye requires the use of remote sensing and walkover surveys to identify the basics of the preferred route before it can be designed (refer to Chapter 4 for guidance on route corridor selection and alignment design).

An old earth road may sometimes be wider than required for the class of road that the traffic level requires for the upgraded road. It may already have some adequate side drains and reasonable crown height. In such a situation it may be less expensive to adopt the existing wider standard by choosing a higher road class than strictly necessary. Each case should be evaluated, and the most economical solution selected.

Designing a road to replace an existing track

In this case the existing geometric standards may be very much lower than those required, hence some substantial re-alignments may be necessary, especially in hilly and mountainous terrain. However, the basic route selection will already have been carried out by virtue of the fact that there is an existing track and the main control points along the alignment will already be defined. A hand-held GPS device may be used to establish the existing horizontal alignment on site. Although required re-alignments may be substantial, an experienced Engineer could in many cases adopt a design-by-eye approach. However, it is anticipated that, in general, the designs will be done with the help of computer aided design programs based on accurate topographical and other survey data (refer to Chapter 4 on route selection).

Designing a new road

Designing a geometric alignment for an entirely new road where none existed before is a considerably more complex process 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 there is a need for a pre-feasibility study to identify possible corridors for the road and to decide whether the project is likely to be viable. This is followed by a feasibility study to determine the best routes within the best corridors and, finally, a detailed design study based on the route selected. The level of detail in this process depends critically on the class of road being designed and the terrain through which it will pass. Errors at this stage can be costly and, once the road is built, can also impose serious burdens in the future if the road requires excessive maintenance.

The principles of route selection are described in detail in Chapter 4 of the Manual. They are based on surveys of various kinds that provide information about all the likely technical engineering issues related to the new road but also surveys concerned with environmental and social issues as well.

The final design is inevitably a compromise between many competing factors and there is no formal way of resolving all of them to everyone's satisfaction. Engineering judgement and sound participatory processes are required in order to arrive at an alignment that is acceptable to all parties including those whose expressed views did not necessary prevail.

6.2.6 Topographical survey

It is recommended that some form of topographical survey be obtained or undertaken prior to any geometric design. The extent to which the topographic survey is required will depend upon the steepness and complexity of the terrain and the extent to which both the horizontal and vertical alignments are required to deviate from the existing alignment to conform with the (revised) geometric design criteria, and the need to mitigate traffic safety hotspots. If the project involves carriageway widening, then sufficient topographic survey will be required to allow the design of this widening, in conjunction with the geometric design and a sufficiently accurate ground model. Drone flown surveys are becoming increasingly popular for undertaking more sophisticated surveys and should be considered when the need arises as these types of surveys can be extremely cost effective. Alternatively, digital elevation models produced by the Shuttle Radar Topography Mission (SRTM) and other platforms can be acquired from the internet which can be used for road planning and design purposes where a high degree of accuracy is not essential.

Where the drainage assessment identifies flood potential at low-lying points on the road it is necessary to use the topographic survey to raise the vertical alignment. It is important, therefore, to ensure that the site inspection team includes highway and drainage specialists, as well as geological expertise in hilly and mountainous terrain. The topographic survey must also be sufficiently detailed and broad enough in its geographical extent to allow the road improvement to be designed accurately. Where the road project is located in flat or rolling terrain and there are few geometric constraints to consider, the design can be based on simple elevational and road width adjustments based on a basic surveyed strip map and standard cross-sections. A center line survey using a standard hand-held GPS device may be adequate for this purpose.

6.3 Principal factors affecting geometric standards

6.3.1 Introduction

The principal factors that affect the appropriate geometric design of a road and which should be considered are:

- cost and level of service;
- traffic volume and composition;
- topography and terrain;
- roadside population (open country or populated areas);
- pavement type;
- soil type and climate;
- safety considerations;
- construction technology;
- administrative or functional classification;
- environmental considerations; and
- manmade features.

Since these factors differ for every road, the geometric design of every road could, in principle, be different. This is impractical, and it is therefore normal practice to identify the main factors and to design a fixed number of geometric standards to cope with the range of values of these key factors. For LVRs in Liberia, four basic categories are defined based on traffic volume described in Section 1.2. These are then modified, sometimes quite considerably, to cater for the other key factors. The most important of these are:

- traffic composition (including pedestrians and non-motorized vehicles);
- topography and terrain;
- roadside activity; and
- pavement type (paved or unpaved).

Varying standards of geometric design do not exist to cater specifically for climate and soil type. However, these factors are taken into account in the design of the drainage features of the road. Part C of the Manual includes guidance on drainage design and shows how drainage affects the road cross-section, and hence the geometric design.

The designer, therefore, has a very wide range of standards from which to choose, ensuring that a suitable standard is available for almost all situations. However, there will be cases where it is impossible to meet any of the standards, for instance in extremely severe terrain conditions. Under such circumstances the standards must be relaxed, and road users must be warned with suitable permanent signage of the reduction.

6.3.2 Cost and level of service

The cost of a road is usually the most critical factor in determining the design standards. It is also the most difficult factor to include in the setting of the design standards. The standard of a road is an index of its Level of Service (LOS). The ‘Level of Service’ is a rather imprecise term that means different things to different people. However, most would agree that the main components of LOS include: speed of travel, safety, comfort, trafficability, passability, and ease of driving, overtaking, stopping and parking.

The chosen LOS is directly associated with traffic volume and, hence, is not treated as a separate variable. The standards for LOS generally increase from the lowest road class to the highest, remaining relatively constant within each class.

6.3.3 Traffic volume and composition

Details pertaining to traffic volume, traffic composition, and the design vehicle are described in Chapter 5.

6.3.4 Topography and terrain

Topography and terrain are major factors in determining the physical location, alignment, sight distances, cross-section and other design elements and has the greatest effect on road costs and therefore it is not economical to apply the same standards in all terrains. In flat terrain the topography may have little influence on the location of the alignment, but it would still impact design elements such as drainage. In mountainous terrain the route alignment and certain design features are entirely governed by the topography.

The geometric design elements of a road depend on the transverse terrain of the land through which the road traverses. Transverse terrain is categorized in three classes as defined below:

Flat:

Level or gently rolling country which offers few obstacles to the construction of a road having continuously unrestricted horizontal and vertical alignment.

Rolling:

Rolling, hilly or foothill country where the slopes generally rise and fall moderately gently and where occasional steep slopes may be encountered. It will offer some restrictions in horizontal and vertical alignment. Liberia is mostly dominated by rolling terrain.

Mountainous:

Rugged, hilly and mountainous country and river gorges. This class of terrain imposes definite restrictions on the standard of alignment obtainable and often involves long steep grades and limited sight distances.

It is important to note that the terrain classification is a terrain feature and not a characteristic of the route alignment selected. Terrain 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 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, special climbing lanes. Fortunately, the technology of trucks has improved greatly over the years and, provided they are not overloaded or poorly maintained, they do not usually require special treatment. On the other hand, animal drawn vehicles are unable to ascend moderate gradients let alone steep climbs and catering for them in hilly and mountainous terrain is rarely possible.

Climbing lanes cannot be justified on LVRs and nor can the provision of very low maximum gradients. The maximum gradients allowable for different road classes are shown in the Tables in Appendix A.2.

In mountainous areas the geometric standards for LVRs take account of the constraints imposed by the difficulty and stability of the terrain. The 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 standards shown in Appendix A.2. Where higher gradients cannot be avoided, they should be restricted in length. On unpaved roads, gradients greater than 10% should not be longer than 250 m and relief gradients less than 6% and at least 250 m long should be provided. Horizontal curve radii of as little as 13 m may be unavoidable.

6.3.5 Roadside population

In any area having a reasonable sized population, or where markets and other business activities take place, the geometric design of the road needs to be modified to ensure safety for the roadside population. This is done by introducing:

- a wider road cross-section;
- lay-bys for passenger vehicles to pick up or deposit passengers;
- roadside parking areas; and
- traffic calming measures.

The additional road width depends on the status of the populated area that the road is passing through. If the road is passing through a highly populated area, an extra paved carriageway, or shoulder, of 3.5 m width is required in each direction for parking and for passenger pick-up, and a 2.5 m pedestrian footpath is also recommended. Lesser populated areas require narrower shoulder widths of 2.5 m, but no additional footpath. In addition, the main running surface is to be paved at least 6.0 m wide. The pavement structure of the widening should be identical to the pavement of the running surface.

6.3.6 Pavement type

For a similar ‘quality’ of travel there is a difference between the geometric design standards required for an unpaved road (gravel or earth) and for a paved road. This is because of the very different traction and friction properties of the two types of surfaces. Higher geometric standards are generally required for unpaved roads.

6.3.7 Soil type and climate

LVRs must be designed with the idea of making use of materials obtained locally to prevent high purchase and transport costs. Local soils such as lateritic gravel, which are found in abundance in Liberia, and sands found in areas close to the coast, provide an opportunity for good road building practice.

Soil type also affects the ideal geometric design, principally in terms of cross-section rather than in terms of the width of the running surface or road curvature. With some problem soils the cross-section can be adjusted to minimize the severity of the problem by, for example, minimizing the speed of water flow, minimizing the likelihood of excessive water inundation or penetration into the carriageway, and/ or moving problems areas further away from the carriageway itself. These aspects are dealt with under pavement design in Part B of the Manual and under drainage design in Part C.

Ideally maximum gradients and road slopes for unpaved roads should also depend on soil types. However, this is usually impracticable because, in most climatic regions, almost any slope causes problems for unpaved roads. Recent research has demonstrated that gravel-surfaced roads are unsustainable in many more situations than had previously been acknowledged. This applies equally to earth roads. Consequently, every effort is being made to introduce or to develop more sustainable surfacings such as that described above for use where unpaved roads deteriorate too quickly. Such surfacings cannot usually be justified for long stretches of road where they are not essential, hence the concepts of spot improvements and environmentally optimized design (EOD) are being developed and refined.

6.3.8 Safety

Experience has shown that simply adopting 'international' design standards from developed countries will not necessarily result in acceptable levels of safety on rural roads. The main reasons include the completely different mix of traffic, including relatively old, slow-moving and usually overloaded vehicles; a large number of pedestrians, animal drawn carts and, possibly, motorcycle-based forms of transport; poor driver behavior; and poor enforcement of regulations. In such an environment, methods to improve safety through engineering design assume paramount importance.

Although little research has been published on rural road safety in Liberia, the following factors related to road geometry are known to be important:

- vehicle speed
- horizontal curvature
- vertical curvature, and
- width of shoulders.

These factors are all inter-related and part of geometric design. In addition, safety is also affected by:

- traffic level and vehicle composition;
- inappropriate public transport pick-up/drop-off areas;
- poor road surface condition (e.g. potholes);
- dust (poor visibility); and
- slippery unpaved road surfaces.

The last three factors are related to pavement materials and structural design covered in Part B of the Manual.

Conflicts between motorized vehicles and pedestrians are always a major safety problem on many rural roads where separation is generally not economically possible. The World Bank Basic Access document (World Bank, 2001) considers that there are sound arguments based on safety for keeping traffic speeds low in mixed traffic environments, rather than aiming for higher design speeds, as is the case for major roads. The use of wider shoulders is suggested, and segregation measures are recommended. These considerations have been incorporated into this Manual.

Traffic level and vehicle composition are both considered important factors for safety. A considerable number of conflict situations can arise when the number of PCUs of non-motorized traffic, motorcycles and 3-wheeled motorized vehicles is large even though the number of 2 (or more)-axle motorized traffic is quite low. Furthermore, the proportion of heavy vehicles on the LVRs in Liberia can be high, leading to more serious conflict situations. The overall traffic class standards are based on the number of 2 (or more)-axle motorized vehicles but additional safety features are based on:

- the number of PCUs of non-motorized traffic, motorcycles and 3-wheeled motorized vehicles; and
- the proportion of heavy vehicles in the motorized stream.

Pedestrians (and draft animals) find it uncomfortable to walk on poorly graded gravel shoulders containing much coarse material, especially in bare feet. They usually choose to walk on a paved running surface, if available, despite the greatly increased safety risk. Thus, provision of a wider unsurfaced shoulder does not ensure greater safety. On the approaches to market villages, where the pedestrian traffic increases greatly on market days, provision of a separate footpath is the best solution provided that the soil is suitable.

A checklist of engineering design features that affect road safety is given in Figure A.6.1. Not all are suitable for rural roads but the general philosophy of design for safety is emphasized. The following factors should be considered when designing for safety:

- Wherever possible, non-motorized traffic should be segregated by physical barriers, such as raised curbs (through villages and peri-urban areas).
- Designs should include features to reduce speeds in areas of significant pedestrian activity, particularly at crossing points. Traffic calming measures may need to be applied.
- To minimize the effect of a driver who has lost control and left the road, the following steps should be taken:
    - Steep open side-drains should be avoided since these increase the likelihood of vehicles overturning; and
    - Trees should not be planted immediately adjacent to the road.

Due to their high costs of installation and maintenance, guardrails should only be introduced at sites of known accident risk.

Junctions and access points should be located where full safe stopping sight distances are available.

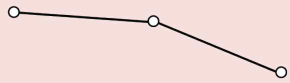
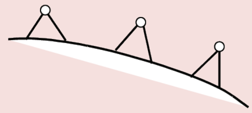
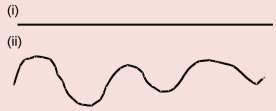
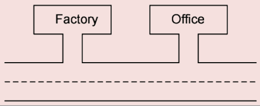
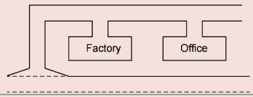
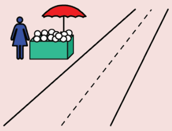
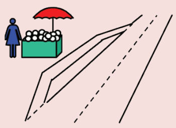
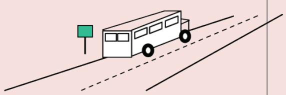
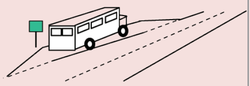
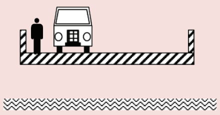
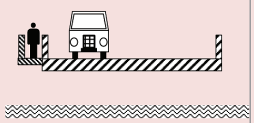
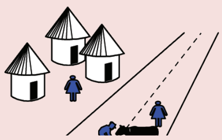
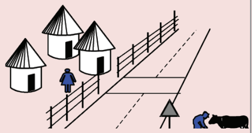
	Undesirable	Desirable	Principle applied
Route location			Major routes should by-pass towns and villages
Road geometry			Gently-curving roads have lowest accident rates
Roadside access			Prohibit direct frontal access to major routes and use service roads
			Use lay-bys or widened shoulders to allow villagers to sell local produce
			Use lay-bys for buses and taxis to avoid restriction and improve visibility
Segregate motorized and non-motorized traffic			Seal shoulder and provide rumble divider when pedestrian or animal traffic is significan
			Construct projected footway for pedestrians and animals on bridges
			Fence through villages and provide pedestrian crossings

Figure A.6.1: Examples of effects of engineering design on road safety

Source: ERA Manual for Low Volume Roads. 2016

Chapter 7 should be consulted for further information and detail on the physical measures which can be employed to improve road safety such as road signage, traffic calming devices, barriers etc.

6.3.9 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. For LVR road works, the optimal solution often lies somewhere between labor-intensive and equipment intensive methods. In such a situation the choice of technology might affect the standards that can be achieved, especially in hilly and mountainous areas. This is because:

- maximum cuts and fills will need to be small;
- economic haul distances will be limited to those achievable using wheelbarrows;
- mass earthworks balancing will need to be achieved by transverse rather than longitudinal earth movements;
- maximum gradients will need to follow the natural terrain gradients; and
- horizontal alignments will need to be less direct.

The design standards in hilly and mountainous terrain are always lower than in flat terrain, but this reduction in standards need not necessarily be greater where labor-based methods are used. Following the contour lines more closely makes the road longer but the gradients can be less severe. Every effort should be made to preserve the same standards in the particular terrain encountered irrespective of construction method.

6.3.10 Administrative function

It is sometimes necessary to take account of the administrative or functional classification of roads in determining the design standards. This is because a certain standard may be expected by the road agency for each functional class of road irrespective of the current levels of traffic. Generally, the hierarchy of administrative classification broadly reflects the traffic levels observed but anomalies are common where, for example, traffic can be lower on a road higher in the hierarchy. It is recommended that the standards selected should be appropriate to the task or traffic level of the road in question but a minimum standard for each administrative class can also be defined if it is policy to do so.

6.3.11 Environmental considerations

The location and design of the road should maximize positive effects and minimize negative effects on the environment. Dust pollution from unpaved roads, quarry operations to extract surfacing gravels, environmental degradation arising from logging activities due to increased access to remote areas are the major concerns. Environmental impact assessments should be carried out for every road design.

6.3.12 Manmade features

Manmade features such as agricultural, industrial, commercial, residential and recreational developments can place significant constraints on the choice of road alignment. Care should be taken to avoid the unnecessary destruction, demolition or severance of valuable properties. The road alignment should fit within any development planning scheme for the area. Information regarding land use and other physical features should be obtained from physical planners or the local authorities to coordinate the project with other planned land use.

6.4 Design speed and geometry

6.4.1 Definitions

Design speed is defined as the maximum (85th percentile) safe speed that can be maintained over a specified section of road when conditions are so favorable that the design features of the road govern the speed. Design speed is used as an index that essentially defines the geometric standard of a road, linking many of the factors that determine the road's level of service. These include traffic level, terrain, pavement type, road safety, population density and road function, to ensure that a driver is presented with a consistent speed environment.

The concept of design speed is most useful because it allows the key elements of geometric design to be selected for each standard of 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 road costs to manageable proportions. The speed is higher in rolling terrain and highest of all in flat terrain.

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

In view of the mixed traffic that occupies the rural roads of Liberia 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, for both surface types, are shown in Table A.6.1.

Changes in design speed, if required because of a change in terrain, should be made over distances that enable drivers to change speed gradually. Such 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 (i.e. considerably more than one single bend). Where this is not possible, warning signs should be provided to alert drivers to the changes.

Table A.6.1: Design Speed

Road Class/ LVR Category		Design Speed (km/h)						
		Unpaved			Paved			Populated Areas
		Flat	Rolling	Mountain	Flat	Rolling	Mountain	
Feeder	Type 1	50	40	30	NA	NA	NA	40
Feeder	Type 2	60	50	30	60	50	40	50
Feeder	Type 3	70	50	30	70	60	40	50
Secondary	Type 4	70	50	30	80	60	40	50

Source: MoPW Feeder Roads Design Manual and Specifications. 2016

6.4.2 Safe stopping sight distance

In order to ensure that the design speed is safe, the geometric properties of the road must meet certain minimum and maximum values. This ensures that drivers can see far enough ahead to carry out normal maneuvers 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. It mainly affects the shape of the road on the crest of a hill (vertical curvature) 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 driver must be able to see any obstacle in 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. The driver needs time to react and time is required for the braking action of the vehicle to slow the vehicle down, hence stopping sight distance is extremely dependent on the speed of the vehicle. The surfacing material and the characteristics of the road surface 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 longitudinal gradient of the road. It is harder to stop on a downhill gradient than on a flat road because a component of the weight 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. On the inside of horizontal curves, it may be necessary to remove trees, buildings or other obstacles to obtain the necessary sight distances. If this cannot be done, the alignment must be changed. In rare cases where it is not possible and a change in design speed is necessary, adequate permanent signage must be provided. Recommended stopping sight distances are shown in Table A.6.2.

Table A.6.2: Stopping sight distance (flat terrain)

Design Speed (km/h)		30	40	50	60	70	80
Stopping sight distance	Feeder roads	30	45	65	85	110	140
	Secondary roads	35	50	65	85	105	130

Sources: MoPW Feeder Roads Design Manual and Specifications. 2016
MoPW Geometric and Pavement Design Standards. 2017
Note: In rolling and mountainous terrain these distances should be increased by 10%.

6.4.3 Safe stopping sight distance for single lane roads (meeting sight distance)

For single lane roads, adequate sight distances must be provided to allow the drivers of vehicles travelling in the opposite direction to see each other, and to stop safely if necessary. This distance is normally set at twice the stopping sight distance (Table A.6.2) for a vehicle that is stopping to avoid a stationary object in the road. An extra safety margin of 20-30 meters is also sometimes added.

Although a vehicle is a much larger object than is usually considered when calculating stopping distances, these added safety margins are used partly due to 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. However, single lane roads have a relatively low design speed, hence meeting sight distances should not be too difficult to achieve.

6.4.4 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 is taken as 2.5 times the stopping sight distance. For example, the safe intersection sight distance required to an intersection for a vehicle travelling at 60 km/h is equal to 85 x 2.5 = 213 m. The sight triangles for drivers approaching an intersection are illustrated in Figure A.6.2.

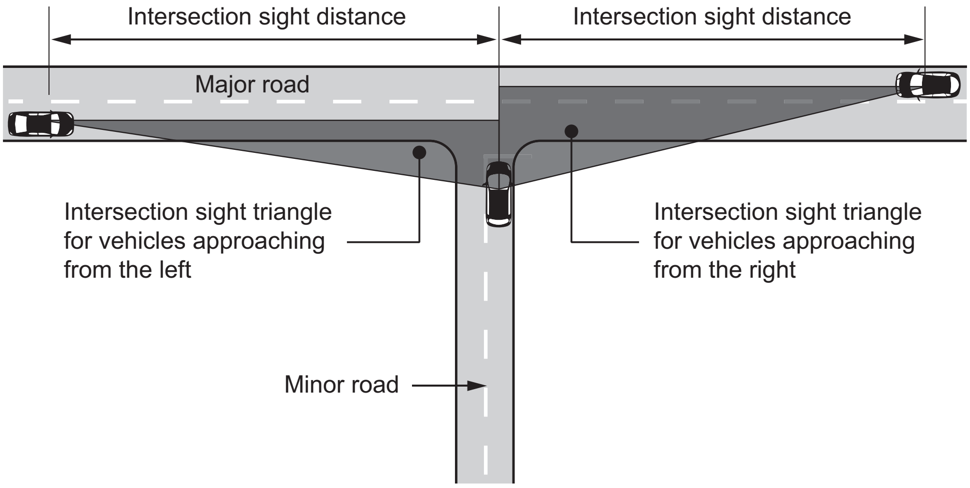


Figure A.6.2: Intersection sight triangles

6.4.5 Passing sight distances

Factors affecting the safe sight distances required for overtaking are more complicated than stopping sight distances 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. Current standards for the design of passing sight distance are based on percentage time spent following. This is because when vehicles are unable to overtake slow leading vehicles, groups of closely spaced vehicles form on the road, separated by large gaps, and the level of service deteriorates.

For single lane roads, overtaking maneuvers are not possible and passing maneuvers take place only at designated passing places. On the 2-lane roads, recommended passing sight distances are provided in Table A.6.3.

Table A.6.3: Passing sight distance

Design Speed (km/h)	40	50	60	70	80
Passing sight distance (m)	165	235	300	445	470

Source: MoPW Feeder Roads Design Manual and Specifications. 2016

6.5 Cross-section

6.5.1 Basic requirements

The cross-section of a road is essentially a geometric design feature but is also intimately related to drainage issues as well as slope stability and erosion problems in rolling and mountainous areas. The cross-section includes the shape and size of the running surface, shoulders, the side slopes of embankments, side slopes to drainage ditches, drainage ditches themselves, and slopes to the batter. Figure A.6.3 shows the elements of a typical road cross-section. Recommended road cross-section configurations, dimensions and slopes for the various types of LVRs can be found in Appendix A.2.

Some aspects of cross-sectional design are concerned with drainage. Further details concerning this aspect are described in Part C of the Manual.

The cross-section of a road may need to vary over a route, but it is essential that any changes take place gradually over a transition length. Abrupt and isolated changes lead to increased hazards and reduced traffic capacity.

A common situation arises at bridge and water crossing points where the existing structure is narrower than desired. In such situations adequate warning signs must be erected to alert approaching drivers.

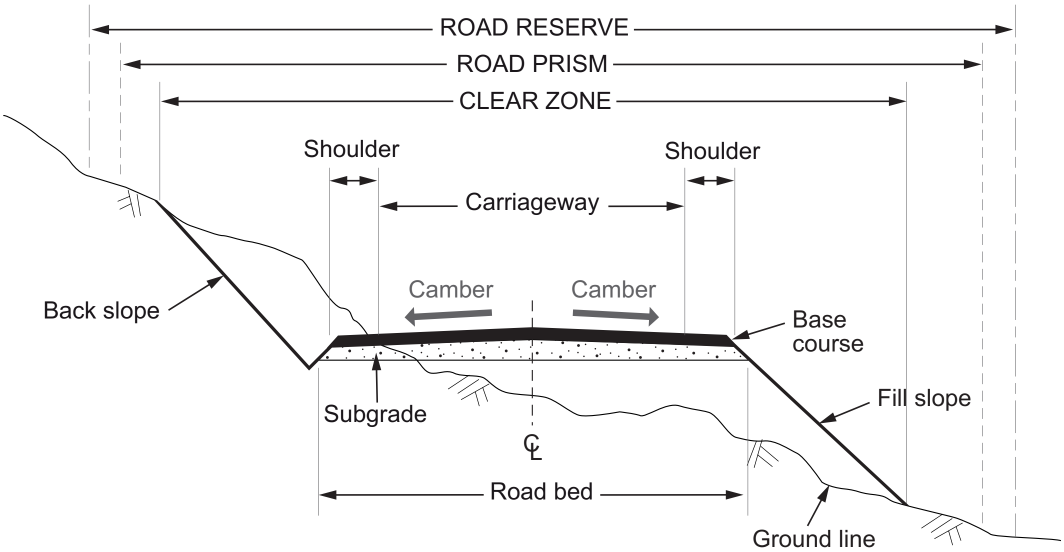


Figure A.6.3: Elements of a typical road cross-section

6.5.2 Width standards

Road width (running surface and shoulders) is one of the most important geometric properties since its value is very strongly related to cost and safety. The tables and typical cross-sections in Appendix A.2 show the standard road widths for each category of LVR.

