MINISTRY OF PUBLIC WORKS
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TRANSPORT

MAINSTREAMING APPROPRIATE LOCAL ROAD STANDARDS AND SPECIFICATIONS AND DEVELOPING A STRATEGY FOR THE MPWT RESEARCH CAPACITY

SEACAP 3

Low Volume Rural Road Standards and Specifications: Part I

Classification and Geometric Standards

UNPUBLISHED PROJECT REPORT

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Lao Low Volume Rural Road Standards and Specifications: Part I

Classification and Geometric Standards

Prepared for: Project Record:	**SEACAP 03. Mainstreaming Appropriate Local Road Standards and Developing a Strategy for the MPWT Research Capacity**
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ABBREVIATIONS & ACRONYMS

AADT	Average Annual Daily Traffic
ADT	Average Daily Traffic
ASEAN	Association of South East Asian Nations
CBR	California Bearing Ratio
CNCTP	Cambodia National Community of Transport Practitioners
CRC	Community Road Committees
CSA	Crushed Stone Aggregate
CSIR	Council for Scientific and Industrial Research (South Africa)
DBM	Dry Bound Macadam
DBST	Double Bituminous Surface Treatment
DCP	Dynamic Cone Penetrometer
DfID	Department for International Development
DoR	Department of Roads
EADT	Equivalent Average Daily Traffic
EDCs	Economically emerging and Developing Countries
ENS	Engineered Natural Surface
esa	equivalent standard axles
FHWA	Federal Highways Association (US)
FM	Fines Modulus
FWD	Falling Weight Deflectometer
GMSARN	Greater Mekong Sub-region Academic and Research Network
GoL	Government of Lao PDR
gTKP	global Transport Knowledge Partnership
GVW	Gross Vehicle Weight
GWC	Gravel Wearing Course
HDM4	Highway Development and Management Model
HQ	Headquarters
HRD	Human Resource Development
IFG	International Focus Group
IFRTD	International Forum for Rural Transport Development
ILO	International Labour Organisation
IRI	International Roughness Index
km	kilometre
LCS	Low Cost Surfacing
LRD	Local Roads Division (DoR)
LVRR	Low Volume Rural Road
m	metre(s)
MCTPC	Ministry of Communication, Transport, Post and Construction (now MPWT)
MERLIN	**M**achine for **E**valuating **R**oughness using **L**ow-cost **IN**strumentation
mm	millimetre(s)
MoU	Memorandum of Understanding
MPa	Mega Pascals
MPWT	Ministry of Public Works and Transportation (formerly MCTPC)
NGPES	National Growth and Poverty Eradication Strategy
NUOL	National University of Lao

OCTPC	Office of Communication Transport Posts and Construction (District Level)
OPWT	Office of public works and transport (at district level – formerly OCTPC)
ORN	Overseas Road Note
PAD	Personnel and Administration Division (MPWT)
PCU	Passenger Car Unit
Pen Mac	Penetration Macadam
PIARC	World Road Association
PTD	Planning and Technical Division (DoR)
QA	Quality Assurance
Ref.	Reference
RRGAP	Rural Road Gravel Assessment Programme (Vietnam)
RRSR	Rural Road Surfacing Research (Vietnam)
RRST	Rural Road Surfacing Trials (Vietnam)
RT1	Rural Transport 1st Project, Vietnam
RT2	Rural Transport 2nd Project, Vietnam
RT3	Rural Transport 3rd Project, Vietnam
SBST	Single Bituminous Surface Treatment
SCC	SEACAP Coordinating Committee
SEACAP	South East Asia Community Access Programme
SIDA	Swedish International Developments Cooperation Agency
SOE	State Owned Enterprise
T	Tonne
TRL	Transport Research Laboratory
UK	United Kingdom
UNOPS	United Nations Office for Project Services
VN	Vietnam
VOCs	Vehicle Operating Costs
VPD	Vehicles per day
WBM	Water Bound Macadam
WLAC	Whole Life Asset Costs
WLC	Whole Life Costs

1 Introduction

1.1 Background and Context

Reducing transport costs through rural road improvement generates significant reductions in poverty. It does this through improving the income earning opportunities of rural people and through reducing the costs of the goods they consume. Rural road construction is therefore seen by the GoL as an important component of the National Growth and Poverty Eradication Strategy (NGPES) target of eradicating mass poverty by 2010 and general poverty by 2020. Inherent in this strategy is the requirement that all villages should have year round motorable access by 2020.

