MINISTRY OF PUBLIC WORKS
AND 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 III

Application of LVRR Standards and Specifications

UNPUBLISHED PROJECT REPORT

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Low Volume Rural Road Standards and Specifications: Part III

Application of LVRR Standards and Specifications

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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 Document aims

This document provides background to the LVRR Standards and Specifications contained in the two companion volumes;

- Part I: Classification and Geometric Standards, - containing the definition of the traffic limits to Lao LVRRs and the related geometric standards
- Part II: Pavement Options and 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.

This document is not intended as a LVRR Road Design manual but it does serve to highlight important issues and provide guidance on the general application of the Standards and Specifications as well outlining key procedures.

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 documents.

Currently there are no Standards and Specifications within the MPWT that are targeted at the specific requirements for the appropriate design and construction of low volume rural roads. This volume and its two companions are responding to the identified need for such Standards and Specification appropriate to the development of affordable and sustainable rural access in Lao, as required by the NGPES strategic aims of reducing mass poverty by 2020.

1.2 Document Content

Following the Introduction, Chapter 2 summarises principles guiding the development of the LVRR Standards and Specifications. Chapter 3 presents a diagram for use by District (OPWT) engineers aimed at guiding them through the pavement selection and design framework. Key issues related to this diagram are discussed and, where relevant, reference is made to sources of additional information.

Chapter 4 then provides background information and support to the main road design tables and figures in Part II and Chapter 5 provides a brief comment on the key drainage and structures issues. Chapter 6 discusses important points relating to construction procedures and their supervision within the LVRR environment. Chapter 7 then outlines the approach to LVRR impacts on the Green Environment.

Finally there are a series of Appendices containing specific detailed information on selected key topics.

1.3 Document use

It is recognised that the LVRR Standards and Specifications will be used by mainly at OPWT level and there is therefore a need for clear guidance on their application by engineers who may have little practical design experience other than with unsealed gravel surface options. This Part III document may also be of use as background for small to medium contractors, most of whom will have limited experience in road building procedures other than those associated with unsealed gravel wearing course construction.

As 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 the LVRR Standards and Specifications it is necessary that this Document should provide a technical background and justification for the use of these documents.

2 LVRR Principles

2.1 General background

It is well understood that a road pavement is generally necessary because travelling on most alignment soils usually leads to deterioration rutting and deformation such that the route becomes impassable, although some stronger soils will satisfactorily carry low flows of traffic throughout most of the year if formed into a camber and properly drained, and maintained. Therefore the primary purpose of structural design of road pavements is to disperse the loads created by vehicle tyres and reduce the stresses on the subgrade (the alignment soils) to such a level that the subgrade does not deform. This is done by means of a road pavement designed to reduce subgrade stresses to tolerable levels whilst at the same time ensuring that the pavement layers themselves are strong enough to accommodate the stresses and strains to which each layer is exposed.

Whatever is constructed, the condition of the road will not remain constant; it will deteriorate with time under the effects of traffic and the environment. The rate of deterioration and long term effect of this will depend on a number of factors relating to the appropriateness of the original design and the actual maintenance input. It is necessary to design a road that will do its job of carrying traffic and resisting the environment satisfactorily for a specific length of time, remaining in an acceptable condition with the expected level of maintenance.

Whilst the behaviour of road pavements is complex, it is clear that subgrade stresses from traffic loading are reduced by increasing the thickness of the road pavement, and the risk of the pavement failing itself is reduced by specifying materials of adequate quality.

For Low Volume Rural Roads designed according to the Standards defined in Part I, it is possible to reduce the thickness of the pavement compared to conventional high-traffic road design because the assumed loading by the ‘design’ vehicles has itself been reduced, leading to expected lower stresses on the subgrade. It is important to recognize that thickness and materials quality are interlinked, such that better quality materials in the pavement allow thinner pavements to protect the subgrade.

In the preparation of actual pavement designs, matters such as the availability and quality of local materials, the quality of construction that may be expected and the capability of local contractors have to be considered. As with all road construction works, it remains important that good engineering practice is encouraged and the appropriate specifications adhered to. Should there be significant shortcomings in the achievement of the design and specification requirements, the performance of the pavements/surfacings can be expected to be compromised.

2.2 Environmentally Optimised Design

Environmentally Optimised Design (EOD) can be considered as the over-arching principle for the application of the LVRR Standards and Specifications. It covers a spectrum of solutions 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 (Variable Longitudinal Design). The two end-members of this spectrum may be described as follows:

> **Variable Longitudinal Design:** Applies the principle of adapting roads designs to suit environments at a regional scale to the individual road alignment scale and allows differing pavement options to be selected in response to different impacting factors along an alignment and hence a more focussed use of limited construction resources.
>
> **Spot Improvements**: Involves the appropriate improvement of specifically identified road sections either in actual need of upgrade or deemed to be at high risk of failure, and allows the appropriate application of limited resources to be targeted at key areas on existing earth or gravel road links to improve access throughout the year.

Within the context of LVRR Standards and Specifications it is important to distinguish Spot Improvement applications from routine, periodic or emergency maintenance. Spot Improvement is engineering based and involves pavement options and other solutions compatible with the design life of the road.

The pavement, surfacing and drainage options contained within this document are designed to applicable both to Spot Improvement and Variable Longitudinal Design solutions.

2.3 Pavement options

The pavement framework included in Part II consists of three basically different pavement structures: unsealed gravel; flexible with a bituminous seal; and a rigid structure with a plain (non-reinforced) concrete pavement. All are single lane roads with intermittently trafficable shoulders. For the gravel and the concrete pavements, those layers form the surfacing and the upper structural layer. For the sealed roads the surfacing does not provide any structural strength, but it does provide the vitally important role of protecting the structural layers below from the effects of rainwater.