In Liberia, LVRs which carry traffic volumes of AADT <20 vpd (Type 1) are effectively single lane roads. For LVRs with an AADT 21 - 50 vpd (Type 2) the traffic is less than 5 vehicles per hour in each direction. Vehicles will invariably travel down the center of the road unless another vehicle is seen approaching. In this case, the two vehicles can normally pass each other safely except for larger vehicles which may need to slow down. If there are significant numbers of large vehicles, then the road width recommended for traffic Type 3 should be used. For Type 3 and Type 4 LVRs the same principle applies. Although provision for passing is made easier, if there is an excessive number of larger vehicles in the traffic stream the level of service will be compromised.

In Liberia, the traffic volume on the feeder road system, or Type 1 to Type 3 LVRs, is low and the roads generally do not require shoulders. However, the lower order secondary roads, or Type 4 LVRs, are required to have shoulders. The overall width of gravel roads shown in the tables (Appendix A.2) includes the width of the shoulder, as it is difficult to define the edge of the carriageway (start of the shoulder) on a gravel or earth road. Recommendations regarding widths of shoulders are given in Section 6.5.4.

Where spot improvements are made which involve a short length of paved surfacing (e.g. on a steep incline) then the width used should be that shown in the respective tables for paved roads. This includes the width of the shoulders.

6.5.3 Single lane roads and passing places

The recommended minimum carriageway width for single-lane roads is 3.0 m. Passing places may be required, depending on the traffic level. Provision for other traffic and pedestrians must be introduced through the provision of shoulders if the numbers of other road users exceeds specified levels. The overall width should allow two vehicles to pass at slow speed and hence depends on the design vehicle.

Passing places should normally be provided every 300 m to 500 m depending on the terrain and geometric conditions. Care is required to ensure adequate sight distances and the ease of reversing to the nearest passing place, if required. Passing places should be built at the most economic locations rather than at precise intervals, provided that the distance between them does not exceed the recommended maximum. Ideally, the next passing place should be visible from its neighbor.

The length of passing places is dictated by the maximum length of vehicle expected to use the road. In most cases, a length of 25 m for a passing place, including tapers, is sufficient for LVRs.

The width of the passing places depends upon the width of the road itself. Enough overall width should be provided for two design vehicles to pass each other safely at low speed. Therefore, a total trafficable minimum width of 6.3 m is required (providing a minimum of 1.1 m between passing vehicles). Allowing for vehicle overhang when entering the passing bay, a total road width of 7.0 m is recommended at passing places.

6.5.4 Shoulders

The shoulders of a road must fulfil the following functions:

- Provide structural support to the edges of the road;
- Allow wide vehicles to pass one another without causing damage to the road edge;
- Provide safe room for temporarily stopped or broken-down vehicles;
- Allow pedestrians, cyclists and other vulnerable road users to travel in safety;
- Allow water to drain from within the pavement layers; and
- Reduce the extent to which water flowing off the surface can penetrate into the pavement (often done by extending a seal over the shoulder).

Shoulders. paved or unpaved, have an important structural function and act as edge supports to contain the running carriageway without which the road may move laterally and deform. Therefore, there is a minimum width of shoulder that is required to perform this function. Depending on the properties of the material and the traffic, this can range from 0.2 m to 1.5 m. In Liberia, 0.5 m wide shoulders are incorporated in the carriageway width of feeder roads. For secondary roads, minimum 1.0 m wide shoulders are standard.

Shoulders perform an important traffic-carrying function for non-motorized vehicles and pedestrians. Additional shoulder widths are recommended should there be a high volume of non-motorized transport and 2- and 3-wheeled vehicles (defined as more than 300 PCUs per day on average).When the road passes through denser areas of population, additional width is provided for parking and for other roadside activities. This widening may be considered as shoulder widening, although the need to provide access to shops and market areas means that the construction is usually of an extra carriageway.

In the case of paved roads, the shoulders may be gravel or paved, although the latter is recommended. Paved shoulders encourage non-motorized traffic to use the shoulders rather than the carriageway. On the approaches to villages and towns the local traffic builds up quite quickly and therefore consideration should be given to extending paved shoulders for considerable distances each side of the town or village. No standard guidance can be given, and each situation should be treated on its merits.

Shoulders of unpaved roads should be constructed with the same material as the carriageway and should have the same crossfall as the carriageway. However, In the case of paved roads where the shoulders are gravel, it is recommended that the crossfall of the shoulder be 1.5 to 2.0% steeper than that of the carriageway.

Shoulder widths in mountainous terrain are generally reduced to minimize the cost of earthworks. Usually the design of the overall cross-section in such terrain will include significant drainage and erosion control features and the shoulder will form an important component of this.

6.5.5 Camber and crossfall

Camber is essential to facilitate surface drainage. Ponding of water on a road surface quickly leads to deterioration. In Liberia, paved roads should be constructed with a camber of 3% due to the high rainfall.

Drainage is less efficient on rough surfaces and therefore the camber needs to be higher on unpaved roads. However, if the soil or gravel is susceptible to erosion, high values of camber can cause erosion problems. Steep camber can also cause driving problems, but on low traffic rural roads vehicles generally travel in the middle of the road and steep camber is not a significant problem for drivers. In Liberia, unpaved rural roads are generally constructed using a camber of 6%.

6.5.6 Superelevation

Superelevation is generally not necessary on low traffic feeder roads. Vehicles tend to use the inside half of the road on curves to avoid the effects of the adverse camber. Furthermore, rainwater is required to travel over the full width of the carriageway which leads to excessive erosion of the road surface. It is, however, recommended that superelevation be applied to all paved LVRs and unpaved secondary roads.

For paved LVRs the removal of adverse camber results in an effective superelevation of 3% (Figure A.6.4). This is used to determine the minimum radii of curvature for such roads. At higher speeds the radius of curvature must be large if the superelevation remains at 3%. Where a large radius curve is difficult to achieve due to obstacles in the alignment, superelevation of up to 8% can be used with a resulting decrease in the required horizontal radius of curvature (see Table A.6.8). Minimum radii for the various geometric standards and design speeds are shown in the tables provided in Appendix A.2.

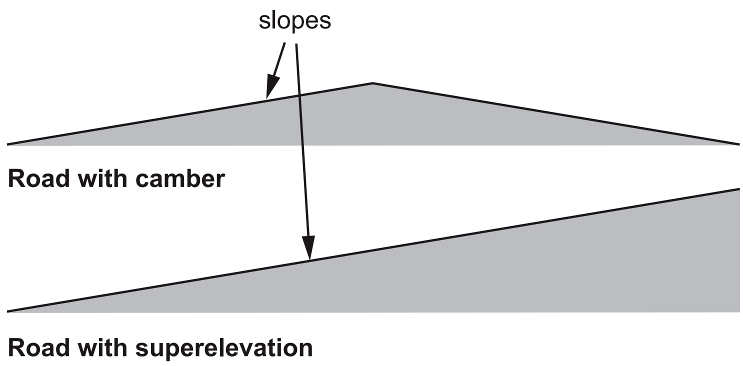


Figure A.6.4: Camber and superelevation

The change from normal camber on straight sections of road to a super-elevated section should be made gradually (Figure A.6.5). The length over which superelevation is developed is known as the superelevation development length and is dependent on design speed. Two-thirds of the superelevation development should be provided for on the tangent before the start of the curve. The remainder of the development is contained within the curve. The rate of change of road slope should be distributed uniformly throughout the length of the transition development.

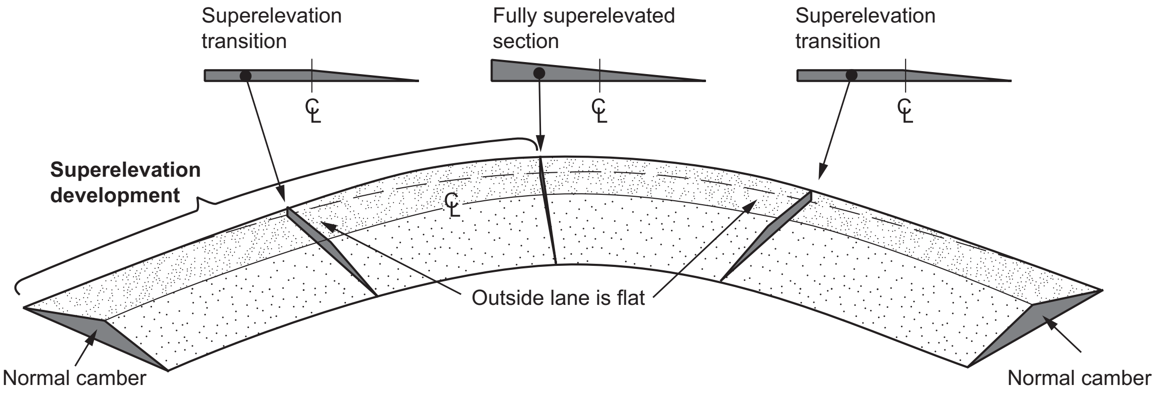


Figure A.6.5: Development of superelevation

Recommended superelevation development lengths are provided in Table A.6.4.

Table A.6.4: Superelevation development lengths

Design Speed (km/h)	Development Length (m)
30	25
40	30
50	40
60	55
70	72
80	92

Source: ERA Manual for Low Volume Roads. 2016

Example

A new paved road designed to a 60 km/h design speed, which is to be constructed with a camber of 3% and a horizontal curve superelevation of 6% will require a superelevation development length of 55 m. The rate of change in road slope per linear meter of road over the development length can be calculated as follows:

Road slope change (%/m) = (superelevation slope – camber slope) / development length

= (6% - (-3%)) / 55 m

= 0.16% per m

6.5.7 Side slopes and embankments

Side slopes should be designed to ensure the stability of the roadway and to provide a reasonable opportunity for recovery if a vehicle goes out of control and leaves the carriageway. In addition, the position of the side drain invert should be a reasonable distance away from the road to minimize the risk of infiltration of water into the road pavement structure if the drain should be full of water for any length of time. Figure A.6.6 illustrates the road edge and defines the various elements.

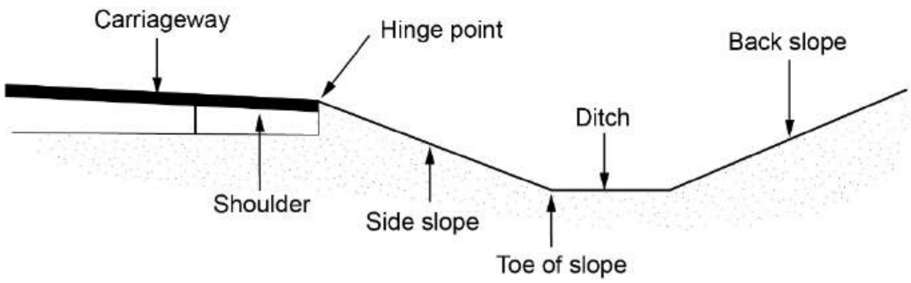


Figure A.6.6: Details of the road edge

The side slope is defined as 'recoverable' when drivers can recover control of their vehicles should they encroach over the edge of the shoulder. Side slopes of 1:3 or flatter are recoverable. Research has shown that rounding at the hinge point and at the toe of the slope is also beneficial.

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. Vehicles on such slopes can be expected to reach the bottom of the slope. A slope that is steeper than 1:3 falls into this category.

The selection of side slope and back slope is often constrained by geotechnical considerations concerning embankment height, height of cuts, drainage considerations, and stability of slopes. These aspects are described in Part C of the Manual. Where slope stability problems are likely to occur, slope configuration and treatment should be based on expert advice. Basic topography, right of way limits, and economic considerations also play an important role.

Flatter side slopes are recommended for low road embankments and where expansive clay is used in the embankment (Table A.6.5). On low embankments the cost of providing flatter side slopes is more affordable than on high embankments, and less land take is required.

Table A.6.5: Recommended side slopes for standard cross-sections for traffic safety

Material	Height of slope (m)	Side slope	Safety classification
All standard fill materials	0 - 1.0	1V:4H	Recoverable
	1.0 - 2.0	1V:3H (2)	Marginal
	2.0 - 3.0	1V:3H	Marginal
	>3.0	1V:1.5H (3)	Critical
Expansive clays (1)	0 - 2.0	1V:6H	Recoverable
	>2.0	1V:4H	Recoverable

Source: Modified from ERA Manual for Low Volume Roads. 2016

Notes:

1. The use of expansive clays on road formation is only recommended on very low traffic unpaved roads.
2. 1V:4H side slope is recommended for secondary roads.
3. For fill slopes safety barriers should be provided on embankments > 3 m high with slopes steeper than 1:3.

6.5.8 Clear zones

Many accidents are made more severe because of obstacles that an out-of-control vehicle may collide with. The concept of clear zones identifies these obstacles and attempts to eliminate such hazards.

The most common hazards are headwalls of drainage culverts and road signage. The clear zone defined for high volume roads is substantial (minimum 5 m is typical) but for LVRs this is impractical. Ideally it should extend at least to the toe of the embankment and should always be greater than 1.5 m from the edge of the carriageway. At existing culverts and bridges the clear zone should not be less than the carriageway width. If this criterion cannot be met, the structure must be widened. New drainage culverts must be designed with a 1.5 m clearance from the edge of the shoulder. Horizontal clearance to road signs and marker posts must also be an absolute minimum of 1.5 m from the edge of the carriageway. Vertical clearances between the top of the road surface to overhead structures and services, such as overpass bridges and power cables, must not exceed an absolute minimum of 4.5 m absolute minimum on feeder roads and 5 m on secondary roads.

6.5.9 Cross-section in hilly and mountainous terrain

For new road construction in hilly or mountainous terrain there are three main choices of cross-section – full cut, part cut/part fill, and full fill, though in practice the vertical and horizontal alignment constraints impose a significant control on the choice of cross-section at any one location. A balance of cut and fill, either in the same cross-section or within economic haul distance, is desirable on economic and environmental grounds where side slopes are up to about 25°.

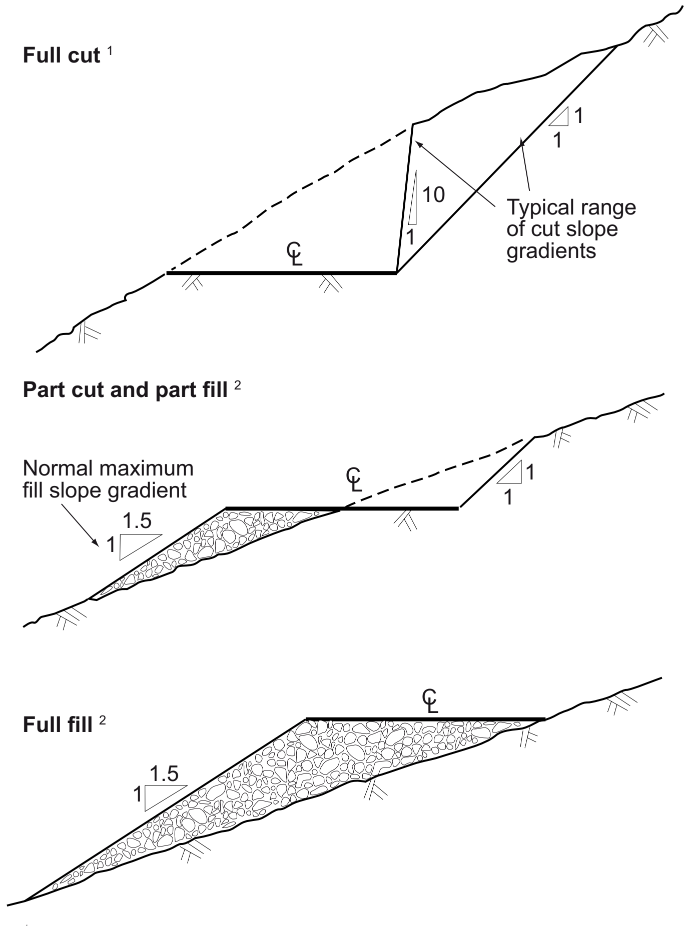


Figure A.6.7: The three main cross-section options

1. May require cut slope protection or stabilization above the road.
2. Will require below-road retaining wall on slopes steeper than 25° unless rock fill or reinforced fill is used.

Where side slopes are 30° or more the cost of constructing the road on fill becomes increasingly significant and full cut becomes the most economic option (Table A.6.6). The reason for this is that fill slopes become difficult to construct on side slopes much above 25°, when the use of expensive retaining walls and reinforced fill is necessary. Full cut is the cheapest option on steep slopes, even when spoil haulage and safe disposal are taken into account. Another advantage with a full cut cross-section is that there is little need for subgrade compaction. On labor-based LVR projects this can be an important consideration. Table A.6.7 summarizes the main advantages and disadvantages with the three options.

Table A.6.6: Cost comparison for full cut, half cut-half fill and full fill cross-sections

Natural slope angle (degrees)	Cost units per meter run of road		
	Full cut	Half cut, half fill	Full fill
10	15	5	12
20	43	16	39
30	77	170	437
40	204	319	559
50	305	505	n/a

High full fill costs for natural slopes ≥30° are due to retaining wall requirements.
Modified from Hearn 2011.

Table A.6.7: Advantages and disadvantages with types of cross-sections

Type of section	Advantages	Disadvantages
Full cut	■ Road formation requires minimum compaction because it is formed entirely in natural ground.[1] ■ No requirement for fill slope placement or compaction. ■ Potential source of fill material for use elsewhere along the road. ■ Potential source of rock for masonry, aggregate and drainage backfill. ■ Usually the only practical solution if existing ground slope > 50°.	■ Greater height of cut may lead to greater instability and/or erosion. ■ May result in large volumes of spoil requiring safe disposal.
Part cut and part fill	■ Volume of spoil minimized if balanced cut/fill can be obtained. ■ Minimum impact on landscape.	■ Requirement for fill placement and compaction. ■ May require below-road retaining wall or reinforced fill to avoid excessive area of fill if existing ground slope > 25°.
Full fill (including wall-retained fill)	■ Usually only practical solution when traversing re-entrants or water courses. ■ Usually only practical solution (with fill retaining structure) on steep rock slopes if jointing is unfavorable to stability.	■ Requirement for significant fill import, ground preparation (including benching), placement and compaction. ■ Will require below-road retaining wall or reinforced fill to avoid excessive fill area if existing ground slope > 25°. ■ Impracticable if existing ground slope > 40°.

[1] Transported soils and some low-density residual soils exposed in the subgrade of some full cut sections require compaction and possibly replacement.

Modified from Hearn 2011.

Depending upon the geological conditions, full cut cross-sections can provoke slope instability through the removal of slope support (Figure A.6.8). This applies to both new road construction and the widening of existing roads and it applies to slopes formed in rock and soil. Where the strata or the main jointing patterns in the rock can be seen to be dipping into the slope (“favorable dip” in Figure A.6.8), the excavation of the cut slope is unlikely to trigger large-scale sliding. Where the strata dip is unfavorable then excavation can be expected to trigger slope instability problems. The extent of these problems depends upon the strength of the rock along its joints, which is a function of tightness, degree of weathering and water pressures. These factors should be considered if a full cut cross-section is selected.

The same situation occurs in soil slopes. Where the soils are inherently loose and weak, where they have previously failed and where water tables are high, full cut excavation usually leads to slope problems. The alternative involves retained fill or reinforced fill, both of which are expensive and both of which can be difficult to construct in confined spaces and where foundations are weak. In such situations, it is advisable to consult a specialist engineering geologist or geotechnical engineer. Where the geological conditions are so extreme that expensive technical solutions are required, then it may be more economic in both the short and long term to change the road alignment.

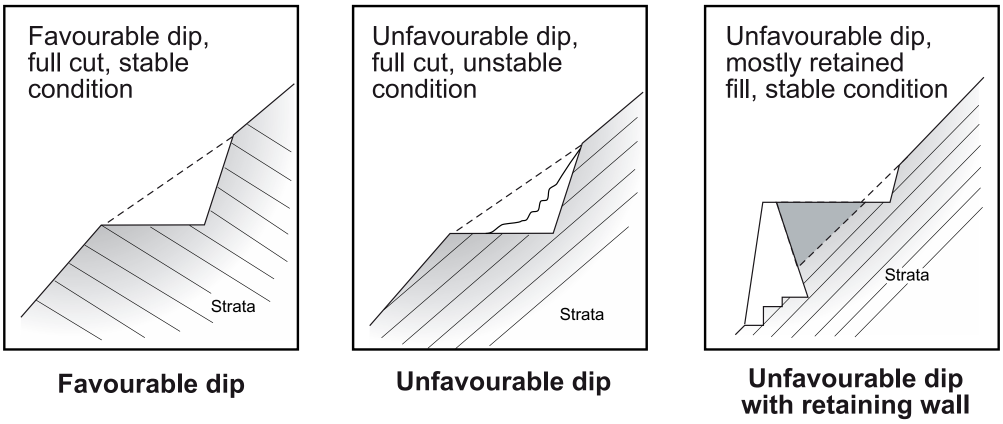
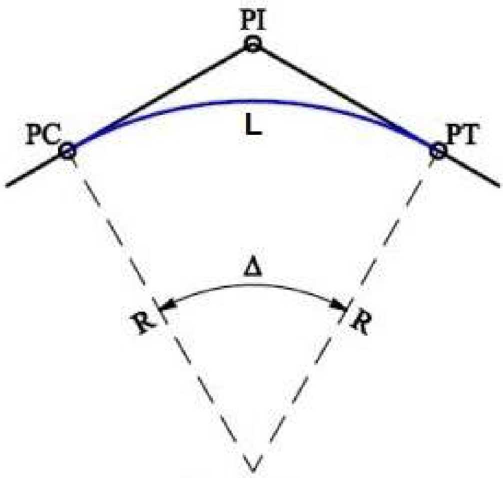


Figure A.6.8: Unfavorable and favorable rock strata and jointing patterns

6.6 Horizontal alignment

6.6.1 Components of horizontal alignment

The horizontal alignment consists of a series of straight sections (tangents) connected to circular curves. Long tangents in excess of about 4 km should be avoided as this usually leads to excessive speeding. The design of horizontal curves is to ensure that vehicles can negotiate them safely. The design of horizontal curves, including computations of appropriate radius, superelevation and setting out, is recommended where the design speed exceeds 50 km/h. The alignment design should avoid sharp changes in curvature, thereby achieving a safe uniform driving speed. The standard components of a simple horizontal circular curve are illustrated in Figure A.6.9.



PI – Point of Intersection
PC – Point of Curvature
PT – Point of Tangency
L – Circular Curve Length
R – Circular Curve Radius
Δ – Central Angle

Figure A.6.9: Elements of a simple horizontal curve

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 tires and the road surface assisted by the crossfall or superelevation.

For all paved roads and higher order unpaved roads there are also constraints on the maximum crossfall or superelevation slopes, which translates directly into minimum values of horizontal radii of curvature. The recommended minimum radii based on design speed are shown in Table A.6.8.

Table A.6.8: Minimum horizontal radii of curvature

Design Speed (km/h)	Unpaved		Paved	
	Camber (%)	Minimum radius (m)	Maximum superelevation (%)	Minimum radius (m)
30	6	30	3	25
40	6	60	4	50
50	6	95	5	85
60	6	135	6	125
70	7(1)	185	7	175
80	8(1)	230	8	230

1. Based on the application of superelevation for unpaved secondary roads only.

6.6.2 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 will exceed design speeds; and
- At or near intersections and approaches to bridges or other water crossing structures.

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. Care should be exercised to ensure the curves are not too tight.

Another aspect is to ensure that there are enough opportunities for safe overtaking. 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.

The recommended lengths for horizontal curves based on design speed are shown in Table A.6.9.

Table A.6.9: Recommended minimum length of horizontal curves

Design speed (km/h)	30	40	50	60	70	80
Minimum curve length (m)	50	70	80	100	120	140

Source: Modified from Ghana MRH Design Standards for DFR, 2009

6.6.3 Curve widening

Widening of the carriageway where the horizontal curve is tight is sometimes necessary to ensure that the rear wheels of the largest vehicles 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.

Vehicles need to remain centered in their lane to reduce the likelihood of colliding with an oncoming vehicle or driving on the shoulder. Sight distances should be maintained as described previously. The levels of widening shown in Table A.6.10 are recommended except for roads carrying the lowest levels of traffic (AADT ≤ 20). Widening should be applied on the inside of the curve and introduced gradually.

Table A.6.10: Widening recommendations

Single lane roads		2-lane roads	
Curve radius (m)	Width of widening (m)	Curve radius (m)	Width of widening (m)
< 30	1.5(1)	< 20	Hairpin bend (1)
30 - 60	1.0	20 - 40	1.5
61 - 150	0.6	41 - 60	1.2
> 150	0.0	61 - 120	0.9
		121 - 250	0.6
		> 250	0.0

Sources: MoPW Feeder Roads Design Manual and Specifications. 2016
Draft SLRA Road Design Manual. Part 1 Geometric Design. 2012

1. See Section 6.7.4 dealing with hairpin stacks.

6.7 Vertical alignment

The two major elements of 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 driver 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.