It is estimated that in order to achieve these targets, it will be necessary to rehabilitate approximately 11,000 km of rural roads which have fallen into disrepair and construct approximately 10,000 km of new rural roads. There are clear technical challenges associated with these targets and in order to achieve these targets, it is necessary that the rural roads are designed, constructed and maintained to appropriate standards.

During the past 20 years or so, DfID and other Donors have supported research on various aspects of low volume roads specifically with the aim of reducing costs and increasing the effectiveness of the provision of such roads for rural and peri-urban communities. Much of this research has been highly successful, resulting in innovative and unconventional approaches that can provide highly beneficial and cost effective solutions for low volume roads in these counties, for example, the use of alternative sustainable road surfacings.

Key to the success of these innovative solutions is recognition that conventional assumptions regarding road design criteria need to be challenged and that the concept of an appropriate, or Environmentally Optimised Design, approach provides a way forward. Low volume road standards and designs need to support the function that the road is providing as well as recognising the important influences of the deterioration mechanisms. The use of locally available, but frequently non-standard, pavement construction materials plays a significant role within this concept.

International and regional research in recent years has indicated that Low Volume Rural Roads (LVRR) tend to respond to the dominance of a range of factors, collectively known as the "road environment", that together describe the matrix of road environment issues that need to be addressed by design response factors such as, road geometry, pavement type and drainage arrangements. It is now believed that the relative influences of road deterioration factors are significantly different for low volume rural roads compared with higher category roads. One of the implications from this is that appropriate road design options need to be specially researched and adopted for LVRR regimes.

1.2 Requirement

Undertaking research and developing likely solutions is not nearly enough. There has to be a framework within which they can be mainstreamed. Suitable LVRR Standards are therefore seen as essential to provide the context and control framework within which local resource-based pavement options may be assessed and selected for appropriate use in Lao. These standards should ideally identify classes of rural road in terms of usage and geometry that can be linked to sustainable pavement options defined by appropriate technical specifications.

Many low volume rural road alignments may have developed over the years from tracks rather than being newly constructed and hence little attention may have been given to imposing overall LVRR Standards. The result may be that there are basic design deficiencies on existing LVRRs, with variable widths and geometry and poor drainage provisions. This situation may be further compounded in Lao by the number of Donors, Agencies and NGOs involved in the Lao rural infrastructure development utilising a their own standards. This can lead to higher maintenance costs and poor safety.

Appropriate overall LVRR Standards, involving Classification and Geometric Design are therefore seen as a priority by the GoL and MPWT for a number of reasons.

1.3 Document Users

This first LVRR document, dealing with Classification and Geometric Standards, is currently linked to two companion LVRR volumes; they are:

- Lao LVRR Standards and Specifications Part II: Technical Specifications – containing technical specifications for an initial short list of pavement and surfacing options and a matrix of standard designs based on these options.
- Lao LVRR Standards and Specifications Part III: Guidelines on the Application of LVRR Standards and Specifications – containing advice on the application of Parts I and II within an Environmentally Optimised Design strategy ranging from Spot Improvement to the construction or upgrade of whole road links.

Other documents dealing with issues such as structures (bridges and culverts) and maintenance may at some future date be incorporated into the LVRR suite of Standards.

An important aspect of the NGPES is the increased decentralisation of rural road management to Community Road Committees (CRCs) at ‘kum ban’ (village cluster) or village level. For this reason this document and its companions are primarily aimed at the design, construction and supervision of LVRRs by district authorities (OPWTs). It is intended that all rural roads falling within the Low Volume envelope, whether funded by Donors, NGOs or GoL should be designed and constructed following these Standards.

2 Principles

2.1 General

A road classification based on road task allows for a consistent treatment of all similar roads within the infrastructure system in terms of their design, construction, maintenance requirements, users expectations, and safety.

The main objective of the LVRR Standards and Specifications is that they must be appropriate for Lao in terms of current road usage and the proposed extensive rural infrastructure developments. The LVRR Standards and Specifications are:

- Task based – they suit the road function and its traffic (the people as well as the vehicles) which will pass along them.
- Local resource based and compatible with the road sector in Lao: the engineers and technicians who will design the roads, the contractors and labourers who will construct them, the villagers who maintain them and the construction materials that are available.
- Finally they must facilitate the construction of roads with whole life asset costs that will not exhaust the provincial and district budgets or place excessive maintenance burdens on local communities.

The LVRRs Standard and Specifications are intended for application in the construction or upgrade of all-weather roads so as to provide all-year basic access to villages and communities with minimal disruption. Good road engineering principles have been adhered to and careful consideration has been given to the safety of pedestrian, non-vehicular traffic, and light 2 or 3-wheeled motorized traffic.

2.2 The Low Volume Rural Road Environment

The LVRR Standards have been drafted with a view to their application in an Environmentally Optimised Design (EOD) strategy that takes full account of the various road environment impact factors within two principle categories; task and environment. EOD can be considered as the over-arching principle for a spectrum of practical actions for improving or creating low volume rural access – from dealing with individual critical areas on a road link (Spot Improvements) to providing a total whole rural link design, which, in the latter case, could comprise different design options along its length.

Some of the road environment factors impact upon the surface of the road, others on the pavement and others on geometric aspects such as width, gradient and curvature. These factors and their impacts on road design are discussed in detail in Part III of the Standards and Specifications.

2.3 Safety Issues

Although little research has been published on rural road safety the following factors are considered to be important:

- Vehicle speed
- Poor visibility (dust)
- Horizontal and vertical curvature
- Traffic mix separation (wide shoulders)
- Slippery unsealed road surfaces
- Poor road surface condition (potholes etc)
- Inappropriate public transport pick-up/set-down areas

Conflicts between motorised vehicles and pedestrians or bicycles are a major safety problem on the type of mixed traffic rural roads that occur in Lao where separation is generally not economically possible. The World Bank Basic Access document (2001) considers that there are sound arguments on safety grounds for keeping traffic slow in mixed traffic environments rather than aiming for higher design speeds as is the case for larger roads. The use of widened shoulders in standard designs is also suggested. These LVRR Standards have adopted these recommendations.

3 LVRR Classification

3.1 Introduction

The current Lao PDR Road Classification is defined in the Lao Road Design Manual, (1996) and seven road design classes were specified in this original manual, from Class I to VII based on decreasing traffic volumes from Class I with more than 8,000 vehicles per day to Class VII with less than 50 vehicles per day.

A subsequent modification (MCTPC, 2003) recommended a split in the lowest Class VII into two classes VII and VIII for traffic categories 21 to 50 ADT and less than or equal to 20 ADT, respectively. This modification has not been officially adopted into the Road Law and this current LVRR Document may be seen as a further development of the ideas contained in the currently established framework.

3.2 The LVRR Classification

There clearly has to be an upper limit to the roads that may be included within the LVRR approach to rural road design and construction. In general terms this limit is indicated on Figure 1 as being a road environment below which traffic is not the dominant factor influencing road deterioration. This is a general conceptual figure which needs to be interpreted and adapted for specific regions bearing in mind their particular characteristics.