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

6.7.1 Gradient

Where possible, road gradients should be kept as low as possible, but 0.5% is the absolute minimum to ensure longitudinal drainage. Two-wheel drive trucks can generally cope with gradients of 15%, except when heavily laden. International rural road standards have a general recommended limit of 12% for small heavily laden trucks, but this can be increased to 15% for short sections (< 250 m) in areas of difficult terrain. The Liberian authorities have adopted these same maximum limitations for feeder roads, but for secondary roads a desirable maximum of 8% and absolute maximum of 12% is recommended.

Where truck speeds are reduced to an unreasonable speed as a result of climbing excessively long lengths of upgrades, climbing lanes can be considered. However, as slow moving vehicles are mostly inconvenient for roads carrying high traffic, climbing lanes are not normally appropriate for LVRs.

Regional experience indicates that unpaved road sections in excess of 6% gradient are often unsustainable in the medium to long term. It is expected that the use of alternative surfacings will become more common in Liberia to provide a more sustainable solution in critical areas such as on steep sections. Therefore, criteria need to be developed to identify the critical areas where alternative surfacings are to be recommended. The recommended maximum gradients based on design speed are shown in Table A.6.11.

Table A.6.11: Recommended maximum gradient

Design speed (km/h)	30	40	50	60	70	80
Flat terrain	7%	7%	7%	7%	7%	4%
Rolling terrain	9%	9%	9%	8%	8%	6%
Mountainous terrain	10%	10%	10%	10%	10%	8%

Source: MoPW Geometric and Pavement Design Standards. 2017

6.7.2 Crest curves

The minimum length of the curve (L) over the crest of the hill between the points of maximum gradient on either side is related to gradient and to the stopping sight distance and 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 LVRs.

The minimum length of the curve is defined by L=KG, where K is a factor derived from the stopping sight distance, and G is the algebraic difference in grade (%). Minimum values of K are provided in Table A.6.12.

Table A.6.12: Minimum values of K for crest curves

Design speed (km/h)	30	40	50	60	70	80
Feeder roads	5	8	12	20	35	46
Secondary roads	2	4	7	11	17	26

Sources: MoPW Feeder Roads Design Manual and Specifications. 2016
MoPW Geometric and Pavement Design Standards. 2017

Example

The minimum length of crest curve for a feeder road with a design speed of 40 km/h on a steep uphill stretch of 10% followed by a downhill stretch of the same slope = 8 x (+10 - (-10)) = 160 m.

6.7.3 Sag curves

Sag curves are the opposite of crest curves in that vehicles first travel downhill and then uphill (through a valley). 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 somewhat less important than road safety issues. However, at night 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 determination of curve lengths for feeder roads is based on driver comfort criterion as the driving speed at night is assumed to be low and therefore sight distance is not considered a significant influence. For secondary roads, where travel speeds are expected to be higher, the determination of curve length is based on headlight illumination sight distance rather. Minimum values of K are provided in Table A.6.13.

Table A.6.13: Minimum values of K for sag curves

Design Speed (km/h)	30	40	50	60	70	80
Feeder roads	5	8	12	18	20	25
Secondary roads	6	9	13	18	23	30

Sources: MoPW Feeder Roads Design Manual and Specifications. 2016
MoPW Geometric and Pavement Design Standards. 2017

Example

The minimum length of sag curve for a secondary road with a design speed of 60 km/h on a steep downhill stretch of 10% followed by an uphill stretch of the same slope = 18 x (+10 - (-10)) = 360 m.

6.7.4 Hairpin stacks

Climbing sections on mountainous roads are often best designed using hairpin stacks. The advantages are that the most favorable site for ascending the mountain can be selected and a more direct and therefore shorter route will often be possible. However, there are several limitations. For example, the limited space available to construct cut and fill slopes necessitates either a reduction in geometric standards or more expensive retaining structures. For LVRs the former solution should be adopted. Furthermore, a lack of suitable sites for disposal of spoil and access difficulties for plant can pose difficulties during construction.

If there are problems of slope instability, they may extend from one loop to another and so the advantage of attempting to choose the most stable section of the mountain is lost. This issue is dealt with in Part C of the Manual.

Stormwater run-off becomes very concentrated on hairpin stacks, so although the number of drainage structures and erosion controls may be reduced, their capacity needs to be increased. The risk associated with failure of the drainage system is therefore correspondingly high and minimizing this risk adds to the cost. 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 reduces drainage problems and limits the danger of instability to fewer hairpin loops.

The key aspect of the geometric design of hairpin stacks 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 AADT >50 vpd and up to 6% for AADT <50 vpd.

Curve widening is required where the curve radius is small to ensure that large vehicles can negotiate the bends (Table A.6.10). Widening is also required for safety reasons and to provide a refuge area if a vehicle breaks down. For LVRs it is recommended that the curve radius at the center line of the road should be an absolute minimum of 13 m and the road should be at least 8 m wide.

6.8 Harmonization of horizontal and vertical alignment

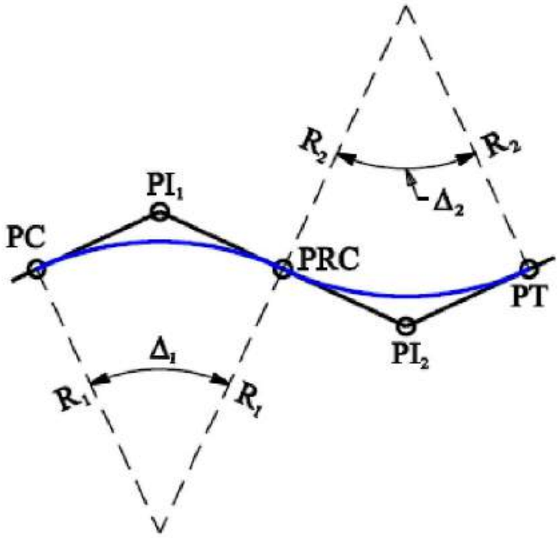
6.8.1 Situations to avoid

When designing the horizontal alignment of a road, the designer must ensure that the other elements of the design are complementary to each other. It is therefore important to note that there are several design situations that could produce unsatisfactory combinations of elements even though the design standards have been followed. These are designs that could provide surprises for drivers by presenting them with unfamiliar conditions compromising the safety of the facility.

Avoiding such designs is more important for classes of road where design speeds are higher and 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.

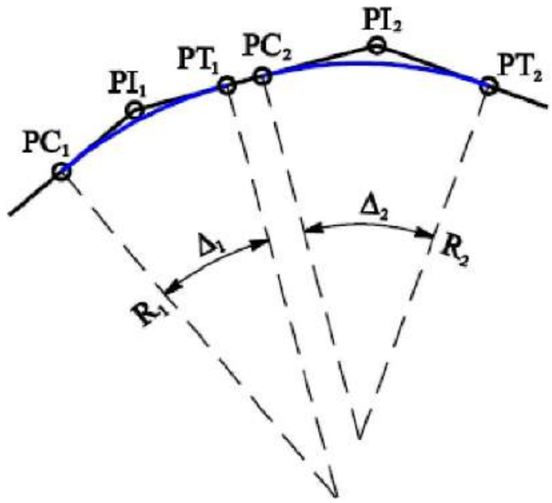
Reverse curves

A horizontal curve followed immediately by a curve in the opposite direction. This configuration makes it difficult for the driver to keep the vehicle on its intended side of the road. In the case of paved roads, it is difficult to accommodate the required superelevation development within the space available.



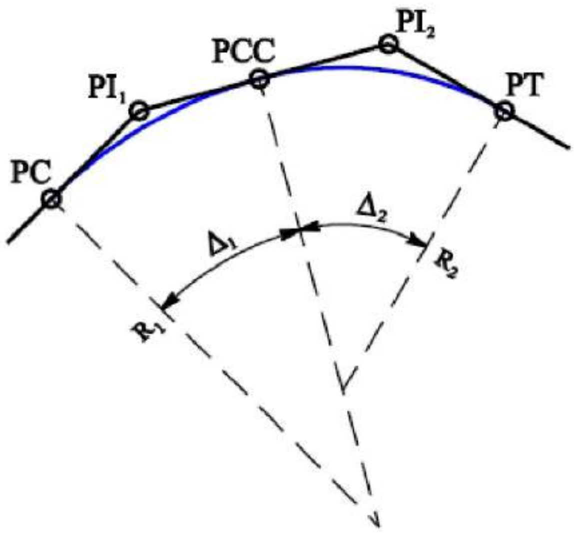
Broken back curves

Two horizontal curves in the same direction connected by a short connecting tangent. Drivers do not usually anticipate that they will encounter two successive curves close to each other in the same direction. In the case of paved roads, it is difficult to accommodate superelevation development within the space available in the situation where curve radii differ.



Compound curves

A horizontal curve connected to another of different radius. Drivers do not usually expect to be confronted by a change in radius, and therefore in design speed. If the change is too great, some drivers are likely to be travelling too fast when entering the tighter part of the compound curve from the larger radius curve. Compound curves should be avoided where curves are sharp and where the difference in radii is large. Thus, in any compound curve the smaller radius should not be less than 67% of the larger one.



Isolated curves

An isolated horizontal 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 good practice to avoid the use of minimum standards in such situations. An added bonus is that, provided no extra cutting or filling is required, the use of a larger radius of curvature results in a shorter and less expensive road. Curve widening can help to alleviate this problem if a higher radius curve cannot be used.

Long curves

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 large radius should be used in such situations.

6.8.2 Balance

There are several competing factors in providing the optimum horizontal alignment. Small radii curves 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.

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. In summary, engineering choice plays a part in the final design which is a balance between competing requirements.

6.8.3 Phasing

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 poor phasing are as follows:

A sharp horizontal curve following a pronounced crest curve where the unexpected bend can be hazardous, especially at night. The solution to this is to separate the curves to use a gentler horizontal curve, or to begin the horizontal curve well before the summit of the crest.

Both ends of the vertical curve lie on the horizontal curve. If both ends of a crest curve lie on a sharp horizontal curve the radius of the horizontal curve may appear to the driver to decrease abruptly over the length of the crest curve. If the vertical curve is a sag curve the radius of the horizontal curve will appear to decrease. The solution is to make both ends of each curve coincide or to separate them completely.

A vertical curve overlaps both ends of a sharp horizontal curve. This creates a hazard because a vehicle must turn sharply while sight distance is reduced on the vertical curve. The solution is to make both ends of each curve coincide or to separate them completely.

6.9 Junctions and intersections

Road accidents are most likely to occur at junctions and intersections. Hence, where possible, a safe environment should be created, and good sight distances provided particularly under night driving conditions. The following principles should be considered when locating and designing an intersection:

- Intersections should not be located on high cut and fill embankments, near to bridges or structures, on small radius curves, or on super-elevated curves.
- To ensure good visibility, vegetation should be permanently cleared from the area surrounding the junction.
- Avoid building intersections on moderate to steep gradients or at the bottom of sag curves as vehicle acceleration and deceleration distances are compromised. A maximum gradient of 3% is recommended however 6% may be adopted in more difficult terrain.
- The ideal intersecting angle of connecting roads should be 90° as this provides maximum visibility in both directions, however visibility is not seriously affected as long as the angle exceeds 70°.

Where two roads must cross each other, a simple cross junction is adequate for LVRs. However, where possible, it is preferable to provide two staggered T-junctions as illustrated in Figure A.6.10. The most heavily trafficked road is retained as the through route whilst the minor road is split so that traffic must enter the major road by making a left turn onto the major road and then a right turn to re-enter the minor road. The number of possible maneuvers where the traffic from the minor road must cross the traffic stream on the major road are then reduced by 50%. The entry points of the two arms of the minor road should be spaced at least 40 m apart.

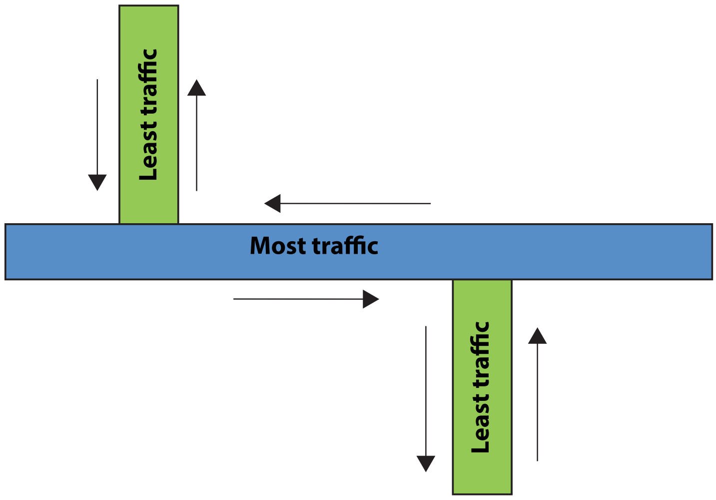


Figure A.6.10: Preferred intersection design

Source: ERA Manual for Low Volume Roads, 2016

6.10 Selecting the geometric design standards

6.10.1 Procedure

The following steps and flow diagram (Figure A.6.11) show how the appropriate geometric standards for LVRs are selected. The references referred to in each step should be consulted for further details.

Step 1 (Section 5.3): Determine the design traffic volumes in terms of motorized and non-motorized traffic as well as the proportion of heavy vehicles. 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.

Step 2 (Section 5.6): Determine the design heavy traffic volume thresholds. This later influences the category, or type, of LVR selected using the total motorized traffic volume in Step 4 to compensate for excessively high proportions of heavy vehicles expected in the traffic stream.

Step 3 (Section 5.7): Determine the passenger car equivalency (PCU) of expected non-motorized traffic and 2- and 3-wheeled motorized vehicles. The numbers and characteristics of all the other road users are to be considered, and therefore it is here that the road layout may need to be altered and additional width provided for safety, and to improve serviceability for all road users (e.g. reduce congestion caused by slow moving traffic). The impact that excessive PCUs of non-motorized transport and 2- and 3-wheeled motorized vehicles has on selecting the road geometric characteristics for design purposes is assessed in Step 10.

Step 4 (Section 1.2): Using Table A.1.1, select the appropriate category, or Type, of LVR to be used based on the previously determined total design motorized traffic volumes adjusted for excessive heavy vehicle volumes where appropriate from Step 2.

Step 5 (Sub-Section 6.3.4): Determine the terrain class. This is either classed as being flat, rolling, or mountainous and has influence on the road geometric characteristics.

Step 6 (Sub-Section 6.3.5): Determine whether the road passes through populated areas (towns, villages, market areas) or open country. This influences the selection of the geometric features of the road. Populated areas may require parking areas, lay-bys, bus bays, areas for traders etc.

Step 7 (Sub-Section 6.3.6): Determine whether the road is expected to be paved within the design period. This has an impact on the selection of the geometric criteria used for design. For most road classes there are options for road pavement type. The adoption of an Environmentally Optimized Design (EOD) policy will mean that different parts of the road may be designed with a different pavement or surfacing. The choice of road pavement type is described in Part B of the Manual.

Step 8 (Sub-Section 6.4.1): Select the design speed for the road. Most road geometric standards are based on the design speed.

Step 9 (Section 6.4): Select the minimum sight distance requirements to be used for design purposes for stopping, for intersections, and for passing.

Step 10 (Section 6.5): Determine the widths of the carriageway, shoulders, roadside ditches and clear zones, as well as the cross-sectional slopes of the carriageway, shoulders, sides and embankments. Increase the shoulder width if the expected number of PCUs of non-motorized transport and 2- and 3-wheeled motorized vehicles exceeds 300 per day. At this stage additional factors which affect the geometric standards should be considered, such as additional road safety features and the construction technology to be employed.

Step 11 (Sections 6.6 and 6.7): Select the minimum road alignment curvature requirements for the horizontal and vertical alignment. For lower traffic LVRs this is done manually in the office or in the field on a curve-by-curve basis. For higher traffic LVRs the vertical and horizontal alignment is normally generated by a computer program from the topographical survey data.

Step 12 (Appendix A.2): Using the category, or type, of LVR determined in Step 4, along with the decision whether to pave the road from Step 7, select the appropriate geometric design standards and characteristics summarized in the tables and typical cross-sections in Appendix A.2. It should be noted that the tables and cross-sections contain only the most relevant information on geometric standards and therefore the chapters leading up to the selection process should be consulted for further guidance and information.

6.10.2 Matrix of Standards

The four basic types of LVR (Table A.1.1) have been expanded to accommodate the various factors which influence the design standards. This includes terrain, roadside population, and whether the road is to be paved. This resulted in the development of seven distinct design standards as follows:

1. Type 1 unpaved Feeder roads (AADT 1-20)
2. Type 2 unpaved Feeder roads (AADT 21-50)
3. Type 2 paved Feeder roads (AADT 21-50)
4. Type 3 unpaved Feeder roads (AADT 51-150)
5. Type 3 paved Feeder roads (AADT 51-150)
6. Type 4 unpaved Secondary roads (AADT 151-300)
7. Type 4 paved Secondary roads (AADT 151-300)

Geometric design standards for these seven categories of LVR are summarized in Appendix A.2.

6.10.3 Completion of the design process

The completion of the design process is the preparation of a trial alignment to be used as a check to ensure that all the standards have been met. If not, alternative alignments should be tried. In extreme conditions it may not be possible to adhere to all of the standards at all points along the road. In such cases engineering judgement or additional technical advice may be needed.

The pre-feasibility study should have shown that the costs of the road are likely to be acceptable in relation to the budget and the economic benefits of the road. However, at the design stage it may be found that the engineering problems are more expensive to solve than anticipated. If the costs are high the feasibility of the project may need to be reviewed.

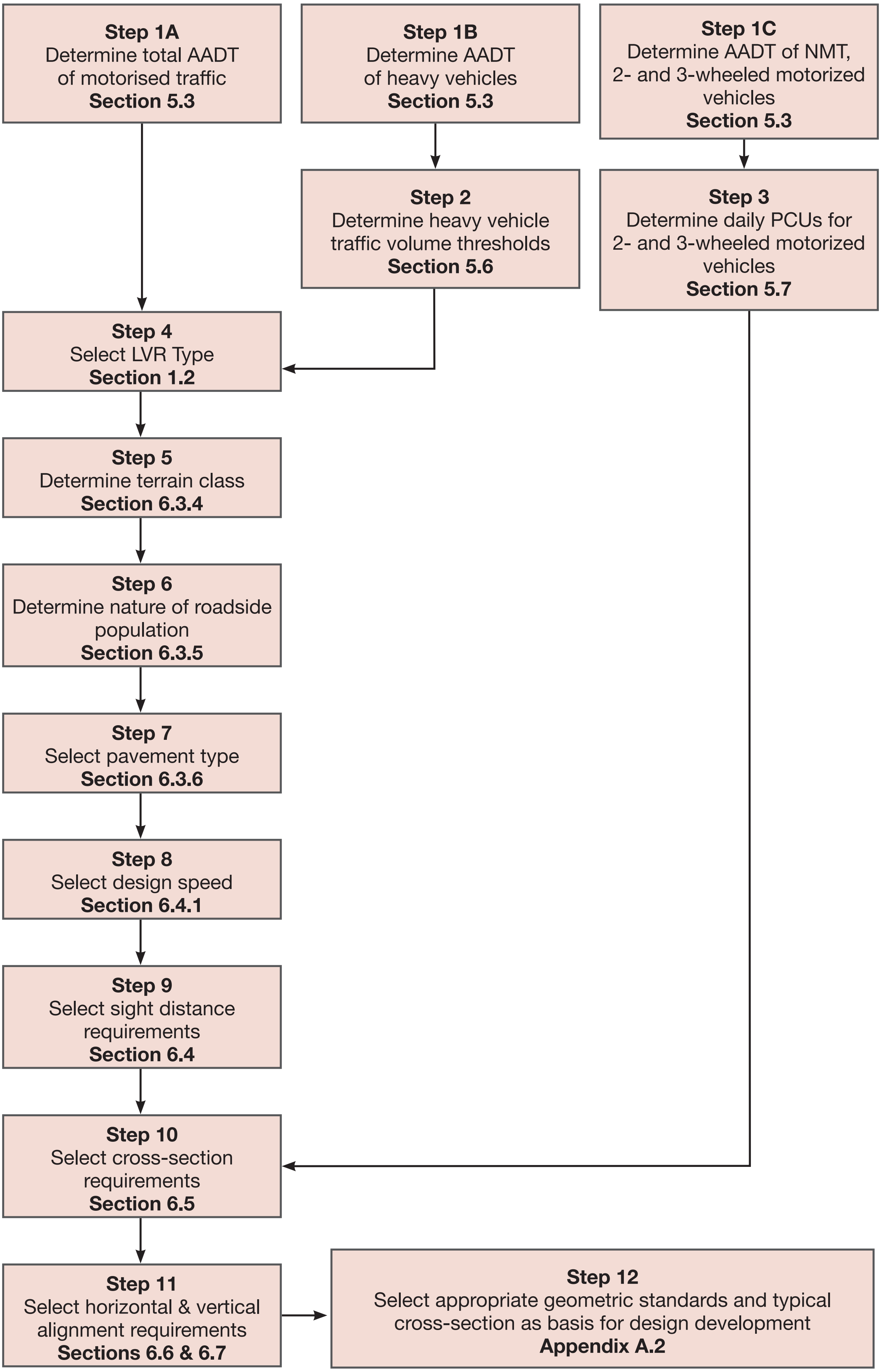


Figure A.6.11: Procedure for selecting geometric design standards

7. ROAD SAFETY

7.1 Introduction

Although accident data and statistics in Liberia are generally not available, the number of road accidents is seemingly quite low. This is believed to be as a result of a low vehicle volumes and low speed promoted by most roads being unimproved tracks. Motorcycles make up an overwhelming majority of all accidents, but accidents involving cyclist and pedestrians are also significant. Poor road design and condition are major contributors to the cause of these accidents. Every effort should be made to reduce the number of serious and fatal accidents including bringing about awareness and educating the public in road safety.

There are several key principles of design that can considerably improve the safety of LVRs. These are:

- Designing for all road users. This includes non-motorized vehicles, pedestrians, etc. and has implications for most aspects of road design, including cross-sectional features previously described.
- Providing a clear and consistent message to the driver. Road layouts should be easily and immediately understood by road users and should not present them with any sudden surprises. This should also ensure that demands are not placed upon the road user which are beyond his or her ability to manage.
- Encouraging appropriate speeds and behavior by design. Traffic speed can be influenced by altering the appearance of the road, for example by providing clear visual clues such as changing the shoulder treatment or installing prominent signage.
- Conflicts cannot be avoided entirely but can be reduced by design, such as staggering junctions, or using guardrails to channel pedestrians to safer crossing points.
- Creating a forgiving road environment that accommodates driver error or vehicle failure to the extent that this is possible without significantly increasing costs.

The geometric design of roads has an important part of achieving a safe road environment. This is highlighted throughout the Manual through the following:

- Road and shoulder widths are adequate to accommodate pedestrians and other forms of non-motorized transport.
- Moderate design speeds have been used for elements of road alignment.
- Parking places and lay-bys have been included for public transport vehicles in populated areas.
- Account has been taken of reduced friction on unpaved roads.
- Acceptable road slopes for drainage of road surface and out-of-control vehicle recovery have been recommended.
- Adequate sight distances have been provided.

However, there are several other steps that could be taken to improve safety. These include:

- Traffic calming measures to reduce speeds in populated area.
- Road markings and signage.
- Segregating non-motorized and motorized vehicles in populated areas.
- Providing crash barriers at dangerous locations.
- Carrying out a professional safety audit at the design stage.

7.2 Traffic signs

7.2.1 Introduction

Clear and efficient signage is an essential part of the road system. Road users depend on signs for information and guidance, and road Authorities rely on signage for traffic control and regulation, and for road safety.

The physical layout of the road must sometimes be supplemented by effective traffic signing to inform and to warn drivers of any unexpected changes in the driving conditions. Some of the common situations are mentioned below, but each situation is unique, and the severity of any particular situation can vary considerably. For cost effectiveness, signs should be restricted to situations where there is a real need to inform road users. It is recommended that the judgement of an experienced road safety expert is obtained at the design stage.

For an existing road that is to be upgraded, the hazardous locations should be identified at an early stage and, ideally, should be corrected in the new design. If this is not possible, then suitable permanent road signs should be installed. Temporary signage should be used when roadworks are being carried out or are required.

There are three general classifications of traffic signs:

- Regulatory Signs: indicate legal requirements for traffic movement and are essential for all roads.
- Warning Signs: indicate conditions ahead that may be hazardous to road users.
- Information Signs: convey information of use to the road user.

Further information and details of standard traffic sign requirements can be found in the Road Signs and Markings Standards manual (2017) compiled by the Liberia Ministry of Transport and Ministry of Public Works.

7.2.2 Regulatory signs

Regulatory signs are a range of signs used to control the actions of road users in the interest of safety. They indicate or reinforce traffic laws, regulations or requirements which apply either at all times or at specified times or places upon a public road facility. They include traffic flow control signs that regulate the movement of traffic, command signs that tell you what to do under a given set of circumstances, and prohibition signs that indicate what is not allowed. It is an offence for road users to disobey any of these signs. The signs are displayed as white discs with a red border and black message symbol or word. Temporary versions of the signs have a yellow background.

The most commonly used regulatory sign is the speed limit sign which indicates the maximum speed permitted on a road or over a particular section of the road. A general speed limit is applicable on all roads and does not have to be displayed by a road traffic sign. Other regulatory signs required on LVRs may include vehicle restrictions such as for weight, length and width.

7.2.3 Warning signs

Warning signs are used to alert drivers to dangers or potential hazards that are not clearly visible from a safe distance ahead. They are usually found some distance before the hazard to allow the driver enough of time to react. The signs are displayed as white triangles with a red border and black message symbol or word. Temporary versions of the signs have a yellow background. Hazard marker plates are rectangular red and white plates (or red and yellow for temporary versions) that are positioned at the hazard itself, for example, at bridges or drifts, on sharp bends or at an obstruction at the edge of the road.