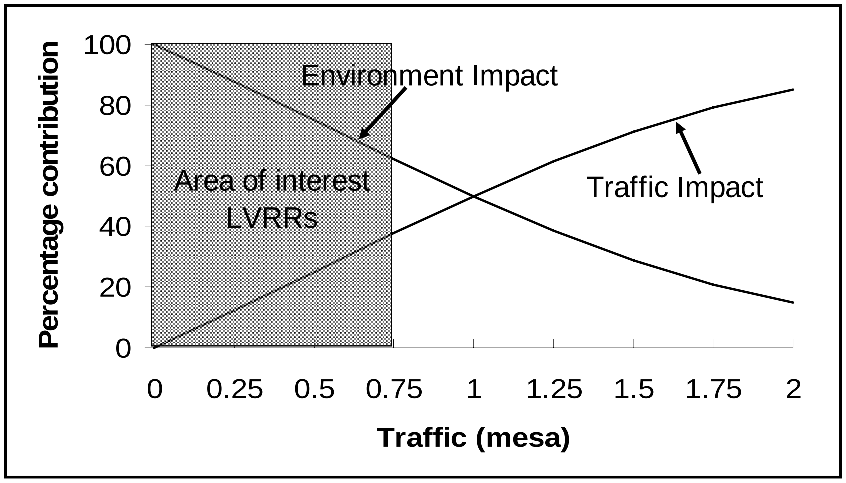

Figure 1, Relative Impacts of Traffic and other Road Environment Factors

The LVRR Classification for Lao encompasses roads that are suitable for up to medium sized commercial vehicles and with a maximum design loading carried by a single axle of 4.5Tonnes. This limit has been identified as appropriate for a substantial portion of the rural road network in consideration of current and likely future traffic demand, and the pragmatic management of the road network with the limited resources available.

It is important to note that the LVRR Classification does not imply that all Rural Roads or Community Roads (CRs) in Lao must comply with a 4.5T limit; only that roads to be designed under the LVRR principles must do so. If some Rural Roads are deemed to require a higher axle load or higher traffic standard then logically they must be dealt with under other categories in the Lao Road Design Manual.

The proposed Lao LVRR Classification is presented in Table 1 and its relationships with the current Lao Road Design Manual and the 2003 modification are indicated in Figure 2.

Table 1, LVRR Classification

Design Parameter	**Description**	**Definition**	
Road system	Low volume rural roads	For all-year accessibility	
Classification	One-lane roads. Defined by maximum number of 4-wheeled motorized vehicles, maximum axle load and maximum vehicle body width	Traffic lane	One
		Maximum 4-wheeled motorized vehicles	150 per day
		Maximum axle load limit	4.5Tonnes for any vehicle
		Maximum vehicle body width	2.3m

LVRR Standards	Road Design Class	LVRR
	Traffic Volume (AADT)	<150

Lao Road Design Manual	Road Design Class	I	II	III	IV	V	VI	VII
	Traffic Volume (ADT)	>8000	3001-8000	1001-3000	301-1000	101-300	51-100	<51

MCTPC 2003 AADT	VII	VIII
	21-51	<21

Figure 2, LVRR Classification in Relation to Existing Documents

3.3 The Basis for the LVRR Classification

Figure 2 indicates that the LVRR Classification is the broad equivalent to working within the existing LRDM classes VI and VII. Roads with functions above these requirements, and particularly those with a significant risk of heavier axle loads, would fall outside the LVRR designation and would require a different, more rigorous engineering approach to road design.

The review of national and international standards indicated that some countries, such as Vietnam, included sub divisions within the main LVRR classification. Although there may be a logical argument for this subdivision to take advantage of significant cost savings in the reduction of design standards possible with very low traffic levels or very low axle loads, it was not deemed significant within the general Lao rural infrastructure environment.

There remains the option of including a lower axle load sub-division (<2.5 T) if the need for this low standard road becomes clear as part of the developing rural road infrastructure policy. Consideration might also be given in the future to the additional inclusion of a very low 2-wheeled traffic sub-division (axle limit 0.25Tonne).

In terms of evaluating the need for a subdivision and some of the issues to be considered were:

- Any sub-division has to be practicable and have positive design benefit
- Each sub-division must take into account the “Standard Vehicle” requirements
- The practicality of ensuring compliance to very low axle load based classifications and increased risks associated with non-compliance.

The upper limit for LVRR traffic has been set at 150 motorised 4-wheel vehicles per day with an upper axle load limit of 4.5 Tonne in line with the “Design Vehicle” concept. That is rural roads are designed to accept the most common type of 4-wheeled vehicle and to accept the largest vehicle that might use the road, Table 2.

Table 2, Details of the LVRR Design Vehicles

Characteristics		**Unit**	**Kolao**	**GAZ66**	**Isuzu N Series**
Overall length		m	5.42	5.50	6.59
Wheel base		m	3.28	3.30	3.37
Track	Front	m	1.57	1.80	1.68
Track	Rear	m	1.48	1.80	1.65
Overall width		m	1.82	2.20	2.29
Height (of cab)		m	1.91		2.20
Tare weight		Tonnes		3.50	2.58
Gross vehicle weight		Tonnes	3.34	5.50 (est).	6.20
Estimated loading front @GVW	Front	Tonnes	1.00	1.50	2.00
Estimated loading rear @GVW	Rear	Tonnes	2.34	4.00	4.60
Wheels		Number	6	4	6
Wheel and/or tyres	size			12 x 18	6Jx17.5

Note: The Isuzu N series comprises a wide range of vehicle formats with variable specifications; the largest dimensions are shown in the above table

The light pick-up type is very common on Lao roads and is most likely to serve rural areas and access roads to villages. An example is the Kolao Porter model from Hyundai. The largest vehicle is likely to be the “Rice truck” which performs an extremely important function for rural communities because it provides them with a means of milling the rice ready for bagging for consumption or market. It is typically a modified GAZ 66 flat bed medium truck with a rice milling machine located on the rear.

4 Geometric design

4.1 General Approach

Geometric design is the process whereby the layout of the road in the terrain is designed to meet the needs of the road user. The geometric design standards provide the link between the cost of building the road and the benefits to road users. Usually, but by no means always, the higher the geometric standard, the higher the construction cost and the greater the road user benefits.

The geometric design standards are intended to provide minimum levels of safety and comfort for drivers by provision of adequate sight distances, coefficients of friction and road space for manoeuvres, provide the framework for economic design and ensure a consistency of alignment. Geometric design covers road width, crossfall, horizontal and vertical alignments and sight lines.

There is a clear difference in most cases between the geometric design for an unsealed gravel road and that for a sealed road, resulting from the variable nature of unsealed surfaces and their generally lower surface friction properties. Higher geometric design criteria are generally required for these unsealed roads. A road that is to be sealed at later date should still be designed to the higher unsealed geometric road standards.

The LVRR geometrics recognize that many of the road users will not be 4-wheeled motorized users. Therefore, wide shoulders of at least one metre will be required. It is intended that the roads follow the terrain as much as possible (thus minimising earthworks) and that the geometrics will permit a full line of sight and stopping distance requirement. For single-lane roads the latter is approximately twice that of two-lane roads.

4.2 The LVRR Geometric Standards

The Geometric design is based on best practice drawn from the Lao Road Design Manual and the review of regional and international documents. The proposed LVRR Geometric Standards are presented in Table 3. The basis for developing these standards is discussed in relation its key aspects in the following Section 4.3.

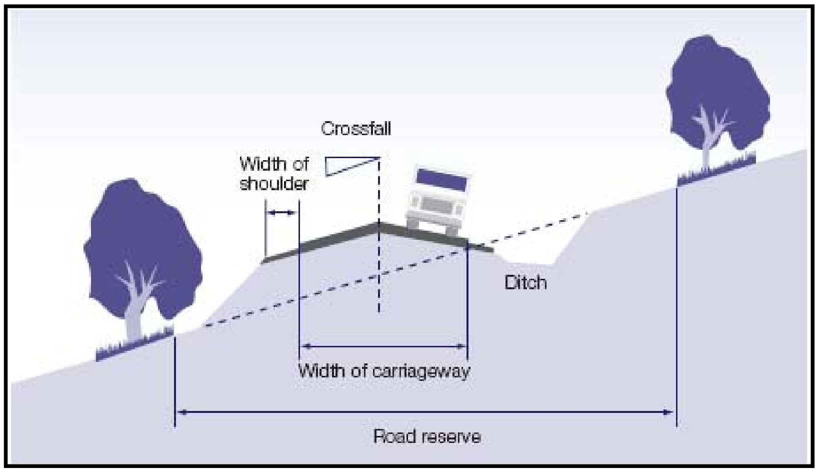

Figure 3, Key Elements of a Road Cross Section (TRL ORN 5, 2005)