The most common use for warning signs is to indicate situations where the geometric standards for a particular class of road have been changed along a short section of road. This is usually caused by a constraint of some kind that has prevented the standard from being applied continuously and therefore causes an unexpected and potentially dangerous situation. Examples are a sharp bend, a sudden narrowing of the road, an unexpectedly steep gradient, or an unexpected school crossing. There are many examples and engineering judgement is required.

A common situation occurs in populated areas where traffic calming measures have been introduced. Speed humps are a particular problem because they are often not sufficiently visible from a reasonable distance, and sometimes they have been badly designed and provide more of a jolt to the vehicle than intended. It is therefore good practice to provide warning signs for these, especially on roads that are likely to be used by traffic unfamiliar to the area.

An important consideration on unpaved roads is that the road markings that are generally used on paved roads to improve safety cannot be applied to unpaved roads. This means that if drivers need to be warned of a hazard that is traditionally done by means of road markings this will have to be done by means of traffic signs.

7.2.4 Information signs

Information signs provide information about the road ahead, so road users can plan their road and lane usage accordingly. Guidance signs indicate the route details, for example distances and directions to destinations and public facilities, as well as traffic lane arrangements ahead.

Information and guidance signs are less vital on the lower classes of road frequented primarily by local people. However, for road classes where the AADT exceeds 75 vehicles per day on which a considerable proportion of drivers will not be local, information signs are desirable. They obviate the need for drivers to stop in populated areas to ask questions of pedestrians and hence improve safety, but in most cases this effect is very marginal, especially if the road standards that should be provided in populated areas have been applied. Hence the convenience of some information signs is part of the provision of a particular level of service to the traveler.

7.3 Road markings

Road markings are traffic signs painted onto paved road surfaces, and consist primarily of center lines, lane lines, no overtaking lines and edge lines. As with traffic signs, these too are classified into Regulatory, Warning, Information and Guidance markings. They have the same meanings as the traffic signs, and road users should react accordingly. Surface markings are painted in white or yellow according to the message they convey.

Other pavement markings such as ‘stop’, pedestrian crossings and various word and symbol markings may supplement pavement line markings. In cases where a warning is deemed necessary for safety reasons, but road markings cannot be used, road signs must be used instead.

The extent to which road markings, signs and other road furniture is required depends on the traffic volume, the type of road, and the degree of traffic control required for safe and efficient operation. Road markings are generally not justified on LVRs, however on a paved, two-lane road, a center line is desirable. Such a road is not likely to have been built unless the traffic justifies it and hence, for safety reasons, a center line is recommended. The main elements are:

- Traffic signs provide essential information to drivers for their safe and efficient maneuvering on the road;
- Road markings to delineate the carriageway center line and edges to clarify the paths that vehicles should follow; and
- Marker posts to indicate the alignment of the road ahead and, when equipped with reflectors, provide optical guidance at night.

7.3.1 Object markers

Physical obstructions in or near the carriageway should be removed in order to provide the appropriate clear zone. Where removal is impractical, such objects should be adequately marked by painting or by use of other high-visibility material.

7.3.2 Road studs

Reflective road studs should be provided on all paved roads. Typically, these are used to improve guidance at night, particularly where road markings become ineffective, or where rainy or misty conditions are a common occurrence. If there are budget limitations their use can be confined to sharp radius bends where the road edge and lane demarcations may be obscured during darkness or abnormal weather conditions. It is recommended that no fewer than three road studs should be visible to a driver at any one time to define a specific line.

Road studs are to be provided to demarcate the road edges or road center line, the latter being the minimum provision. Road studs should be positioned in the center of the gaps between dashed road lane markings or 50 mm away from the inside of the road edge. Where painted road edge lines are provided, the road studs should be positioned 50 mm away from the outside of the painted road edge line and in line with the center-line studs.

The recommended spacing of road studs is provided in Table A.7.1. Under certain extraordinary conditions, the spacing (center to center – c/c) of road studs may be reduced to the intermediate spacings as indicated. Typically, this would be where visibility is obscured by rain or mist. Under abnormal conditions such as areas with heavy rain or heavy mist, the spacings may be reduced even further as indicated.

Table A.7.1: Recommended longitudinal road stud spacing

Location	Normal m - c/c	Intermediate m - c/c	Abnormal m - c/c
Rural	24	12	6
Urban	18	9	3

7.3.3 Marker posts

There are two types of marker posts in use namely guideposts and kilometer posts. Guideposts are intended to make drivers aware of potential hazards such as abrupt changes in shoulder width and alignment or approaches to structures. On unpaved roads they are often the only option for warning drivers of such hazards. Their use is strongly recommended. They should be painted white and include a panel of retro-reflective material. Kilometer posts are a requirement for higher order roads and are therefore normally only required on roads where the AADT exceeds 150 vehicles per day.

7.4 Traffic calming

7.4.1 Introduction

The seriousness of road accidents increases dramatically with speed and hence very significant improvements to road safety are possible if traffic can be slowed down. This process is called traffic calming. All such methods have their advantages and disadvantages and the effectiveness of the methods also depends on aspects of road user behavior.

The effect of any traffic calming measure on all the road users should be carefully considered before they are installed. Some are not appropriate for unpaved roads, and others unsuitable if large buses are part of the traffic stream. Some are very harsh on bicycles, motorcycles and motorcycle taxis, and others are totally unsuitable when there is any animal drawn transport.

Three types of traffic calming measures are recommended:

- Vertical deflection (road humps, rumble strips and jiggle bars);
- Horizontal deflection (raised islands and road narrowing / staggering); and
- Visual deflection (gateways, pre-warnings and village treatment).

7.4.2 Speed humps and speed cushions

Road humps are the most commonly used form of traffic calming device used to slow traffic on paved roads. They are raised sections installed across the road extending uniformly from one side of the road to the other. Unlike rumble strips, speed reduction humps are quite high and, if they are designed badly, they can cause considerable vehicle damage. They are often used very effectively in villages but usually unpopular with road users. The locations of speed humps should be discussed with local communities to identify the specific locations where pedestrians use the roads and where vehicles travel at high speeds. Examples of speed humps are shown in Figure A.7.1.

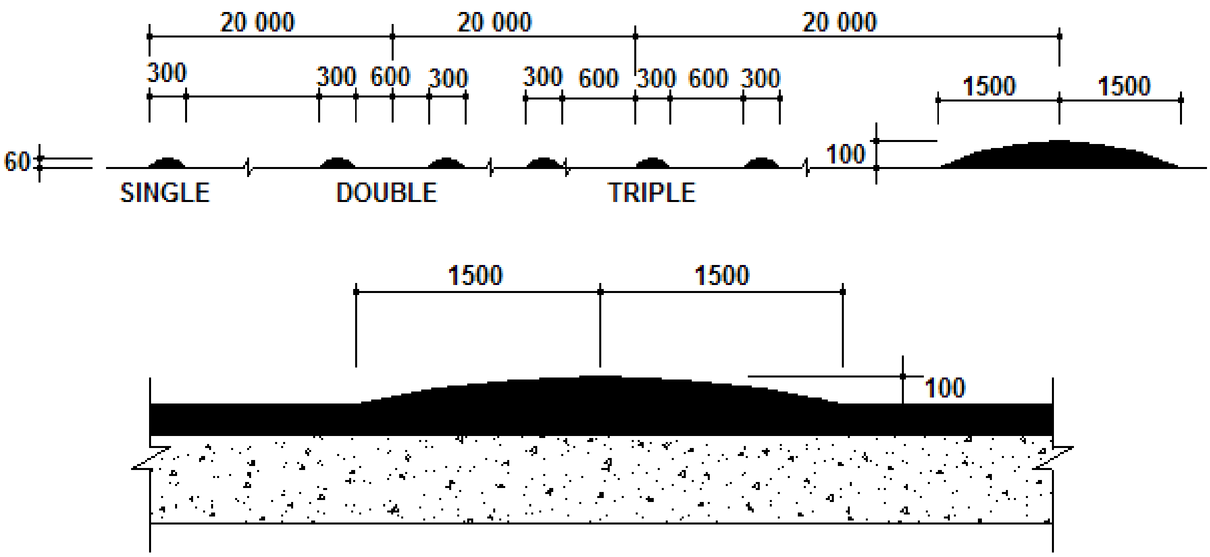
Figure A.7.1: Speed hump application

The following should be considered when adopting this form of traffic calming measure:

- On new roads or roads being upgraded, speed humps or cushions should be included as a standard part of the design.
- On existing roads where there are currently no speed humps, they should be provided where the need is identified.
- Speed humps should cover the full width of the road but ponding of rainwater behind speed humps should be avoided otherwise potholes will form.
- Stripes should be painted on speed humps using reflective road paint to make them visible, particularly at night, and the stripes should be repainted when the paint becomes worn.
- Advance warning of speed humps should be provided preferably using a road sign situated 50 m before the hump. Marker posts should be installed alongside the hump indicating the actual location of the hump. Marker posts should be fitted with reflectors so that they can be seen at night.
- The use of speed humps should be avoided on slopes.

Speed humps

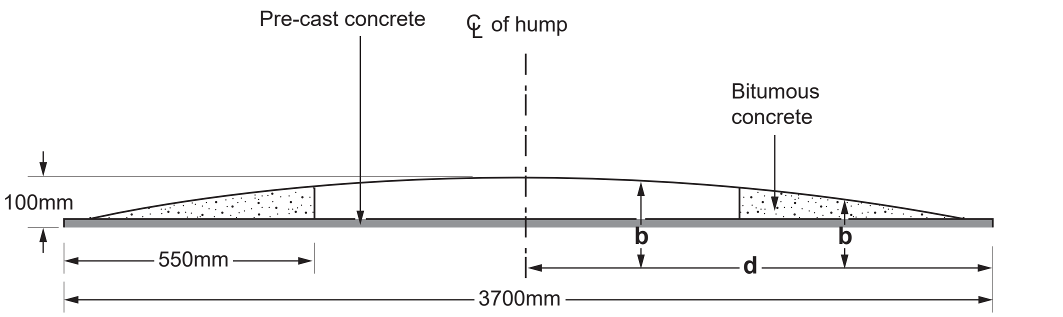
Standard hump: This is the most common type of speed hump used to reduce speed on both paved and unpaved roads. On paved roads, the hump is generally constructed of asphalt or concrete and combined with rumble strips. The rumble strips provide advanced warning to drivers of the hump ahead. On unpaved roads, the hump is constructed of the same material as the wearing course, however without the advance rumble strips. It is recommended that this type of hump be used on lower speed roads such as on the feeder road system. Further details of the hump and rumble strips are shown in Figure A.7.2.



Note: Dimensions in mm

Figure A.7.2: Details of the standard hump / rumble strips combination

Watts profile hump: This type of speed hump, although longer than the standard speed hump, is designed to provide a more comfortable ride for passengers and the least damaging effect on vehicles in addition to reducing speed. The Watts profile hump is appropriate to paved roads and is generally constructed using asphalt or concrete. If the hump is constructed of concrete, it should be reinforced with a layer of steel mesh for increased durability and to control cracking. It is recommended that this type of hump be used on higher speed roads such as on the secondary and primary road systems. Details of the Watts profile hump are shown in Figure A.7.3.



d (mm)	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800
b (mm)	100	100	99	97	95	93	90	86	81	76	71	65	58	51	43	34	25	16	5

Cross Section A-A

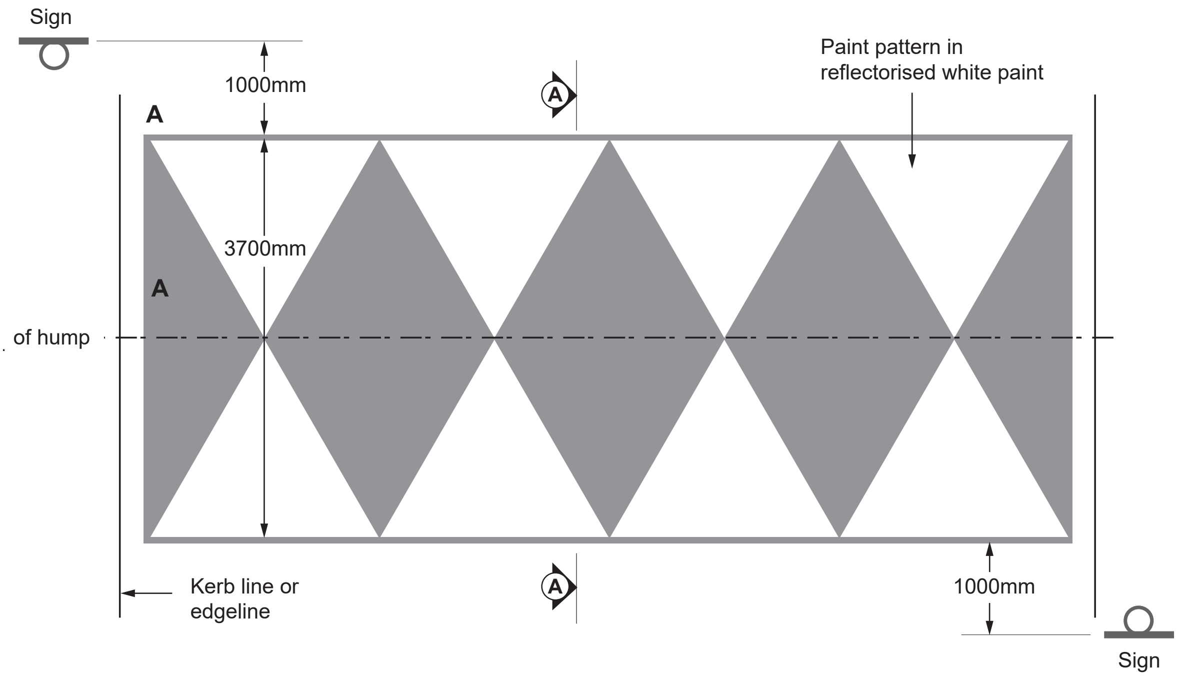


Figure A.7.3: Details of the Watts Profile Hump

Source: Modified from ERA Manual for Low Volume Roads, 2016

Flat-top hump: When speed humps are used to reduce speeds ahead of pedestrian crossing points, it is increasing common practice to combine the pedestrian crossing and speed hump. The flat-topped hump is typically used in this application. This type of hump is only appropriate to paved roads and comprises of a flat top portion with a ramp on either side. If the hump is constructed using concrete, it should be reinforced with a layer of steel mesh. Details of the flat-topped hump are shown in Figure A.7.4.

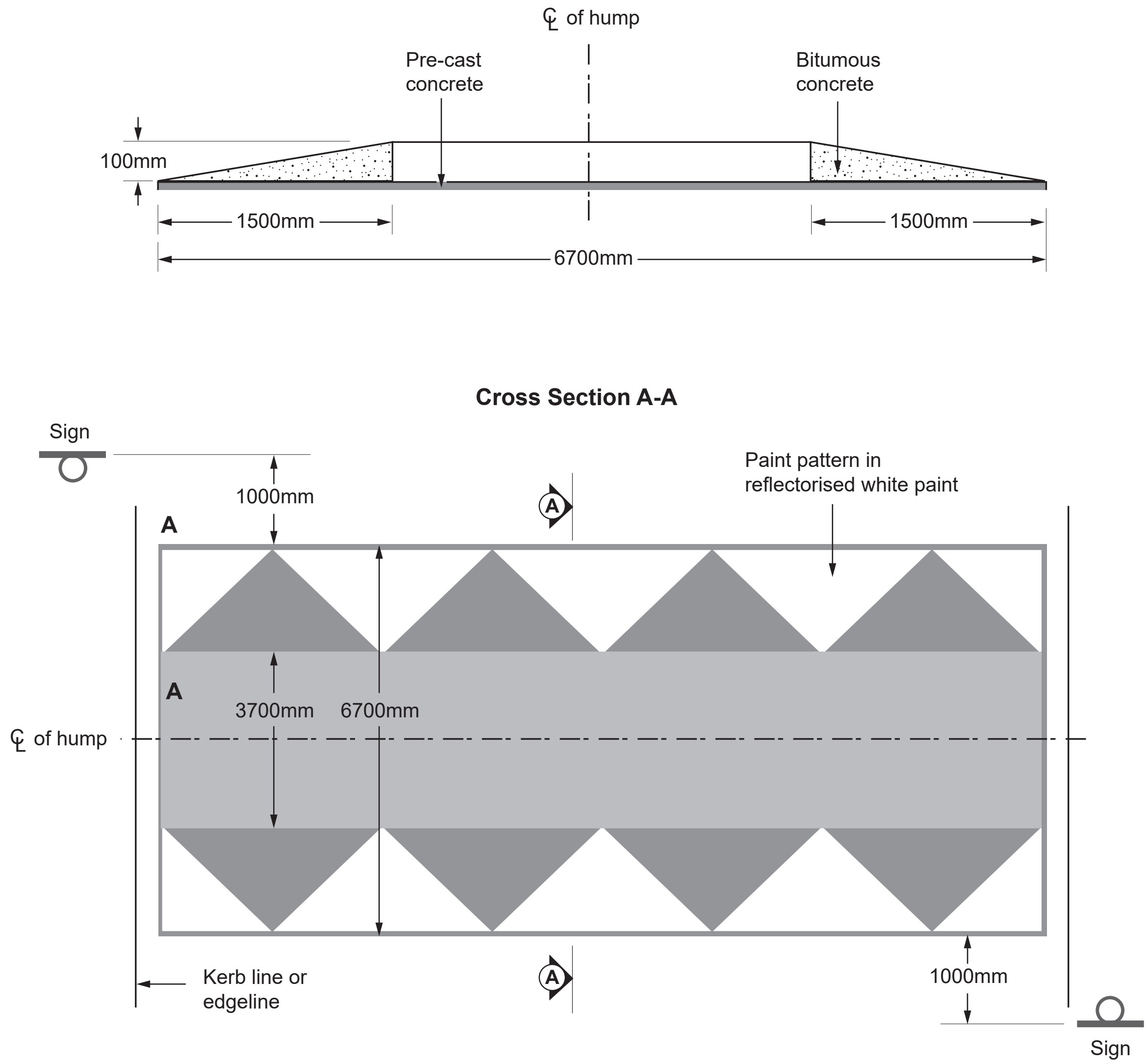


Figure A.7.4: Details of a flat-top hump

Source: Modified from ERA Manual for Low Volume Roads, 2016

Speed cushions

Speed cushions are based on a similar principle to the speed hump however they are only applicable to paved road. The hump is not continuous across the road. The width of a two-lane road is usually covered by two or three cushions with gaps between them. The idea is that large vehicles will not be able to pass without at least one wheel running over one of the humps, but bicycles and motorcycles can pass between them without interference. A speed cushion is shown in Figure A.7.5.

Figure A.7.5: Speed cushion application

7.4.3 Rumble strips

Rumble strips are applicable to paved roads only. They are formed of artificial road texture that causes tire noise and vehicle vibration if the vehicle is travelling too fast. They are generally used across paved roads where they are uncomfortable to drive across at speed and are effective in alerting road users and slowing down the traffic. They are particularly effective when used in combination with road humps, typically at the approaches to villages. Examples of rumble strips are shown in Figure A.7.6.

Figure A.7.6: Rumble strip application

7.4.4 Jiggle bars

Applicable to paved roads only, jiggle bars are a similar method used for slowing traffic as rumble strips. The noise generated by a vehicle passing over the strips is the main factor in causing vehicles to slow down. Jiggle bars are spaced closer together than rumble strips. An application of jiggle bars is shown in Figure A.7.7.

Figure A.7.7: Jiggle bars application

7.4.5 Speed bumps

Speed bumps are similar to speed humps but have a more abrupt design. They consist of a portion of raised pavement typically between 10 cm and 15 cm high, and about 75 cm long. Unlike speed humps, which result in a rocking motion for a passing vehicle, speed bumps can produce a severe jolt even at moderate speeds, potentially resulting in damage to the vehicle and/or loss of control. Such risks, which are particularly marked in the case of motorcycles, mean that their use is generally limited to private roads, and car parks. They are not recommended for use on public roads.

7.4.6 Road islands

These are generally used in built-up areas on paved sections of road. The provision of raised islands in the center of the road carriageway may be used to separate two-way traffic; restrict overtaking; separating motorized traffic from vulnerable road users; and to provide refuge for pedestrians crossing the road. Center islands are also used at approaches to built-up areas to make it clear to road users that they are approaching a populated area.

7.4.7 Road narrowing and staggering

This particularly applies to 2-lane paved roads and is designed to produce artificial congestion by reducing the width of the road over a very short distance at intervals along it. The road width can either be reduced from the center of the road through the installation of center islands or reduced from the roadside using road edge islands. The narrowing can be constructed using raised curbed islands or road markings. Road staggering can be introduced by installing roadside islands on alternate sides of the road. In both cases the space available for traffic is reduced which will encourage drivers to slow down. Road narrowing is illustrated in Figure A.7.8.

Figure A.7.8: Road narrowing

7.4.8 Town gates (Gateways)

These are generally used on paved trafficked roads to make a clear entrance to an area with a lower speed limit. This form of traffic calming is introduced visually to road users through provision of adequate signage, center islands, humps and jiggle bars to encourage drivers to slow down when approaching a village or small settlement. The village name is sometimes also displayed here. This application can be used on unpaved roads in the form of signage only. Design details for gateways are given in Figure A.7.9 and an example is shown in Figure A.7.10.

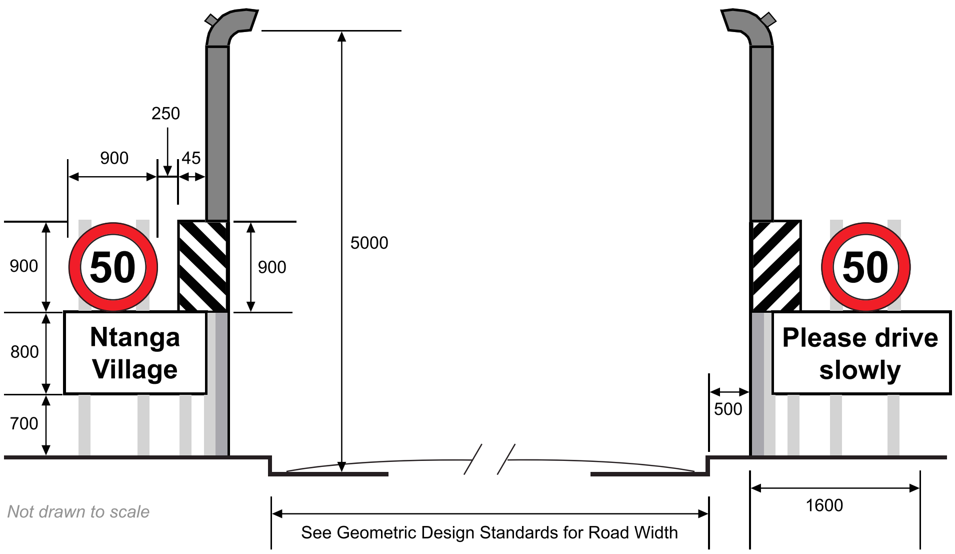


Figure A.7.9: Typical gateway details

Source: Modified from ERA Manual for Low Volume Roads, 2016

Figure A.7.10: Gateway

7.4.9 Pre-warnings

The purpose of pre-warnings is to warn road users about a hazard, settlement or speed restriction ahead and ensure to be made aware of the need to slow down. These can simply be warning signs fitted with supplementary plates indicating relevant information. Pre-warnings can also be supplemented with rumble strips to alert drivers.

7.4.10 Pedestrian crossings

These are applicable to paved roads and are placed where large numbers of pedestrians cross the road, or where there is a special need for protection of vulnerable road users, for instance outside schools. Pedestrian, or zebra, crossings may be provided at road intersections or between intersections also known as "mid-block". Pedestrian crossings should always be supported with speed reducers such as humps, center islands and road narrowing.

It is recommended that center islands, curbed or painted, be installed where pedestrian crossings traverse more than two lanes to provide refuge for pedestrians and may be combined with flat top humps as previously described. Furthermore, curbed build-outs should be provided where there is roadside parking.

Pedestrian crossings shall be preceded by a STOP line marking when used at a traffic signal-controlled crossing or intersection, or by a YIELD line marking when used at a sign-controlled crossing or intersection. STOP and YIELD lines shall be positioned at least 1 m away from the pedestrian crossing at road intersections and recommended to be at least 3 m away for mid-block pedestrian crossings.

Pedestrian counts and pedestrian crossing behavior should always precede the design of traffic calming projects to ensure that the most appropriate application and location is selected. A typical layout of a pedestrian crossing is given in Figure A.7.11 and examples are shown in Figure A.7.12.