Table 3, Low Volume Rural Road Geometric Standards

Design Parameter	**Comment**		**Definition**		
Design speed	Defined by Terrain		Design speed for Terrain:		
			Flat Rolling	Rolling	Mountainous
			50km/h	40km/h	30km/h
Carriageway	Defined by vehicle body widths and number of non-motorized road users		Minimum 2.5m, Maximum 3.5m (See Table 4 for selection)		
Shoulder			Minimum 1m, Maximum 1.5m each side of road (See Table 4 for selection)		
Maximum gradient	Defined by terrain with a limit of 6% for gravel surfacing		Flat	Rolling	Mountainous
			6 %	8 %	10 %[1]
Cross fall	Defined by surfacing type	Gravel	6 %[2]		
		Sealed	4 %		
Stopping sight distance	Defined by design speed and surfacing type		Meeting sight distance, for design speeds:		
			50km/h	40km/h	30km/h
		Gravel	130m	100m	60m
		Sealed	100m	70m	50m
Minimum horizontal curve radius	Defined by design speed and surfacing type for single lane road.		Horizontal curves, for design speeds:		
			50km/h	40km/h	30km/h
		Gravel	110m	70m	40m
		Sealed	95m	60m	35m
Minimum vertical curve radius	Defined by design speed for either crest or sag curves and by surfacing type		Vertical crest curves, for design speeds:		
			50km/h	40km/h	30km/h
		Gravel	1528m	890m	370m
		Sealed	1025m	520m	270m
			Vertical sag curves, for design speeds:		
			50km/h	40km/h	30km/h
		Gravel or Sealed	390m	250m	140m

1. Gradients up to 15% permitted in cases where lower gradients would incur excessive earthworks and construction cost and where lengths of alignment >10% are kept to <300m

2. Gravel crossfall must be maintained at between 4 and 6%.

4.3 Key Issues

Design Speed: Design speed is a selected speed determined for design and correlation of the geometric features of a road that influence vehicles operation. It is the expected maximum safe speed which will be adopted by the majority of drivers and which can be easily and comfortably maintained over the specified section of road being designed. In the case of the proposed LVRR a maximum design speed of 50km/h was adopted on mixed traffic safety grounds.

Design speed affects the following geometric standards:

- Horizontal alignment
- Vertical alignment
- Curvature
- Sight distance and
- Super elevation on curve.

Carriageway: For LVRRs, single lane operation is considered adequate as there will be only a moderate probability of vehicles meeting, and the few passing manoeuvres can be undertaken at very reduced speeds. Provided sight distances are adequate for safe stopping, these manoeuvres can be performed without hazard, and the overall loss in efficiency brought about by the reduced speeds will be small as only a few such manoeuvres will be involved.

Two options of a 3.5m or a 2.5m wide carriageway are included within the Standards and the decision on this and the related issue of shoulder width is related to vehicle type and the traffic mix, including the amount of non-4-wheeled traffic and non-motorised road users, Table 4.

Table 4, Criteria for Selecting Road Widths

Criteria	**Decision (Shoulder + Carriageway + Shoulder)**
If maximum vehicle width > 2.3m	Use Lao Road Design Manual
If maximum plated axle weight > 4.5T	Use Lao Road Design Manual
If total 4-wheeled traffic AADT > 150	Use Lao Road Design Manual
If maximum vehicle width > 1.8m and <2.3m	Use 1m+3.5m+1m, total 5.5m road width
If maximum vehicle width <1.8m and total AADT of non-motorized road users is <150	Use 1m+2.5m+1m total 4.5m road width
If maximum vehicle width <1.8m and total AADT of non-motorized road users is >150	Use 1.5m+2.5m+1.5m total 5.5m road width

Shoulders: The shoulders of a road must also be carefully considered in line with the following functions:

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

Consideration has also been given to the movement of pedestrians, cyclists and animal-drawn vehicles either along or across the road. Conflicts between slow and fast moving traffic need to be assessed and increased widths of both shoulder may be necessary. The increase in width will vary with the relative amounts of traffic, their characteristics, the terrain and location (eg in village areas).

Cross-Fall: Adequate crossfall is essential to provide adequate surface drainage whilst not being so great as to be hazardous by making road-use difficult. The ability of a surface to shed water varies with its smoothness and integrity and hence there are different values proposed for sealed and unsealed (gravel) roads. On unpaved roads, the minimum acceptable value of crossfall is governed by the need to carry surface water away from the pavement structure effectively, with a maximum value above which either erosion of material or wet surface slipperyness starts to become a problem.