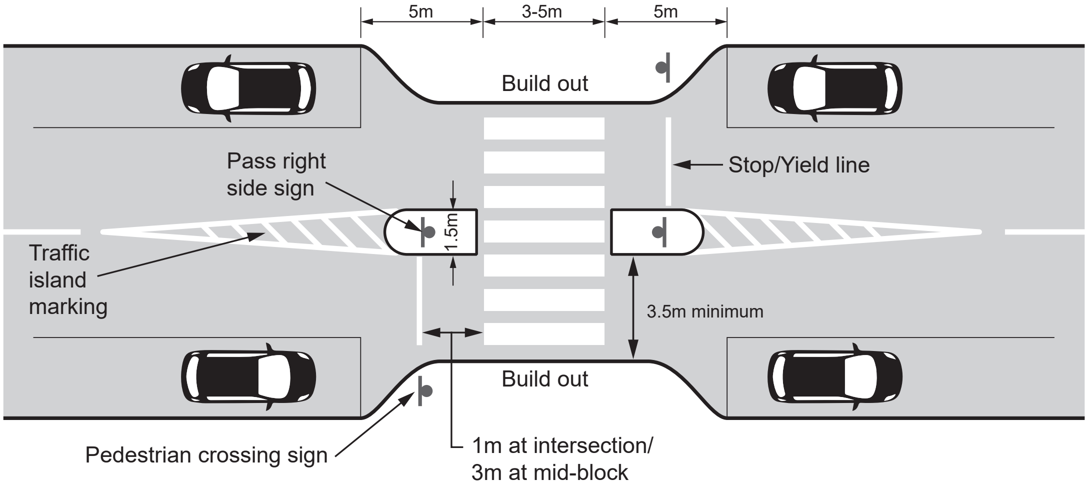


Figure A.7.11: Typical pedestrian crossing details

Figure A.7.12: Pedestrian crossings

7.4.11 Village treatment

The concept of traffic calming has been introduced in other African countries and has been proven successful. It is mainly applicable to paved sections of road. The objective of the village treatment is to create a perception that the village is a low-speed environment and to encourage drivers to reduce speed. This is achieved using a combination of multiple traffic calming measures, pedestrian sidewalks and bus bays. The same application can be used on unpaved roads with the exception that the traffic calming component would consist of earth or gravel speed humps as opposed to that described below. Typically, the road through the village is treated as being in three zones, namely:

- The approach zone;
- The transition zone; and
- The core zone.

Approach zone: This is the section of road prior to entry into the village, where the driver needs to be made aware that the open road speed is no longer appropriate. This is the section of road where speed should be reduced typically from 70 km/h down to 50 km/h, before entering the village. The village entry should be marked by a gateway as described below.

Transition zone: This is the section of road between the village entrance, or Gateway, and the core zone of the village. The target speed, and posted speed limit in this zone would be typically 50 km/h. The first road hump or humps in a series of humps will be located in this zone. In this context, with adequate advance warning provided by the approach zone and gateway, road humps are deemed to be safe.

Core zone: This is the section identified as being in the center of the village, where most of vehicle/ pedestrian conflict is expected to take place. This is normally where many shops or trade stalls are located with bus bays and other pedestrian generating activity. This is the section where the target speed, and posted speed limit, should typically be 40 km/h. Road humps are normally provided within this zone with advisory speed limits of 20 km/h to enforce the lower speed environment required.

A typical treatment, showing the three zones outlined above, is illustrated in Figure A.7.13.

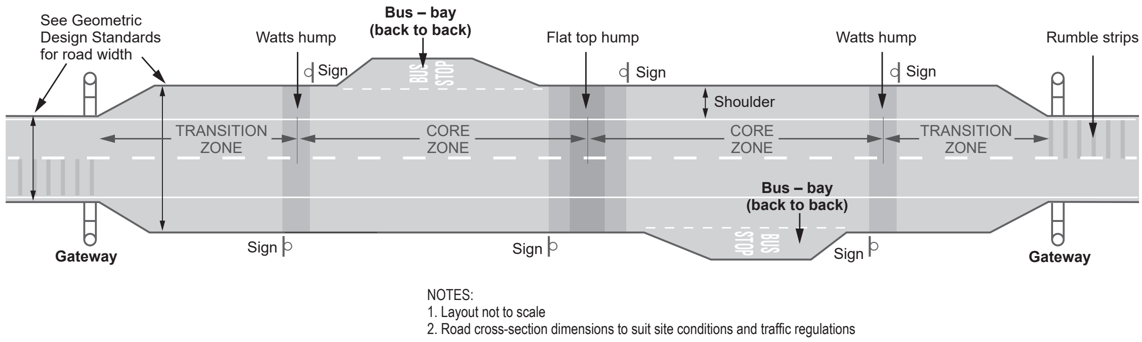


Figure A.7.13: Village treatment - typical layout

Source: Modified from ERA Manual for Low Volume Roads, 2016

Note:

1. Layout not to scale.
2. Road cross-section dimensions to suit site conditions and traffic regulations.

The elements which make up the village treatment are as follows:

1. **The gateway**: See details provided in sub-section A. 7.4.8.
2. **Rumble strips**: See details provided in sub-section A. 7.4.3.
3. **Speed humps**: See details provided in sub-section A. 7.4.2. The recommended spacing and combination of speed humps is shown in Figure A.7.14

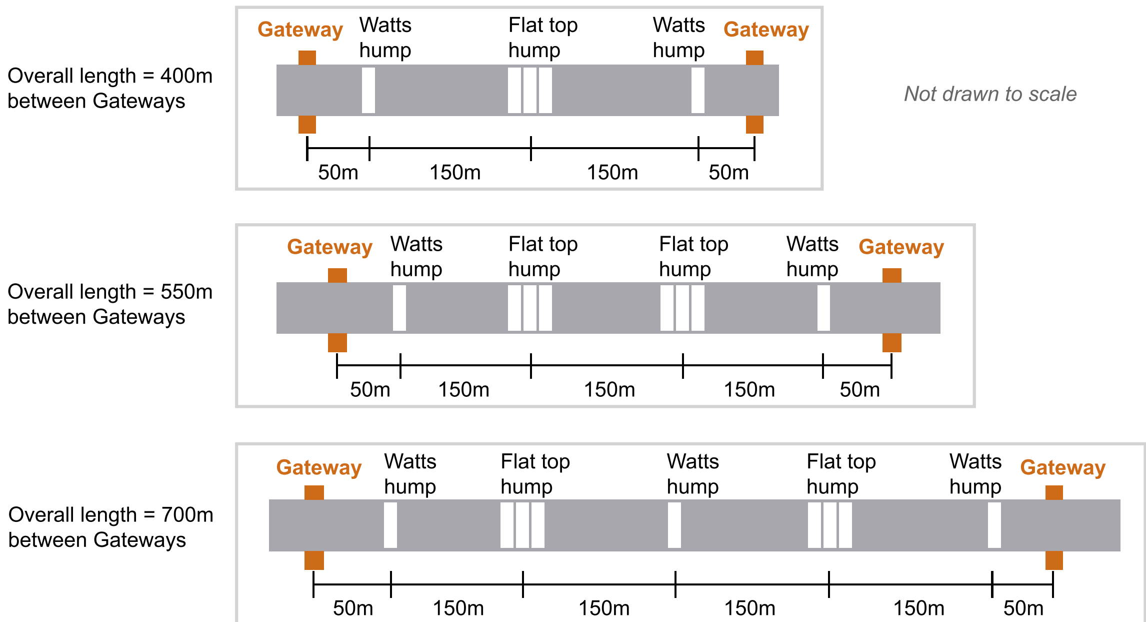


Figure A.7.14: Typical spacing and combination of speed humps

Source: ERA Manual for Low Volume Roads, 2016

4. **Pedestrian crossings**: See details provided in sub-section A. 7.4.10.
5. **Traffic signs and road markings**: These are used to provide warning information to motorists at all elements of the village treatment, such as at entry to the gateway, at the start and exit of the core zone, and in advance of speed humps, while also advising speeds.

6. **Lay-bys or bus bays:** These should generally be provided in the core section of the village and should be in pairs. They should be located back-to-back, so that when there is a vehicle in each bay, they should be facing away from each other. This is so that passengers leaving the vehicle and then crossing the road will be behind a vehicle parked on the opposite side and will not be crossing in front of it. Typical details of lay-bys or bus bays can be found in Figure A.7.15.
7. **Pedestrian routes**: The aim should be to identify the major pedestrian routes within the village, to determine at what point they join the road, and whether any realignment is necessary to ensure that pedestrians are led to appropriate crossing places. The main pedestrian route within a village should always join the road within the core zone.

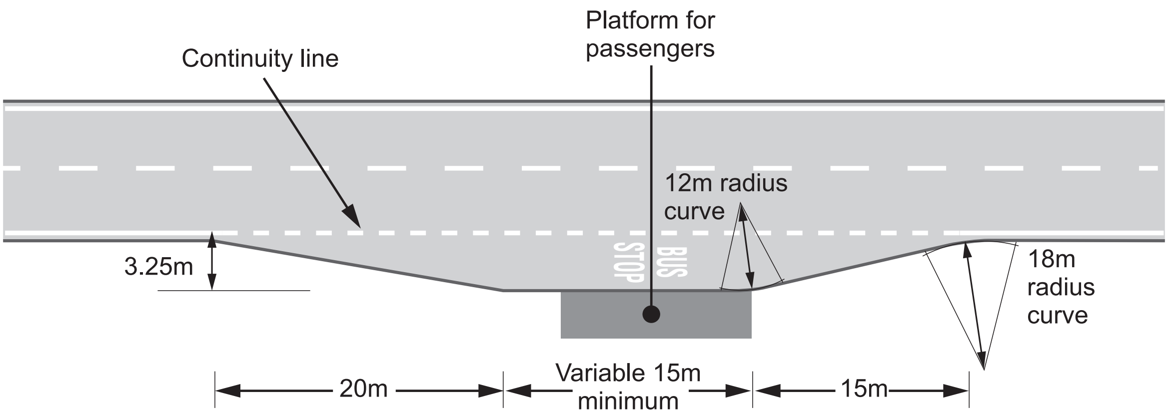


Figure A.7.15: Typical bus bay details

7.5 Safety barriers

7.5.1 Overview

Safety barriers are expensive and seldom justified on LVRs. The geometric design of such roads should be done to eliminate the need for such barriers however they may be required in highly dangerous situations, for example, on excessively sharp bends on mountainous roads that cannot be made safe by other means. In this case the installation of safety barriers is warranted.

The types of safety barriers and application vary, however the most commonly used are raised curbed islands, wooden or steel posts, steel guardrails, and concrete barriers. Raised curbed islands are generally applicable to paved roads and commonly used for segregating motorized and non-motorized traffic. Wooden and steel posts are the cheapest form of barrier however generally not the most effective. Steel guardrails are one of the most effective types of safety barrier and most commonly used. They are cost effective to install compared to concrete barriers, however in the long-term the repair and maintenance of these is more expensive.

7.5.2 Segregating vulnerable road users

Where possible, non-motorized vehicles and pedestrians should be physically separated from the motorized vehicles. While this is not specifically part of the geometric design of the road itself, if the terrain and local conditions are suitable for the construction of parallel pathways wide enough for non-motorized transportation, then some of the geometric features of the roadway designed to accommodate this traffic may not be necessary and considerable savings may be possible. However, if traffic does travel on such pathways, enough connections need to be made to the roadway itself to enable access in either direction.

7.5.3 Crash barriers

Crash barriers are designed to physically prevent vehicles from crossing them. They are an essential feature of high speed roads to prevent vehicles travelling in opposite directions from colliding with each other head-on, but their primary use on LVRs is to prevent vehicles from leaving the road at dangerous places such as when the road comes to its end or where a vehicle could plunge over a hazardous edge as is most likely on mountainous roads. Good geometric design should prevent drivers from experiencing unexpected situations where they might be in danger of losing control, but sometimes crash barriers are required. However, they are expensive to install, and they must be installed properly otherwise they are not likely to be fit for purpose. They are rarely used on LVRs but can justifiably be used in some circumstances such as on roads where the AADT exceeds 150 vehicles per day.

7.6 Motorcycle safety on low volume rural roads

7.6.1 Introduction

Until recently, safety has been only a minor consideration in the management of low volume rural roads in Liberia, due to the low number of vehicles using these roads. However, in recent years the number of vehicles, most notably motorcycles, in rural areas has increased rapidly.

There is no doubt that motorcycles are a dangerous means of transport in comparison with other motorized means. Having only two wheels in contact with the ground, their small size, and lack of protection, makes them more susceptible to loss of control and puts drivers and their passengers at greater risk of serious injury.

Injuries suffered in crashes involving motorcycles on rural roads are more severe than those involving other modes. Poor road user behavior as a result of a lack of training and a lack of law enforcement in rural areas is the most common contributory factor to motorcycle crashes on rural roads.

Speed is widely recognized as a key risk factor in road traffic crashes for all forms of transport. On LVRs, motorcycle speeds are often not high, however speed-related motorcycle crashes do often occur. This is generally due to inappropriate speed for the surrounding environment, for example failing to slow down when passing through settlements or on stretches of road where sight lines are short. However, some element of road design and condition also contributes to over half of all motorcycle crashes on rural roads.

7.6.2 Safety improvements

Over and above the typical safety measures generally applied to the rural road network, the following measures should be considered in the design and construction of roads to ensure motorcycle safety:

- Encourage appropriate speeds through the use of speed humps in areas where speeds must be reduced for the safety and where there are high numbers of pedestrians, such as village centers, outside schools and close to market places.
- Minimize the use of sharp horizontal bends and increase the road width when they cannot be avoided.
- Ensure the road is wide enough for a motorcycle to pass a four-wheeled vehicle safely without being forced to leave the road. A minimum carriageway width of 3.8 m excluding shoulders is recommended. Adequate road width is of critical importance for road safety.
- Provide shoulders on both sides of the road for use by motorcycles. A minimum width of 0.5 m is recommended.
- Ensure that road shoulders are regularly maintained to ensure a safe riding surface. The shoulders, as with the main carriageway, should be free from vegetation, potholes, corrugation, rutting, loose gravel, or oversized material. Surfaces that become slippery when wet are also constitute a risk, as can occur as a result of bleeding of paved bituminous surfaces.
- Ensure where possible that the slope of the shoulder matches that of the main carriageway. It is recommended that unpaved shoulders should have a minimum camber of 4% slope.
- Consider paving the road in situations where the fact that a road is unpaved contributes to risk. Examples include stretches of road that becomes very slippery when wet, or in an area where dust can obscure vision.
- Ensure the surrounding environment is ‘forgiving’, for example by avoiding steeply-angled side-slopes and deep side drains at the edge of the carriageway. Slopes flatter that 1:4 are considered to be ‘recoverable’ for motorcycles.
- Ensure the roadside is free of large hard objects, such as big rocks and trees, from within 5 m of the edge, and within 10 m from the road edge on the outside of curves.
- Use road signs or marker posts to warn of hazards. In high-risk areas, when budget allows, guard rails may be used to protect road users from a roadside hazard.

- Demarcate the edges of bridges and drifts using bollards or masonry blocks on both sides, so that their location is known when they are covered with water. The bollards should be fitted with reflectors for night-time driving. Guard rail protection is also recommended on each side.
- Provide sufficient sight lines on the approach to bridges and drifts. In addition, warning signs are recommended where a bridge or drift is narrower than the approaching road carriageway.

Source: Advice for Motorcycle Safety on Low-Volume Rural Roads, Tanzania (2016)

7.7 Safety audits

The subject of road safety is remarkably complex in that, although many unsafe practices are glaringly obvious, there are many situations where it is difficult to identify what is likely to be unsafe, especially if the project is a new road and one is working from drawings. The history of road safety is full of philosophies that were thought to improve road safety but often had no discernible effect or even made things worse. The problem has always been a shortfall of reliable data. There is no substitute for a systematic method of recording the characteristics of road accidents and analyzing the data, when there is enough for reliable conclusions to be drawn.

Professional road safety auditing is the next best practice and should be regularly undertaken on every road project, particularly for road projects in populated areas. It is anticipated that this practice will become increasingly common in Liberia.

A rudimentary road safety audit checklist, based on that from HD 19/15 of the UK Highways Manual Volume 5, Section 2, Part 2, can be found in Appendix A.3. This provides some basic guidance as to some of the elements which should be considered when undertaking a road safety audit.

8. REFERENCES

The following reference material was used in the compilation of this part of the Manual:

- Federal Democratic Republic of Ethiopia – Ethiopian Roads Authority – Manual for Low Volume Roads (2016)
- ISO 10845 International Standard for Construction Procurement – Part 7 - Targeted Procurement.
- Hearn, G.J. (2015). Route location. Chapter 2 in: O'Flaherty, C (ed) Highway Engineering: the location, design, construction and maintenance of road pavements. 5th edition, Thomas Telford, London.
- Ministry of Public Works – Geometric & Pavement Design Standards (2017)
- Ministry of Public Works – Department of Rural Development & Community Services – Feeder Roads Design Manual & Specifications (2016)
- Ministry of Transport and Ministry of Public Works (2017) – Road Signs and Markings Standards.
- Republic of Ghana – Ministry of Roads and Highways – Design Standards for the Department of Feeder Roads (2009)
- Republic of Ghana – Ministry of Local Government and Rural Development – Practitioner's Guide to Rural Roads Improvement and Maintenance (2014)
- Republic of Ghana – Environmental Protection Agency – Environmental Impact Assessment Guideline for the Transport Sector (2011)
- Sierra Leone Roads Authority – Draft Road Design Manual – Part 1 - Geometric Design (2012)
- World Bank Technical Paper 496 – Ensuring Basic Access for Rural Communities (2001)
- Tanzania – Advice for Motorcycle Safety on Low-Volume Rural Roads (2016)

Appendix A.1: Traffic Count Survey Form

Traffic Count Form (front)

NOTES FOR COMPLETION:
1. Responsible Officer to complete all shaded boxes
2. Enumerator to conduct traffic count as instructed
3. When instructed to do so, Enumerator to provide further details overleaf in interview
4. Responsible officer to check and sign that all data and meta data is complete and genuine

Region: ____ **District:** ____ **Season:** ____ **Date:** ____ **Day:** ____

Link Number: ____ **Link Name:** ____ **Location:** ____ (Km Chainage)

Description of Count Point: ____ **Enumerator:** ____

KEY: / UNLOADED (start marking from bottom of area) x LOADED (start marking from top of area) [DO NOT RECORD VEHICLE MOVEMENTS RELATED TO THE COUNT] **Responsible Officer:** ____

Starting time:	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	COUNT	FACTOR	TOTAL
Pedestrian																			
Bicycle																			
Drawn cart																			
Motorcycle																			
3-wheeler - kekeh																			
Saloon Car																			
Pickup Mini-bus, 4wd																			
Tractor																			
Bus or 2-axle truck with single rear wheels																			
2-axle truck with dual rear wheels																			
3-axle Truck																			
4-axle Truck																			
5-axle or 6-axle Truck																			

Traffic Count Form (back)

NOTES FOR COMPLETION:
1. Boxes with darker shading MUST be completed. Key data from front of form required in case single sided copies made
2. Boxes with paler shading SHOULD be completed when relevant reliable information is available

Region:		District:		Location:	(Km Chainage)		
Link Number:		Link Name:		Date of traffic count:		Date of approval:	
Interviewer:		Enumerator:		Date of interview:		Approved by:	

Sketch map *[if needed to clarify the location of count point]*

Special factors [Circle any major factor contributing to traffic (or the lack of it) on day of count]

FACTOR	Comment (if any)
Market Day	
Funeral	
Wedding	
Construction	
Other (specify on right))	

Socio-Economic characteristics of road link [additional comments on travel, transport and access to health, education and other services]

Main reason for travel/transport:	
Facilities being accessed (travel):	
Typical goods carried (transport):	
Comment on road function: Serving local residents; Link road for through traffic	S L SL — Public Transport? YES No — [add details of public transport if known]

Traffic patterns: ["P" indicates peak days / months]	SUN	MON	TUE	WED	THU	FRI	SAT	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seasonal Accessibility: ["X" indicates impassable to 2wd, "L" indicates limited passability to 2 wd								Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

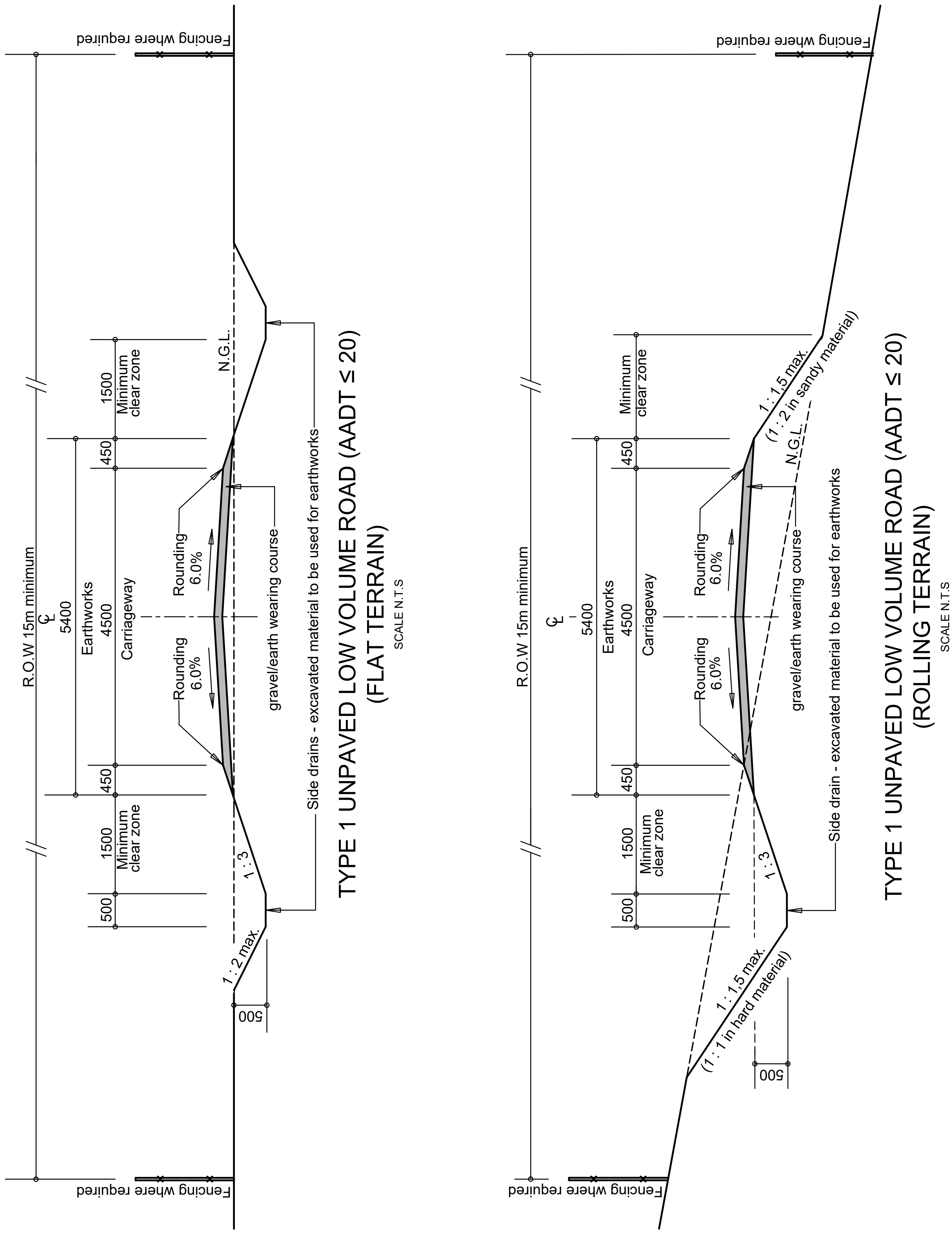
Any other comments *[Including any additional information about typical origin, destination, or loads]*

Appendix A.2: Summary of Geometric Design Standards

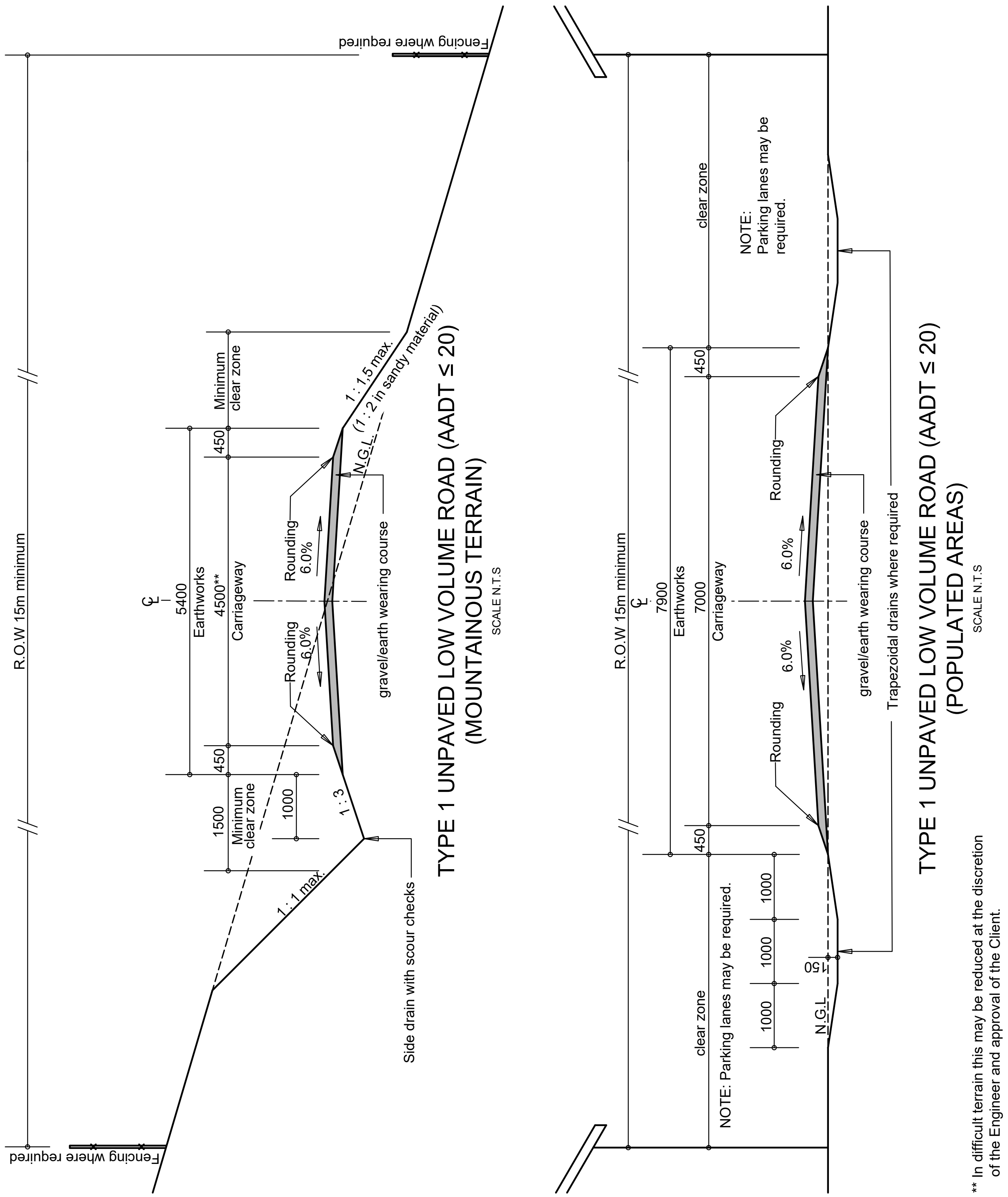
Geometric Design Standards for Type 1 Unpaved Feeder Roads (AADT ≤ 20)

Design Element	Unit	Flat	Rolling	Mountain	Populated areas
Desirable speed	km/h	50	40	30(3)	40
Right of Way (R.O.W.) width	m	15	15	15	15
Carriageway width	m	4.5	4.5	4.5(3)	7.0
Shoulder width	m	0.0(4)	0.0(4)	0.0(3,4)	0.0(4)
Minimum gradient	%	0.5	0.5	0.5	0.5
Maximum gradient	%	7	9(5)	10(5)	9(5)
Normal camber	%	6	6	6	6
Minimum stopping sight distance	m	65	45	30	45
Safe overtaking sight distance	m	235	165	-	165
Minimum horizontal radius for camber = 6%	m	95	60	30	60
Minimum length of horizontal curve	m	80	70	50	70
Minimum crest vertical curve	K	12	8	5	8
Minimum sag vertical curve	K	12	8	5	8

1. If the number of large vehicles is > 10, then Type 2 should be used.
2. On hairpin stacks the minimum radius may be reduced to 13 m.
3. In difficult terrain this may be reduced at the discretion of the Engineer and approval of the client.
4. Increase shoulder widths for NMT and 2- and 3-wheeled motorized traffic > 300 PCUs per day.
5. Length not to exceed 250 m and relief gradient required (< 6% for minimum of 250 m).



Typical Cross-Sections for Type 1 Unpaved Feeder Roads (AADT ≤ 20) – Flat and Rolling

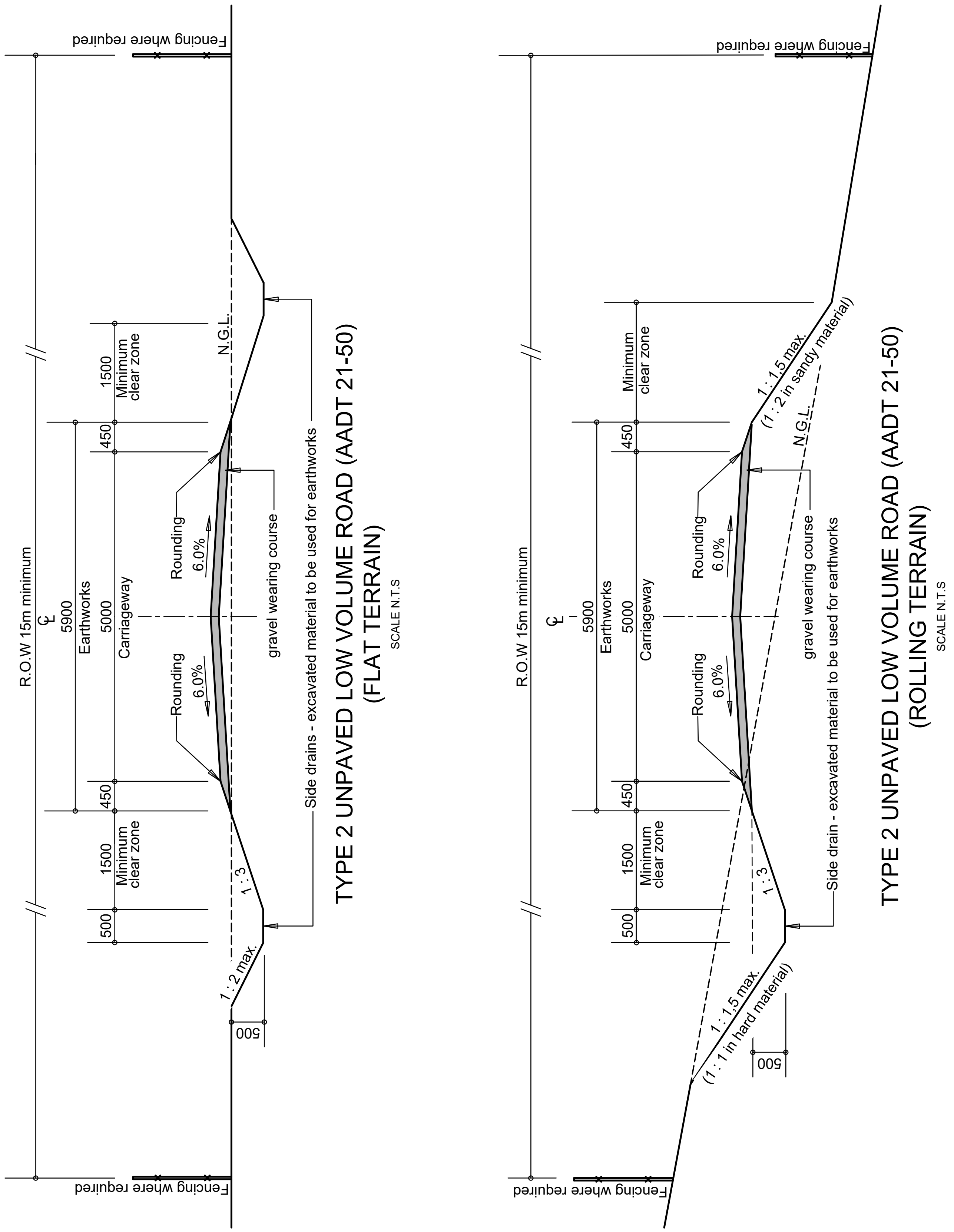


Typical Cross-Sections for Type 1 Unpaved Feeder Roads (AADT ≤ 20) – Mountainous and Populated

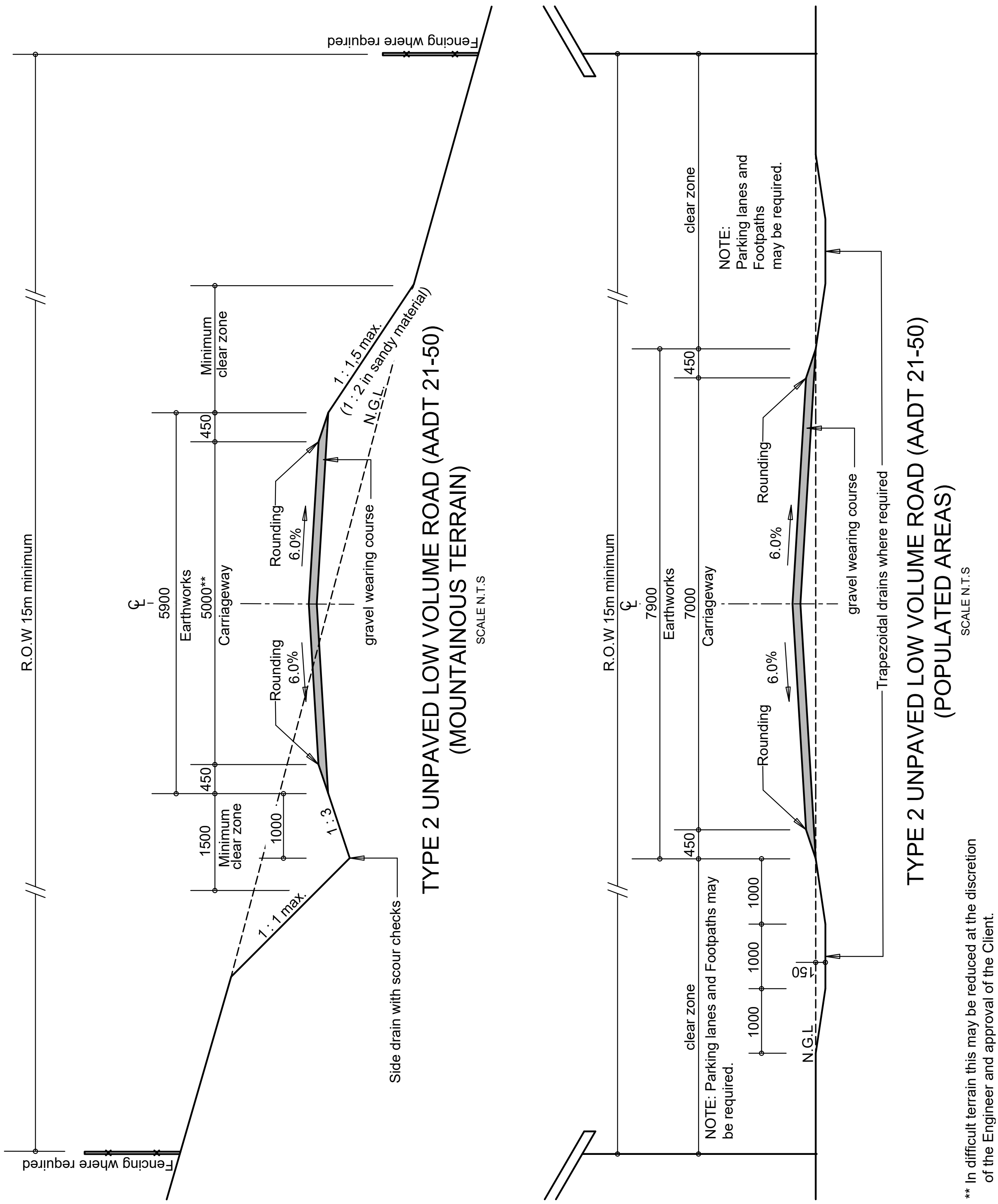
Geometric Design Standards for Type 2 Unpaved Feeder Roads (AADT 21-50)

Design Element	Unit	Flat	Rolling	Mountain	Populated areas
Design speed	km/h	60	50	30(2)	50
Right of Way (R.O.W.) width	m	15	15	15	15
Carriageway width	m	5	5	5(2)	7
Shoulder width	m	0.0(3)	0.0(3)	0.0(2,3)	0.0(3)
Minimum gradient	%	0.5	0.5	0.5	0.5
Maximum gradient	%	7	9	10(4)	9
Normal camber	%	6	6	6	6
Minimum stopping sight distance	m	85	65	30	65
Safe overtaking sight distance	m	300	235	-	235
Minimum horizontal radius for camber = 6%	m	135	95	30	95
Minimum length of horizontal curve	m	100	80	50	80
Minimum crest vertical curve	K	20	12	5	12
Minimum sag vertical curve	K	18	12	5	12

1. If the number of large vehicles is > 20, then Type 3 should be used.
2. In difficult terrain this may be reduced at the discretion of the Engineer and approval of the client.
3. Increase shoulder widths for NMT and 2- and 3-wheeled motorized traffic > 300 PCUs per day
4. Length not to exceed 250 m and relief gradient required (< 6% for minimum of 250 m).



Typical Cross-Sections for Type 2 Unpaved Feeder Roads (AADT 21-50) – Flat and Rolling

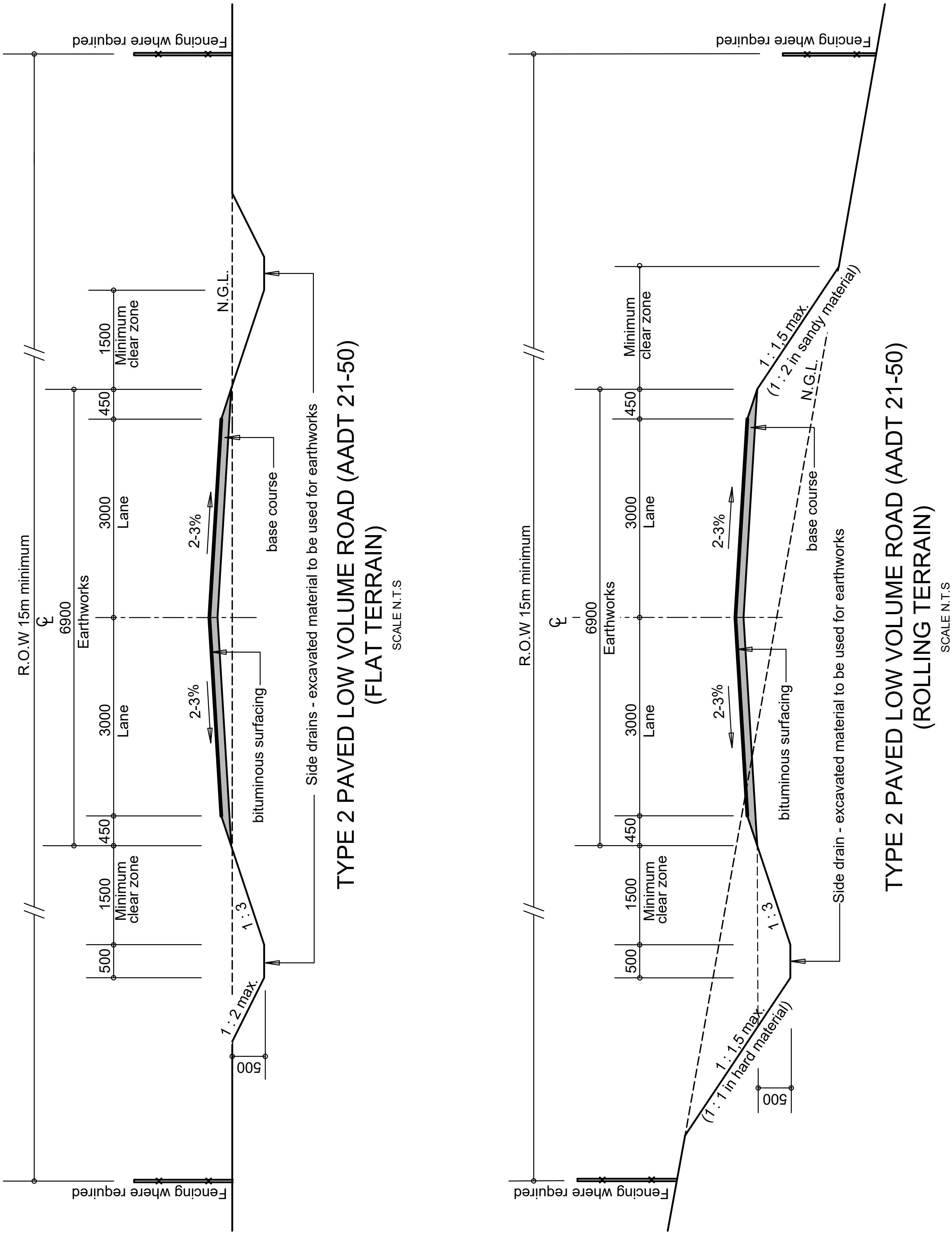


Typical Cross-Sections for Type 2 Unpaved Feeder Roads (AADT 21-50) – Mountainous and Populated

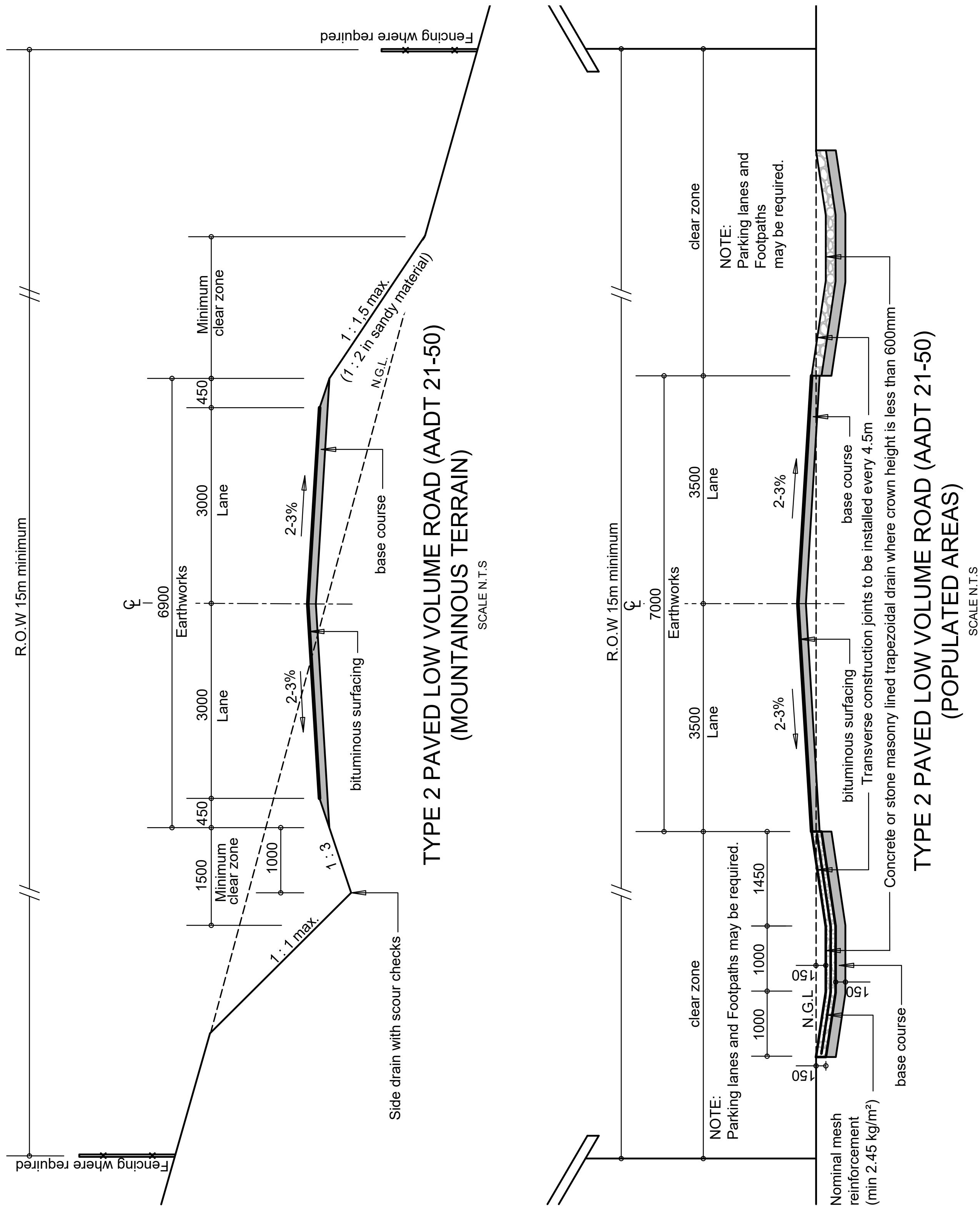
Geometric Design Standards for Type 2 Paved Feeder Roads (AADT 21-50)

Design Element	Unit	Flat	Rolling	Mountain	Populated areas
Design speed	km/h	60	50	40[2]	50
Right of Way (R.O.W.) width	m	15	15	15	15
Carriageway width	m	6	6	6[2]	7
Shoulder width	m	0.0[3]	0.0[3]	0.0[2,3]	0.0[3]
Minimum gradient	%	0.5	0.5	0.5	0.5
Maximum gradient	%	7	9	10	9
Normal camber	%	2-3[4]	2-3[4]	2-3[4]	2-3[4]
Maximum superelevation	%	6	5	4	5
Minimum stopping sight distance	m	85	65	45	65
Safe overtaking sight distance	m	300	235	165	235
Minimum horizontal radius for superelevation = 3%	m	145	90	50	90
Minimum horizontal radius for superelevation = 4%	m	135	85	50	85
Minimum horizontal radius for superelevation = 5%	m	130	85	-	85
Minimum horizontal radius for superelevation = 6%	m	125	-	-	-
Minimum length of horizontal curve	m	100	80	70	80
Minimum crest vertical curve	K	20	12	8	12
Minimum sag vertical curve	K	18	12	8	12

1. If the number of large vehicles > 20, then Type 3 should be used.
2. In difficult terrain this may be reduced at the discretion of the Engineer and approval of the client.
3. Increase shoulder widths for NMT and 2- and 3-wheeled motorized traffic > 300 PCUs per day.
4. Adopt 3% camber in regions of high rainfall.



Typical Cross-Sections for Type 2 Paved Feeder Roads (AADT 21-50) – Flat and Rolling

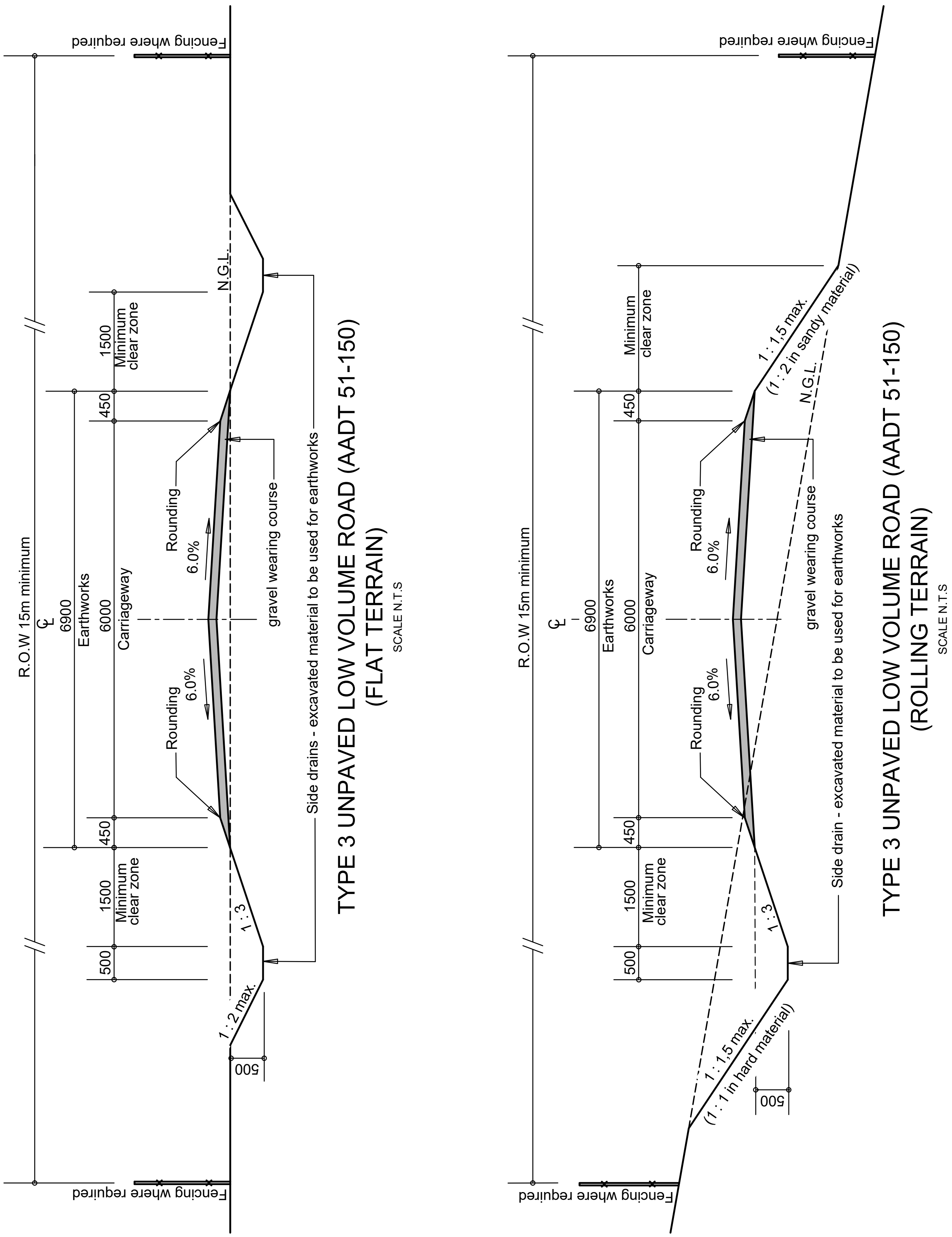


Typical Cross-Sections for Type 2 Paved Feeder Roads (AADT 21-50) – Mountainous and Populated