Super-elevation: The LVRR design speeds of 30 and 40 km/h are below those for which superelevation is generally recommended on unsealed roads. However, the removal of adverse crossfall on horizontal curves below 500m radius is recommended. If superelevetion is deemed to be required for 40-50 km/h roads then it should follow recommended practice with a maximum of normal crossfall (4-6%) and be applied over the distances recommended in the LRDM.

Gradient: Gradient is a major aspect of vertical alignment and is related to vehicle performance and level of service. For the low levels of traffic flow with only a few four-wheel drive vehicles, the maximum traversable gradient is reported as 20% and two-wheel drive trucks are similarly recorded as successfully tackling gradients of 15%, except when heavily laden (TRL ORN6, 1988). Bearing in mind the likelihood of heavily laden small trucks and animal drawn carts, the LVRR Standards have a proposed general recommended limit of 10%, but with an increase to 15% for short sections in areas of difficult terrain. Regional experience indicates that unsealed road sections in excess of 6% gradient are unsustainable in the medium to long term.

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

- stopping sight distance–the distance needed for safe stopping from travelling speed,
- meeting sight distance – the distance needed for drivers of two vehicles travelling in opposite directions to bring their vehicles to a safe stop.

Of lesser importance is passing sight distance; the distance needed to see ahead for safe overtaking.

Road Curvature: In order to ensure compatibility with the existing Lao Road Design Manual the LVRR horizontal and vertical curves have been derived on similar principles to those used in that document and also by AASHTO and ARRB, with the following key factors:

Horizontal curves: Design speed; crossfall: side friction

Vertical crest curves: Meeting site distance (including speed); gradients

Vertical sag curves: Design speed; gradients; road user comfort

5 Drainage

5.1 General Principles

One of the most important aspects of the design of a road is the provision made for protecting the road from surface water or ground water. If water is allowed to enter the structure of the road, the pavement will be weakened and it will be much more susceptible to damage by traffic. Water can enter the road as a result of rain penetrating the surface or as a result of the infiltration of ground water. The road surface must be constructed with a camber so that it sheds rain water quickly and the formation of the road must be raised above the level of the local water table to prevent it being soaked by ground water.

Water can also have a harmful effect on shoulders, slopes, ditches and other features. High water velocities can cause erosion which, when severe, can lead to the road being cut. Conversely, low velocities in drainage facilities can lead to silt being deposited which, in turn, can lead to a blockage. Blockages often result in further erosion.

A good road drainage system, which is properly maintained, is vital to the successful operation of a road. It has four main functions:

- To convey rainwater from the surface of the carriageway to outfalls (streams and turn- outs)
- To control the level of the water table in the subgrade beneath the carriageway
- To intercept surface water flowing towards the road
- To convey water across the line of the road in a controlled fashion.

The first three functions are performed by side drains and the fourth by culverts, drifts and bridges.

Attention is required to ensure that all water discharges do not risk erosion downstream or on adjacent land.

5.2 Existing Drainage Standards

The Lao Road Design Manual guidance on drainage is considered to be applicable to LVRRs. Key elements of this are:

- Side drains
- Turn outs (mitre drains)
- Catch water drains (road cuts)

Further detail is contained in LVRR Standards and Specifications Part II.

6 Acknowledgements

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7 Key Documents

ARRB (2000). Unsealed Roads Manual, Guideline to Good Practice. Giummarra G, editor.

Austroads (1989). Rural Road Design – Guide to the Geometric Design of Rural Roads.

Cook J R and Petts R, 2005. Rural Road Gravel Assessment Programme. SEACAP 4 Module 4 Report.

Giummarra G (2001). Road Classifications, Geometric Designs and Maintenance Standards for Low Volume Roads. Research Report AR354, ARRB Transport Research Ltd, Vermont South, Victoria.

MCTPC, (2003). Specification for Local Roads (District and Rural Roads).

Ministry of Transport (Vietnam) 1992. Rural Road Design Standards – 22TCN 210-92 (in Vietnamese).

Transport and Research Laboratory (1988). Overseas Road Note 5, A Guide to Project Appraisal, TRL, Crowthorne.

Transport and Research Laboratory (1988). Overseas Road Note 6, A Guide to Geometric Design, TRL, Crowthorne.

Thagesen B, (ed.) (1996). Highway and Traffic Engineering in Developing Countries. E & FN Spon.