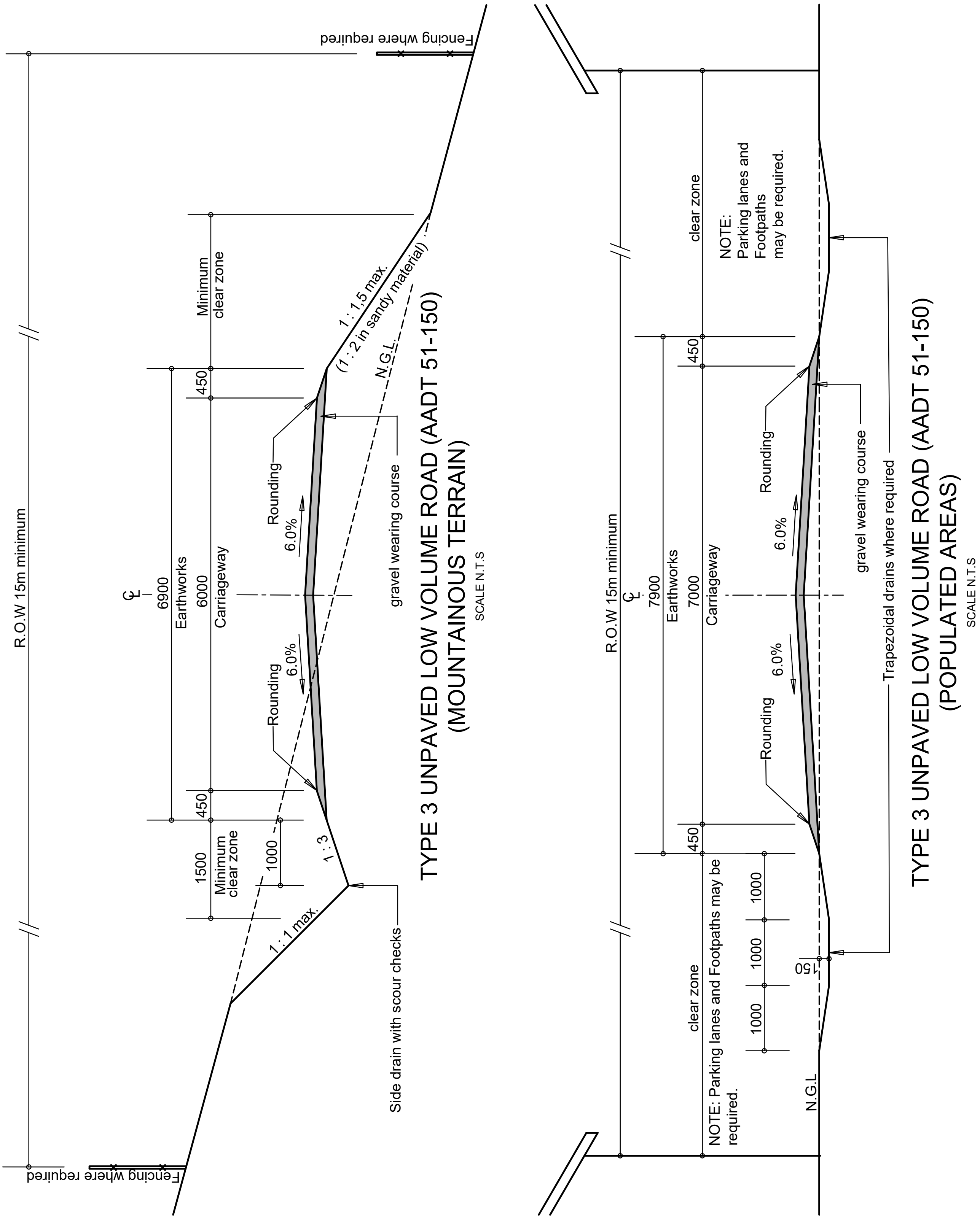
Geometric Design Standards for Type 3 Unpaved Feeder Roads (AADT 51-150)

Design Element	Unit	Flat	Rolling	Mountain	Populated areas
Design speed	km/h	70	50	30(2)	50
Right of Way (R.O.W.) width	m	15	15	15	15
Carriageway width	m	6	6	6(2)	7
Shoulder width	m	0.0(3)	0.0(3)	0.0(2,3)	0.0(3,4)
Minimum gradient	%	0.5	0.5	0.5	0.5
Maximum gradient	%	7	9	10(5)	9
Normal camber	%	6	6	6	6
Minimum stopping sight distance	m	110	65	30	65
Safe overtaking sight distance	m	445	235	-	235
Minimum horizontal radius for camber = 6%	m	195	95	30	95
Minimum length of horizontal curve	m	120	80	50	80
Minimum crest vertical curve	K	35	12	5	12
Minimum sag vertical curve	K	20	12	5	12

1. If the number of large vehicles is > 30, then Type 4 should be used.
2. In difficult terrain this may be reduced at the discretion of the Engineer and approval of the client.
3. Increase shoulder widths for NMT and 2- and 3-wheeled motorized traffic > 300 PCUs per day
4. Parking lanes and footpaths may be required.
5. Length not to exceed 250 m and relief gradients required (< 6% for minimum of 250 m).



Typical Cross-Sections for Type 3 Unpaved Feeder Roads (AADT 51-150) – Flat and Rolling

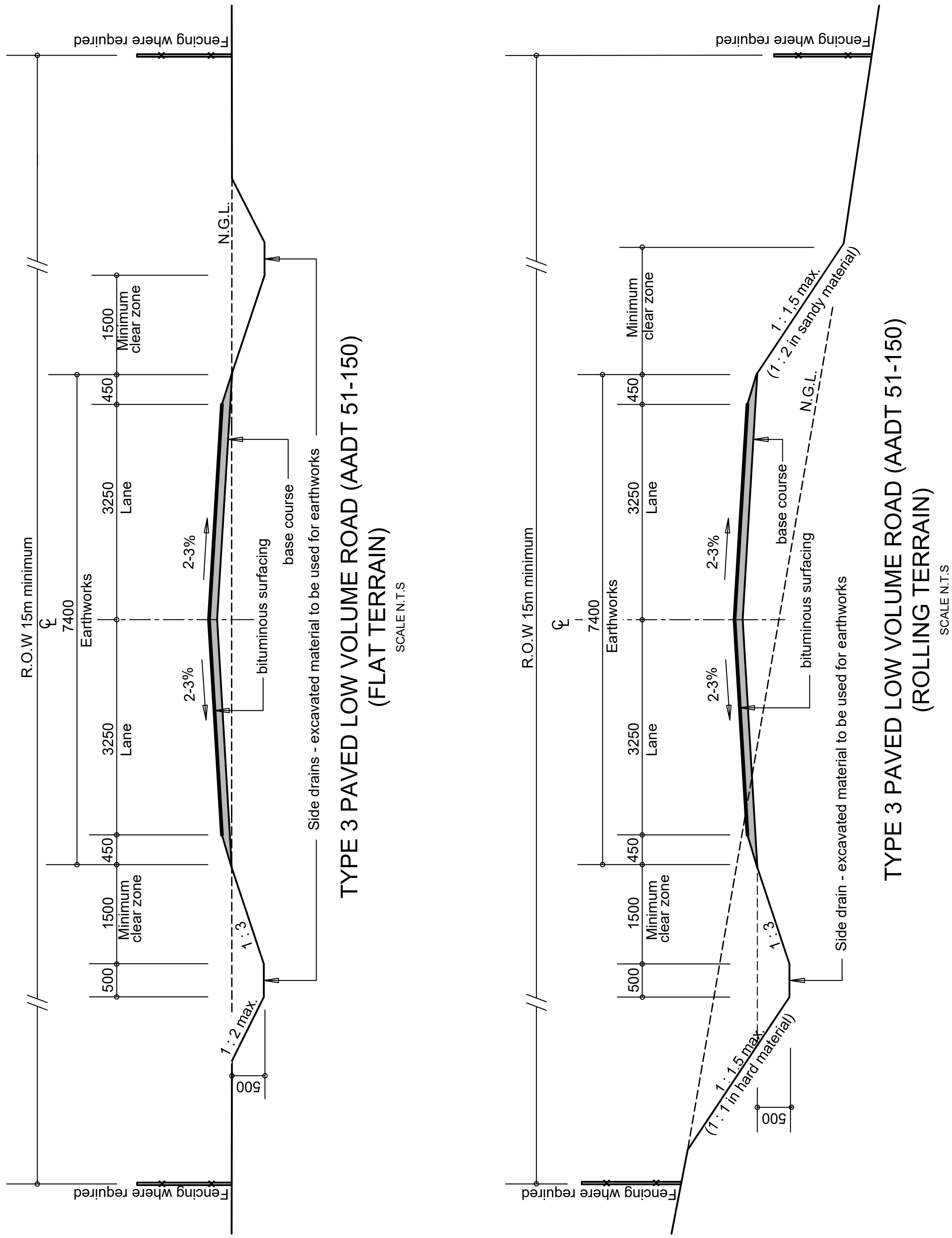


Typical Cross-Sections for Type 3 Unpaved Feeder Roads (AADT 51-150) – Mountainous and Populated

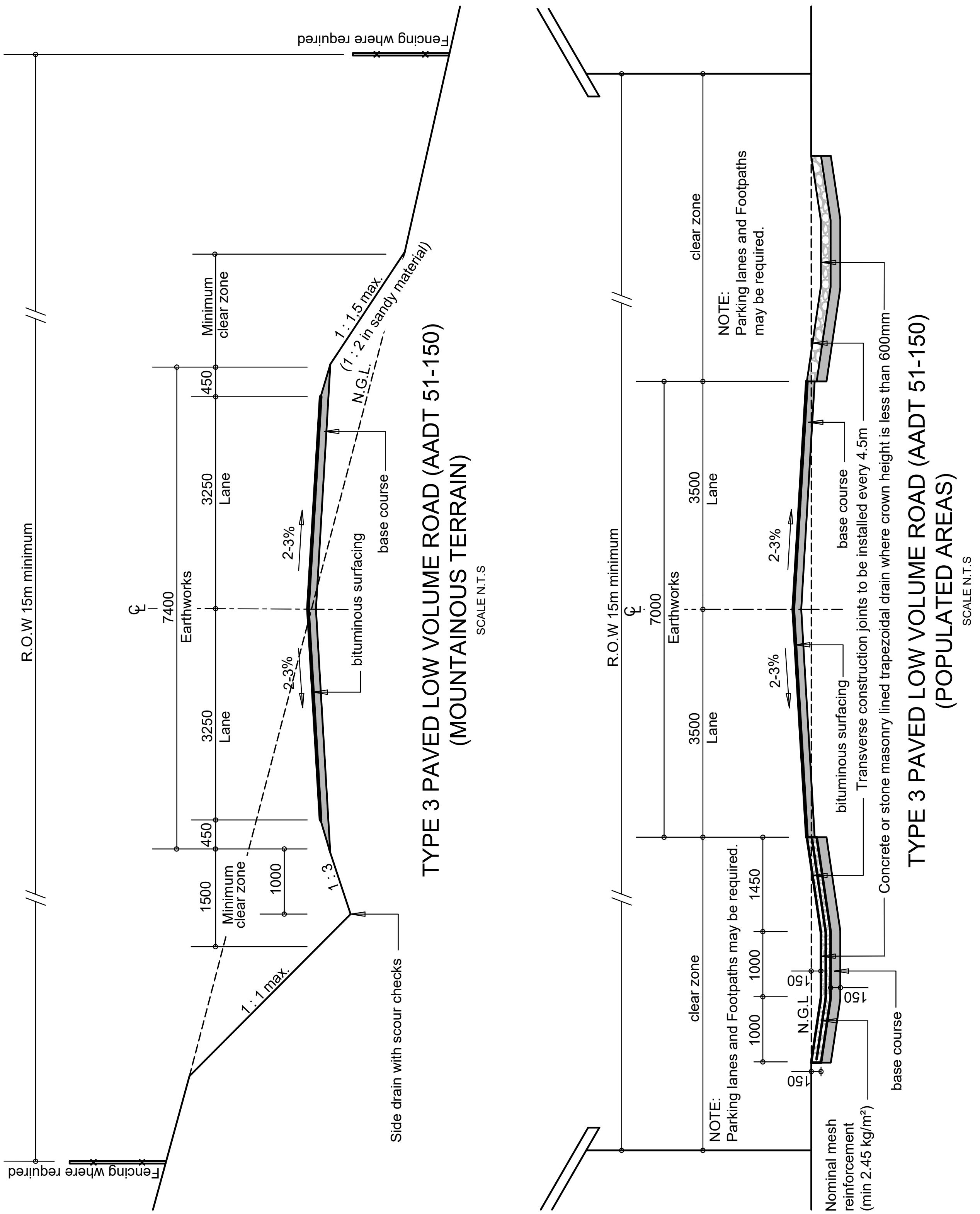
Geometric Design Standards for Type 3 Paved Feeder Roads (AADT 51-150)

Design Element	Unit	Flat	Rolling	Mountain	Populated areas
Design speed	km/h	70	60	40[(2)]	50
Right of Way (R.O.W.) width	m	15	15	15	15
Carriageway width	m	6.5	6.5	6.5[(2)]	7.0
Shoulder width	m	0.0[(3)]	0.0[(3)]	0.0[(2,3)]	0.0[(3,4)]
Minimum gradient	%	0.5	0.5	0.5	0.5
Maximum gradient	%	7	8	10[(5)]	9
Normal camber	%	2-3[(6)]	2-3[(6)]	2-3[(6)]	2-3[(6)]
Maximum superelevation	%	7	6	4	5
Minimum stopping sight distance	m	110	85	45	65
Safe overtaking sight distance	m	445	300	165	235
Minimum horizontal radius for superelevation = 3%	m	215	145	50	90
Minimum horizontal radius for superelevation = 4%	m	205	135	50	85
Minimum horizontal radius for superelevation = 5%	m	195	130	-	85
Minimum horizontal radius for superelevation = 6%	m	185	125	-	-
Minimum horizontal radius for superelevation = 7%	m	175	-	-	-
Minimum length of horizontal curve	m	120	100	70	80
Minimum crest vertical curve	K	35	20	8	12
Minimum sag vertical curve	K	20	18	8	12

1. If the number of large vehicles is > 30, then Type 4 should be used.
2. In difficult terrain this may be reduced at the discretion of the Engineer and approval of the client.
3. Increase shoulder widths for NMT and 2- and 3-wheeled motorized traffic > 300 PCUs per day.
4. Parking lanes and footpaths may be required.
5. If the number of large vehicles < 20 this can be increased to 15%.
6. Adopt 3% camber in regions of high rainfall.



Typical Cross-Sections for Type 3 Paved Feeder Roads (AADT 51-150) – Flat and Rolling

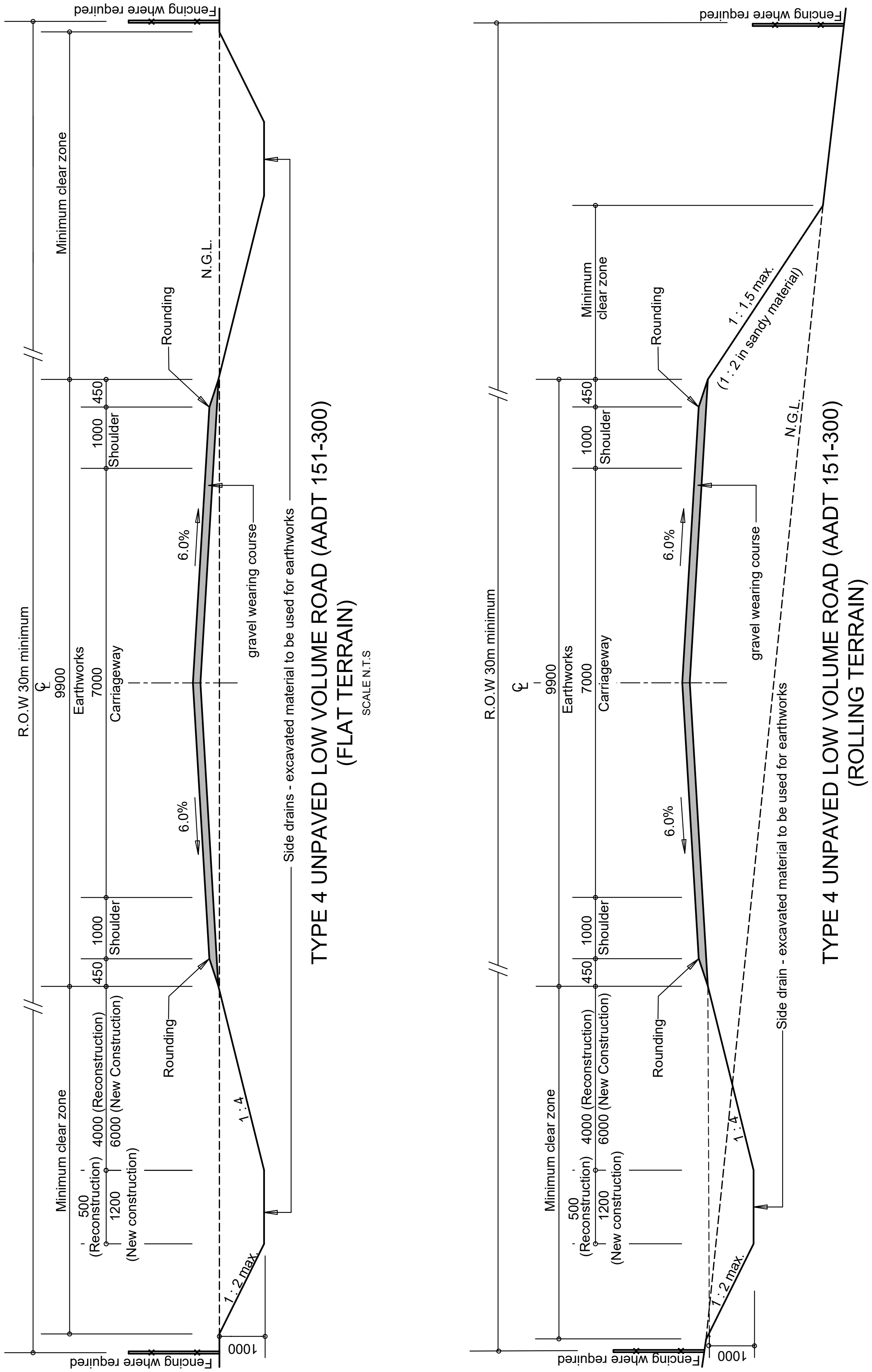


Typical Cross-Sections for Type 3 Paved Feeder Roads (AADT 51-150) – Mountainous and Populated

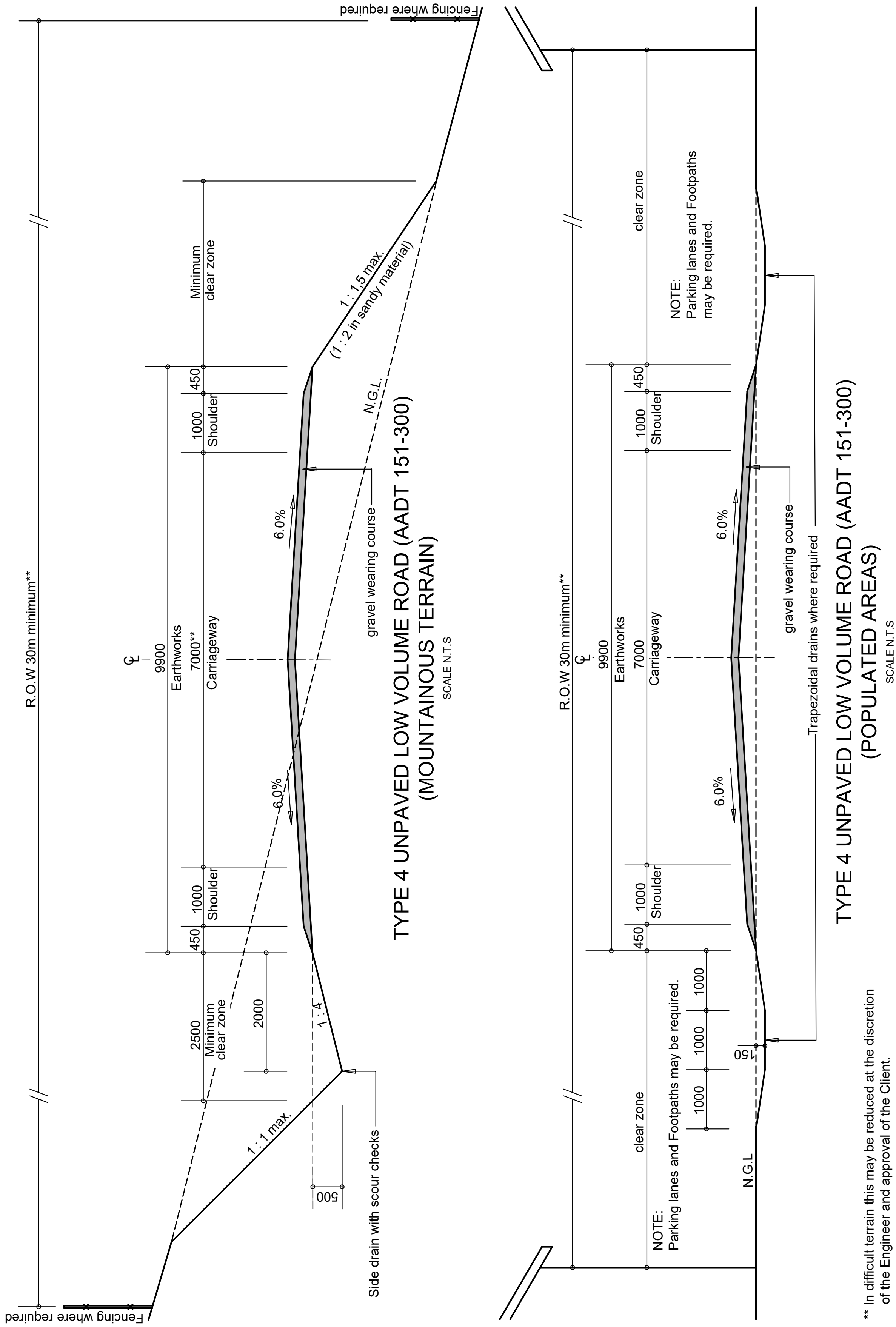
Geometric Design Standards for Type 4 Unpaved Secondary Roads (AADT 151-300)

Design Element	Unit	Flat	Rolling	Mountain	Populated areas
Design speed	km/h	70	50	30(2)	50
Right of Way (R.O.W.) width	m	30	30	30(3)	30(3)
Carriageway width	m	7	7	7(2)	7
Shoulder width	m	1 (4)	1 (4)	1 (2,4)	1 (4,5)
Minimum gradient	%	0.5	0.5	0.5	0.5
Maximum gradient	%	7	9	10	9
Normal camber	%	6	6	6	6
Maximum superelevation	%	7	6	6	6
Minimum stopping sight distance	m	105	65	35	65
Safe overtaking sight distance	m	445	235	-	235
Minimum horizontal radius for superelevation = 6%	m	195	95	30	95
Minimum horizontal radius for superelevation = 7%	m	185	-	-	-
Minimum length of horizontal curve	m	120	80	50	80
Minimum crest vertical curve	K	17	7	2	7
Minimum sag vertical curve	K	23	13	6	13

1. If the number of large vehicles is > 80, the road classes for high volume traffic should be used.
2. In difficult terrain this may be reduced at the discretion of the Engineer and approval of the client.
3. Right-of-way may be reduced to 20 m at the discretion of the Engineer and approval of the client.
4. Increase shoulder widths for NMT and 2- and 3-wheeled motorized traffic > 300 PCUs per day.
5. Parking lanes and footpaths may be required.



Typical Cross-Sections for Type 4 Unpaved Secondary Roads (AADT 151-300) – Flat and Rolling

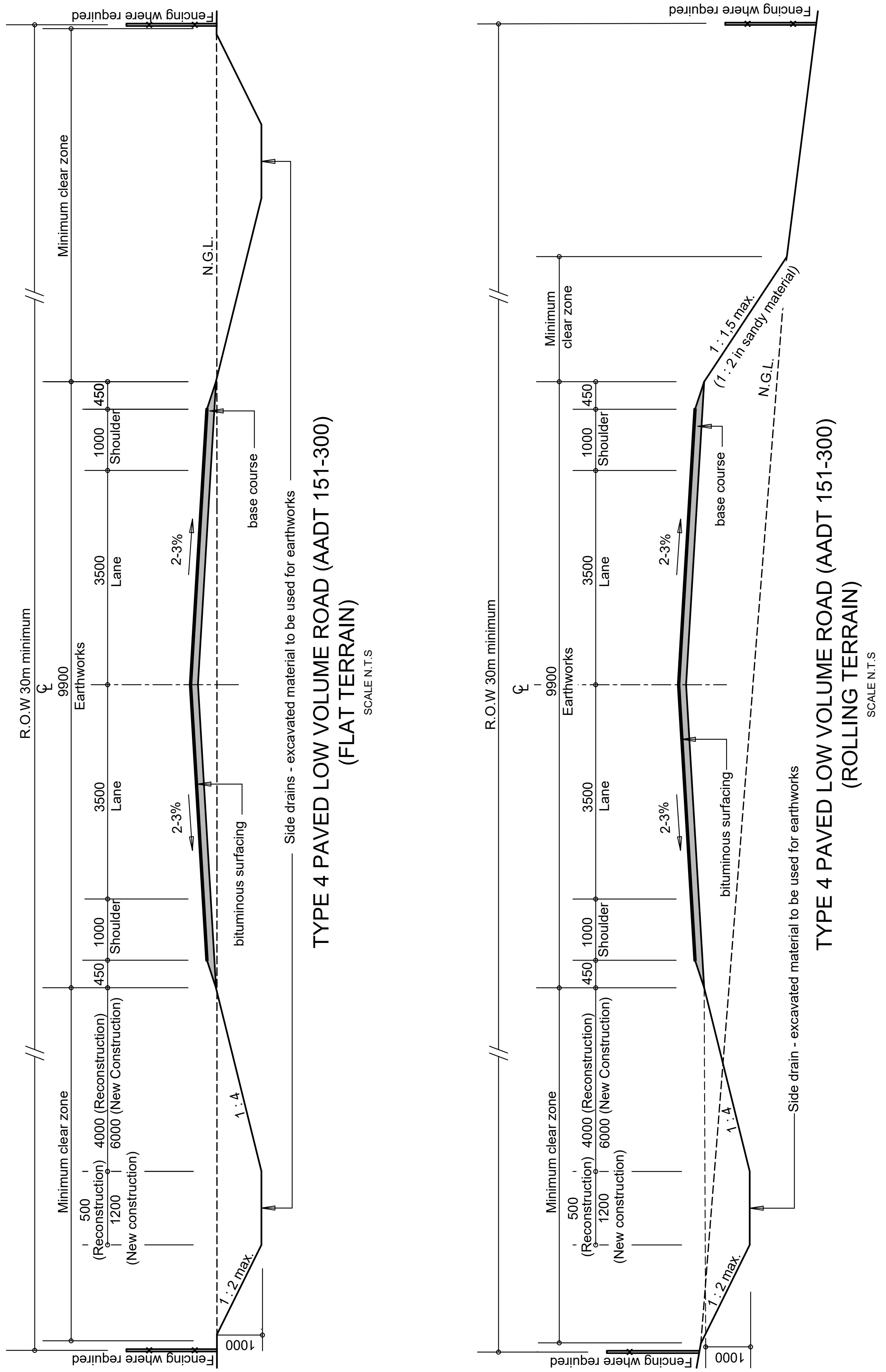


Typical Cross-Sections for Type 4 Unpaved Secondary Roads (AADT 151-300) – Mountainous and Populated

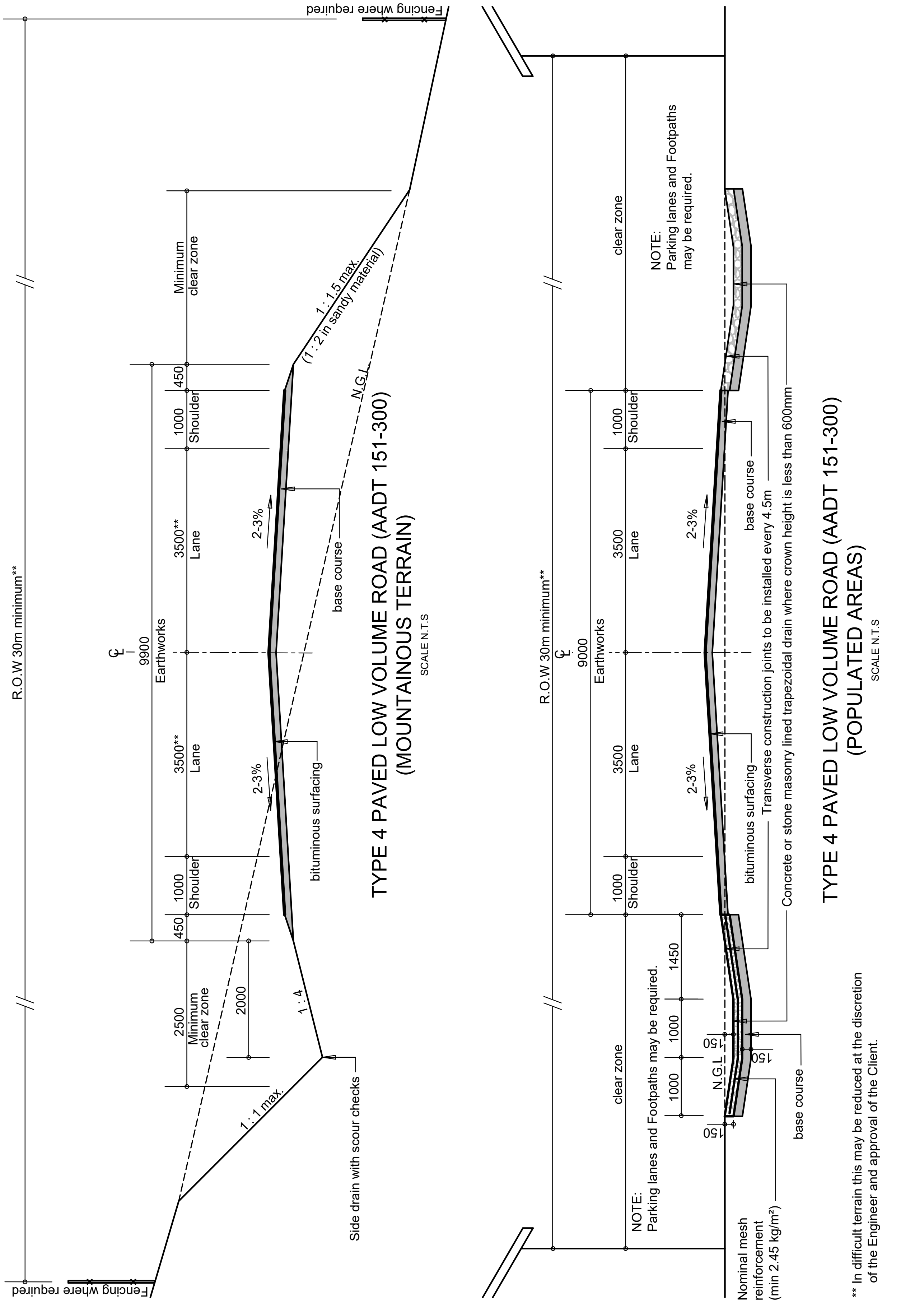
Geometric Design Standards for Type 4 Paved Secondary Roads (AADT 151-300)

Design Element	Unit	Flat	Rolling	Mountain	Populated areas
Design speed	km/h	80	60	40[2]	50
Right of Way (R.O.W.) width	m	30	30	30[3]	30[3]
Carriageway width	m	7	7	7[2]	7
Shoulder width	m	1[4]	1[4]	1[2,4]	1[4.5]
Minimum gradient	%	0.5	0.5	0.5	0.5
Maximum gradient	%	4	8	10	8
Normal camber	%	2-3[6]	2-3[6]	2-3[6]	2-3[6]
Maximum superelevation	%	8	6	4	5
Minimum stopping sight distance	m	130	85	50	65
Safe overtaking sight distance	m	470	300	165	235
Minimum horizontal radius for superelevation = 3%	m	300	145	50	90
Minimum horizontal radius for superelevation = 4%	m	280	135	50	85
Minimum horizontal radius for superelevation = 5%	m	265	130	-	85
Minimum horizontal radius for superelevation = 6%	m	255	125	-	-
Minimum horizontal radius for superelevation = 7%	m	240	-	-	-
Minimum horizontal radius for superelevation = 8%	m	230	-	-	-
Minimum length of horizontal curve	m	140	100	70	80
Minimum crest vertical curve	K	26	11	4	7
Minimum sag vertical curve	K	30	18	9	13

1. If the number of large vehicles is > 80, the road classes for high volume traffic should be used.
2. In difficult terrain this may be reduced at the discretion of the Engineer and approval of the client.
3. Right-of-way may be reduced to 20 m at the discretion of the Engineer and approval of the client.
4. Increase shoulder widths for NMT and 2- and 3-wheeled motorized traffic > 300 PCUs per day.
5. Parking lanes and footpaths may be required.
6. Adopt 2.5% camber in regions of high rainfall.



Typical Cross-Sections for Type 4 Paved Secondary Roads (AADT 151-300) – Flat and Rolling



Typical Cross-Sections for Type 4 Paved Secondary Roads (AADT 151-300) – Mountainous and Populated

Appendix A.3: Road Safety Audit Checklist

The following checklists draw on recognized good practice and should be applied as follows:

Stage A checklist: On completion of design

Stage B checklist: On completion of construction

Stage C checklist: For ongoing monitoring

STAGE A Road Safety Audit Checklist - Completion of Design	
Item	**Potential Issues**
Departures from Standards	What are the road safety implications of any approved Departures from Standards or Relaxations?
	Are these strategic decisions within the scope of the Road Safety Audit?
Cross-sections	How safely do the cross-sections accommodate drainage, signage, pedestrian and cycle routes?
	Could the scheme result in the provision of adverse camber?
Drainage	Do drainage facilities (e.g. gully spacing, gully locations, flat spots, crossfall, ditches) appear to be adequate?
	Is surface water likely to drain across the carriageway and increase the risk of aquaplaning under storm conditions?
	Could excessive water drain across the highway from adjacent land?
Landscaping	Could areas of landscaping conflict with sight lines?
	Could vegetation encroach onto carriageway or obscure signs or sight lines?
Public Utility Services	Are boxes, pillars, posts and cabinets located in safe positions away from locations that may have a high potential of errant vehicle strikes? Do they interfere with visibility?
	Has sufficient clearance of overhead cables been provided?
Lay-bys	Could lay-bys be confused with junctions?
	Is the lay-by located in a safe location? (e.g. away from vertical crests or tight horizontal bends with limited visibility)
	Could parked vehicles obscure sight lines?
	Are lay-bys adequately signed?
Access	Can all accesses be used safely?
	Can multiple accesses be linked into one service road?
	Are there any conflicts between turning and parked vehicles?
	Is adequate visibility provided to/from accesses?
	Do all accesses appear safe for their intended use?

STAGE A Road Safety Audit Checklist - Completion of Design	
Item	**Potential Issues**
Local Alignment	Are horizontal and vertical alignments consistent with required visibility? Any "hidden dips"?
	Will sight lines be obstructed by permanent and temporary features e.g. bridge abutments, signage, parked vehicles etc?
New/Existing Road Interface	Will the proposed scheme be consistent with the standard of provision on adjacent lengths of road and if not, is this made obvious to the road user?
	Does interface occur near any potential hazard, i.e. crest, bend, after steep gradient?
	Where road environment changes (e.g. urban to rural, restricted to unrestricted) is the transition made obvious by appropriate signage and road markings?
Junctions	Are there any unusual features that affect road safety?
	Are any junctions sited on crests?
	Are sight lines adequate on and through junction approaches and from the minor arm?
	Are visibility splays adequate and clear of obstructions such as street furniture and landscaping?
	Are parking or stopping zones for buses, taxis and public utilities vehicles situated within the junction area? Are they located outside visibility splays?
	Is the junction signing adequate, consistent with adjacent signing and easily understood?
	Have the appropriate warning signs been provided?
	Are signs appropriately located, minimize potential strike risk, and are of the appropriate size for approach speeds?
	Are traffic signs mounted to appropriate heights and orientated correctly to ensure correct visibility and reflectivity?
Non-Motorized User (NMU) Provision	Have pedestrian and cycle routes been provided where required?
	Is specific provision required for special and vulnerable groups? (i.e. the young, older users, mobility and visually impaired)
	Are tactile paving, flush curbs and guard railing proposed? Is it specified correctly and in the best location?
	Are these routes clear of obstructions such as signposts, lamp columns etc?
	Are accesses to and from adjacent land/properties safe to use?
	Are facilities required for Non-Motorized Users (NMUs) at junctions, crossings etc.
	Are crossing facilities designed and placed to attract maximum use?
	Is there sufficient visibility and signage for both motorists and for pedestrians/cyclists?

STAGE A Road Safety Audit Checklist - Completion of Design	
Item	**Potential Issues**
Traffic Signs and Road Markings	Will signposts be appropriately located and/or protected?
	Are any road markings proposed at this stage appropriate?
	Do the signs and road markings conform to national standards, policy or regulation?
	Are road signs and markings appropriate to the location, easy to understand, and uncluttered?
	Are signposts passively safe?
	Is the sign reflectivity provided correct?

STAGE B Road Safety Audit Checklist - Completion of Construction	
Item	**Potential Issues**
Departures from Standards	Are there any adverse road safety implications of any Departures from Standard granted since the Stage 2 Road Safety Audit?
Drainage	Does drainage of roads, cycle routes and footpaths appear adequate?
Landscaping	Could vegetation obscure signs or sight lines?
Public Utility Services	Are boxes, pillars, posts and cabinets located in safe positions away from locations that may have a high potential for errant vehicle strikes? Do they interfere with visibility?
Access	Has adequate visibility been provided to/from accesses?
Local Alignment	Are the sight lines clear of obstruction?
New/Existing Road Interface	Is there a need for additional signs and/or road markings?
Junctions	Are all visibility splays clear of obstructions?
	Is signage adequate?
	Do the carriageway markings clearly define routes and priorities?
Non-Motorized User (NMU) Provision	Has adequate visibility and signage been provided for pedestrian and cyclist crossings?

STAGE B Road Safety Audit Checklist - Completion of Construction	
Item	**Potential Issues**
Traffic Signs and Road Markings	Have appropriate signs and/or markings been installed in respect to national standards, policy or regulation?
	Are the visibility, locations and legibility of all signs (during daylight and darkness) adequate?
	Are signposts passively safe?
	Will signposts impede the safe and convenient passage of pedestrians and cyclists?
	Have additional warning signs been provided where necessary?
	Are all road markings/studs clear and appropriate for their location?
	Have all superseded road markings and studs been removed adequately?

STAGE C Road Safety Audit Checklist - Monitoring
During the first year a roadway improvement scheme is open to traffic, a check should be kept on the number of personal injury collisions that occur, so that any serious problems can be identified, and remedial work arranged quickly. Stage 4 collision monitoring reports should be prepared using 12 months and 36 months collision data from the time the scheme became operational. These reports shall be submitted to the Overseeing Organization. The collision records shall be analyzed in detail to identify: (a) Locations at which personal injury collisions have occurred, (b) Personal injury collisions that appear to arise from similar causes or show common factors.
The analysis should include identification of changes in the incident population in terms of number, types, and other collision variables, and comparisons should be made with control data. Where the Highway Improvement Scheme is an on-line improvement then the collision record before the scheme was built should be compared with the situation after opening. The collision data should be analyzed to identify the influence of problems and recommendations identified at previous audit stages, and any Exception Reports.
If collision records are not sufficiently comprehensive for detailed analysis, the police should be contacted to ascertain the availability of statements and report forms, which could aid the 36-month data analysis.
The collision monitoring reports should identify any road safety problems indicated by the data analysis and observations during any site visits undertaken. The reports should make recommendations for remedial action.

Source: Developed from HD 19/15 of the UK Highways Manual Volume 5 Section 2 Part 2.

Appendix A.4: CIs in Planning, Feasibility Study and Design

Key issues to consider during early planning stages

Complementary Interventions (CIs) need to be treated as an integral part of the planning process, in much the same way as environmental and social safeguards. Provision for them should be included in the long and medium-term budgets to prevent them being removed due to inadequate budgeting or fund allocation.

The client should consult with key stakeholders during project identification stages. Key stakeholders at the early planning stage could include those who identified the need for the project and representatives from local administrations. The outcome of the consultations should be an outline or indicative plan for inclusion of complementary interventions in the road project/program.

It is the responsibility of the client to decide on the extent of CIs that are to be considered during feasibility study and prepare the outline plan. The outline plan should describe the category, type and scale of the CIs to be developed further.

Road projects, by their nature, can cover relatively long distances, cross many local administrative boundaries, and affect a number of different communities. Identification of CIs is not therefore a simple task of consulting one community to identify their development needs and priorities, but potentially requires consultation and negotiation with many communities, each with their own internal structures and cultures, needs and priorities. There is an associated risk that each group will think another is being allocated a better 'share' than they are.

The key stakeholders will be expected to have a deeper understanding of the beneficiary communities than the client and should be able to provide guidance on the most locally acceptable means for engaging with local communities and appropriate participatory decision-making methods.

In developing an outline plan the client should consider and provide guidance on the following issues:

- Is the client interested in including CIs in the project?
- What category of CIs are appropriate, bearing in mind the cost/budget, timeframe, scope and complexity of the project?
- How to define the boundaries of where CIs can be implemented – area of influence of the road project?
- What proportion of the road project budget may be set aside for CIs?
- How to determine the level of willingness of local authorities and communities to participate in development and implementation of CIs?
- Who, at the local level, could best assist the client and his service providers to develop and implement the CIs? Is there a need to establish 'Complementary Intervention Oversight Committees' or can existing committees or administrators take on this role?
- What are the best methods for raising awareness of the opportunities for, and identification and prioritization of, CIs? Large meetings or a greater number of small meetings with different groups? Which language(s) to work in? Who are participants and key speakers? How best to present information (in writing or pictures)? Which analysis and decision-making tools are most appropriate? How to consolidate different needs identification and prioritization results?
- What may be the best method for identifying and selecting the proposed CIs – for example, forming a committee with representatives from the district level to determine the shortlist? Or each district presents its shortlist to the consultant/client for consideration?
- Can key stakeholders, based on current local development plans and initial consultation with local authorities within the project area, develop an indicative list of potential CIs?
- What additional funding or resources may be available from other sources to allocate to CIs?
- To what level does the participation process need to extend? This partly depends on the budget and category of intervention agreed on for the specific project. It will also depend on the number and size of communities that live along the road.
- How is each community defined? What is the formal and informal structure for decision making purposes? Who are the key stakeholders – those likely to influence the decisions made and those likely to influence the success of implementation and sustainability of interventions?

- How to ensure vulnerable and/or excluded groups within a community are included in the participation process? (e.g. women, elderly, children, physically and mentally disadvantaged, ethnic or religious minorities, etc.).

Key issues to consider during feasibility study and preliminary design

During the Feasibility Study for new road, the consultant, with guidance from the client and key stakeholders, takes on the responsibility to further investigate the options for and develop preliminary designs and cost estimates for CIs, based on the outline plan previously prepared.

The investigations at this stage are aimed at developing the CIs to a sufficient level of detail to enable reasonably accurate cost estimates to be prepared and impacts to be assessed. CIs are to be included as an integral part of the options analysis and economic analysis of the road project. Despite giving rise to additional costs, they may well raise the economic rate of return of the road investment.

The Feasibility Study consultant will need to continue and expand upon the consultations already undertaken through a detailed participation strategy. Initial awareness should raise the outline road project to the local communities. Information to be given including the approximate timeframe for the project

- Potential route options (the final route selection may mean some communities do not fall within the road project corridor);
- Nature of the works;
- Potential for CIs.

Following on from the awareness raising program, the client or his representative, should work closely with the local authorities and communities to identify and prioritize the potential CIs.

The detailed participation strategy will need to define how decision-making may be devolved to the local level, whilst maintaining an overview and consistency in approach along the road project. It will need to clearly define decision making methodologies and allocate responsibilities for decision making at all levels.

The outcome of the identification and prioritization process should be a list of potential interventions. Ideally, this should be presented as an impact analysis table, with each intervention having an estimated cost, an estimate of the number of people and extent of impact on different groups of people positively or negatively affected by the intervention, and an attempt at quantifying the benefits of the intervention. The location of potential CIs and the intended beneficiaries should be clearly defined.

A preliminary or outline design will also be necessary at this stage to enable relatively accurate cost estimates for each potential CI. The consultant should also identify any sources of additional financing or resources that can be used to implement them. This could include funds coming from the Client through the road project contract, financing promised from other sectors or local authorities, contributions of labor or materials promised from local authorities and local community inputs such as labor.

The local authorities, based on the guidance given by the client, should review the list of proposed interventions and select those which they propose for inclusion in the project. This will be a difficult task and needs to balance allocated budgets against meeting the prioritized needs of the most people in an equitable manner. The decision-making process must be transparent to minimize the potential for conflict and complaint.

Due consideration needs to be given by local authorities to the client on:

- How to divide the CI resources between different communities along the road?
- How to divide the CI resources among the different categories of CI? Is this defined in the policy or is it project specific?
- If interventions are to be demand driven – whose demands are more important? Are all groups equal? What are the implications for decision making and implementation? Are there any development policies that prioritize certain social groups or types of intervention?
- How to coordinate ideas of local communities with development plans of local authorities and higher-level sector organizations (line ministries)?

It is likely that the final selection of CIs will be an iterative process, to ensure ownership at all necessary levels. Conflict management between different groups of one community, between adjacent communities, between different sectors and authorities should be resolved by the appropriate authorities.

The feasibility report should capture the selection methodology, analysis of potential complementary interventions and recommendations for those to be selected for inclusion in the project, along with an outline budget.

Appendix A.5: Examples of CIs by Category and Theme

Theme: Road and Site Safety

Category 1 Management Interventions	Category 2 Opportunity Interventions	Category 3 Enhancement Interventions
▪ Provide illumination/ additional marking in dangerous areas ▪ Extend provision or maintenance of access to specific services and facilities for pedestrians and IMTs ▪ Provide road safety education to employees ▪ Provide access to first aid training for community representatives and to facilities in emergency ▪ Rigorously enforce speed limits of equipment and plant	▪ Distribution of reflective strips for pedestrian, NMT and IMT road users. ▪ Provide boards warning community of construction and road hazards ▪ Provide refresher/first aid training for local health officials	▪ Road safety awareness: schools/community road safety education campaigns – Community theatre, TV and radio etc. ▪ Provide Road Safety equipment, teaching aids or additional equipment

Theme: Transport Services

Category 1 Management Interventions	Category 2 Opportunity Interventions	Category 3 Enhancement Interventions
▪ Ensure adequate physical access for Pedestrian, NMT, IMT and normal RTS is maintained ▪ Provide adequate bus- bays and shelter	▪ Supply IMT to cooperatives/ associations ▪ Provide IMT maintenance training to cooperatives ▪ Provide technical skills training to local transport service operators ▪ Make available mechanical workshops for IMT/RTS repairs	▪ Provide awareness training on options for rural transport services ▪ Provide seed financing for establishment of rotating funds for supply and maintenance of IMT ▪ Provide animal husbandry training

Theme: Support Service Sectors

Category 1 Management Interventions	Category 2 Opportunity Interventions	Category 3 Enhancement Interventions
▪ Provide vehicles and temporary emergency/ first aid services for local communities whose access to mainline services is hindered by the construction works ▪ Supply local health centers with ARVs, and other drugs relating to communicable disease control	▪ Provide HIV/AIDS testing and counselling services along the road corridor for construction workers and local communities ▪ Distribution of first aid supplies to health posts ▪ Assist with the repair, rehabilitation or maintenance of health and education facilities centers (incl. hospices & orphanages)	▪ Provide classroom furniture (desks and chairs) ▪ Promote use of ICT in schools through improved electrical and communications installations, provision of computers, etc. ▪ Provide mosquito nets and mattresses to orphanages, hospices and nurseries ▪ Provide support to initiatives supporting community education and awareness (health, safety, livelihoods and income generation) ▪ Provide water supply/ construct sanitation facilities for roadside communities

Theme: Community Development

Category 1 Management Interventions	Category 2 Opportunity Interventions	Category 3 Enhancement Interventions
▪ Maximize employment opportunities for local communities, including women – provide crèche and other support facilities	▪ Provide advisory services to local administration with regards construction, rehabilitation or maintenance of community infrastructure ▪ Provide ground water recharge schemes, water harvesting or small micro- irrigation schemes ▪ Provide materials, equipment and training to support establishment and development of local SMEs ▪ Supply materials, equipment, labor, etc. for community projects (e.g. pipes, cement, steel, timber, wiring, tractors, excavators, skilled laborers, etc.)	▪ Provide office furniture, accommodation and sanitation facilities for community facilities ▪ Skills enhancement - Train casual and other local laborers (e.g. better livestock management; agricultural methods etc.) ▪ Provide life skills training (e.g. literacy, numeracy, basic accounting, kitchen gardening, sanitation and hygiene, etc.) to local community groups and SMEs

Theme: Road Corridor Environment (including climate change adaptation measures)

Category 1 Management Interventions	Category 2 Opportunity Interventions	Category 3 Enhancement Interventions
▪ Provide temporary and permanent accesses to homes, tracks and paths ▪ Provide water and hand sprinkler systems to local communities to control dust on road sections near their properties as needed ▪ Reinstatement of diversion roads – consider transferring ownership for use by IMTs (particularly in busy/ dangerous areas) ▪ Reinstatement of temporary work areas – e.g. provide designs for utilization of borrow pits to dams or fish ponds ▪ Provide opportunity for community to claim spoiled materials including wood from grubbing, topsoil or oversize ▪ Provide additional soil protection and road/structure erosion protection in vulnerable areas	▪ Plant productive (e.g. fruit, nuts, fuel) trees and plants along roadside and in reinstatement of borrow areas ▪ Establish landfill/waste management sites, utilizing borrow areas and quarries where appropriate, or areas designated by local authorities ▪ Repair to areas suffering previous erosion or siltation damage ▪ Improve access to the road access roads, trail bridges, footpaths ▪ Improve access from the road to local community facilities ▪ Provide road maintenance training e.g. to lengthmen (or other technical training) to local administrations/SME ▪ Rehabilitation and repair to community/village assets: roads, market areas, meeting areas, sanitation/ water supply facilities, drainage systems, etc.	▪ Establish nurseries for supply of trees and shrubs for bio-engineering, fruit orchards, wood lots etc. ▪ Provide protective tubing for saplings, covers for seedlings and water supply ▪ Extend productive planting to other areas identified by local community ▪ Support programs to eradicate invasive plant species ▪ Supply fingerlings for borrow areas upgraded to fish ponds ▪ Build community/village assets – school rooms, health or veterinary posts, storage facilities, training/meeting rooms etc. ▪ Utilize road drainage systems to provide water-harvesting facilities

Theme: Research, Demonstration and Training

Category 1 Management Interventions	Category 2 Opportunity Interventions	Category 3 Enhancement Interventions
▪ Inclusion of Road Authority personnel on contractor's team for professional training/ experience ▪ Inclusion of trial/ demonstration sections for new technical options	▪ Investigate different approaches to CI design and implementation to improve future provision and contract conditions ▪ Provide technical training to local mechanics, electricians, plumbers, carpenters, masons, etc. (e.g. through employment and maintenance at camp /work sites)	▪ Provide technical and management advice and training to local authorities and administrations on key issues