In the pavement design the gravel surfacing and the sealed surfacing are treated in a similar fashion, in that they have been designed to protect the subgrade from excessive stresses imposed by traffic. Whereas this can be achieved fairly readily for the sealed pavements, because the pavement thickness remains constant throughout the life of the pavement, the approach to unsealed gravel pavement design is less straightforward, because the stresses on the subgrade increase as gravel is worn away. This has been taken into account as much as possible by identifying a minimum cover required to protect the subgrade and assigning an additional wearing thickness.

Consideration of the nature of LVRR’s and the relative costs of the different pavement layers has led to extensive use of capping layers in the proposed general pavement designs. These materials are approximately one third of the cost of sub-base materials and are expected to be more readily available. In this way, the thickness of the sub-base and road base materials and thereby their quantities and cost have been kept to a minimum.

Concrete (rigid) pavements are prone to cracking especially if loaded near the longitudinal edges. For single lane roads there is a particular problem because the vehicles will be required to enter onto or leave the concrete pavements to permit other vehicles to pass. For this reason a single thickness concrete pavement of 150mm has been specified which will readily tolerate the stresses imposed by vehicles travelling entirely on the pavement and will resist the stresses imposed where they enter onto or leave the pavement. It will also resist the environmental stresses imposed by the climate.

Throughout the pavement design, unrealistically high expectations of material quality have been avoided to ensure the road structure remains durable in the LVRR environment.

2.4 Pavement design life

Where a sealed pavement is proposed it has an assumed minimum pavement design life of 12 years, for reasons explained in Part II of the LVRR Standards and Specifications.

The concrete pavements will have a structural design life of significantly more than 12 years under the traffic loading anticipated in the design. They should also be durable with regard to road environment effects if specifications and normal good construction practice are followed.

The design life of a gravel wearing course is variable and dependant on the economic and policy considerations, but more importantly on the maintenance strategy for the road. With inadequate maintenance the road will effectively fail and eventually revert to earth standard if the gravel pavement is allowed to wear too thin. Effective routine and periodic maintenance can extend the pavement ‘life’ indefinitely only if the necessary financial resources and organisational capability are in place for regular and timely interventions.

Because of the variation in the design lives of the various pavement types it will be necessary to adopt a rational method for comparing whole life asset costs (WLC) of the design options. It is recommended that the 12-year period is adopted as the evaluation benchmark for comparison of costs and benefits. Accordingly the expected residual asset value of each pavement type should be estimated for the end of this WLC assessment period. Concrete pavements would be expected to have substantial residual value after 12 years. The residual value of gravel pavements will depend upon the maintenance strategy and expected residual gravel thickness after calculating gravel losses and renewal through the periodic maintenance regravelling.

Whole-life costing is not an exercise that local district engineers can be expected to carry out. However it is possible that a representative whole life costing evaluation could be carried out annually by the LRD on behalf of the local stakeholders. This should reflect regional variations in key parameters such as materials source costs, haul distances and mobilisation factors.

2.5 Traffic

Prediction of traffic growth and characteristics over the future design period of a LVRR is problematic. Many factors can influence national and local growth patterns. It is not expected that local engineers will have the time and resources to carry out detailed future traffic assessments and such predictions would be subject to a considerable uncertainty. However, the risks of inaccurate predictions are manageable in the LVRR context.

If within a period of, say, 5 years from the construction of a LVRR pavement the actual traffic or axle loading is observed to be in excess of that assumed at design stage, then measures can be taken to upgrade the carrying capacity of the pavement, for example, by the design and application of a strengthening overlay.

The roads are not suitable for the passage of heavy commercial vehicles because of the loading they will place on the structure and, importantly, the total road widths are inadequate for the passages of these vehicles, bearing in mind both their width and length. Applying the LVRR design principles to roads that have or are likely to have traffic characteristics above the defined limits will almost inevitably lead to their early failure.

3 Outline Pavement Selection and Design Process

3.1 The General Approach

The principal elements in the pavement design process are traditionally focussed only on the choice of materials and their thickness within each pavement layer. Good engineering practice in which the design process takes into account the whole road environment need to be applied to all levels of road engineering if designs are to be cost effective and sustainable in engineering, social and economic terms. This is particularly important for LVRR where the relative impacts of the factors that make up the whole road environments may be different. Table 1 presents the key elements of this road environment that impact most directly on the road design process. It is now appreciated that these additional road environment factors must be taken into account if the selected designs are to be cost-effective and sustainable in engineering, social and economic terms.

A paving selection procedure has been developed for LVRRs in Lao based on SEACAP and other related research initiatives which is based on two key principles:

1. The pavements must be fit for purpose in terms of local needs, traffic volume and axle loads,
2. The pavements should be compatible with the governing road environment factors

A two phase selection approach is proposed as shown in Figure 1 comprises:

1. Phase I: General assessment of appropriate pavement option(s) compatible with the road environment and budget constraints.
2. Phase II: Detailed design of the selected pavement components (e.g. layer thicknesses) compatible with engineering standards and requirements

The key physical issues that need to be addressed in seeking appropriate selection procedures are in particular:

1. Erosive climate-terrain environments in some provinces,
2. Lack of natural construction materials in some areas,
3. Traffic and axle loading data and constraints on traffic,
4. The construction and maintenance regimes,
5. High water tables and flooding,
6. Impact of earthworks on pavement design in hill/mountain areas,
7. Localised steep gradients,
8. The availability and engineering character of construction materials.

Table 1, Road Environment Impact Factors

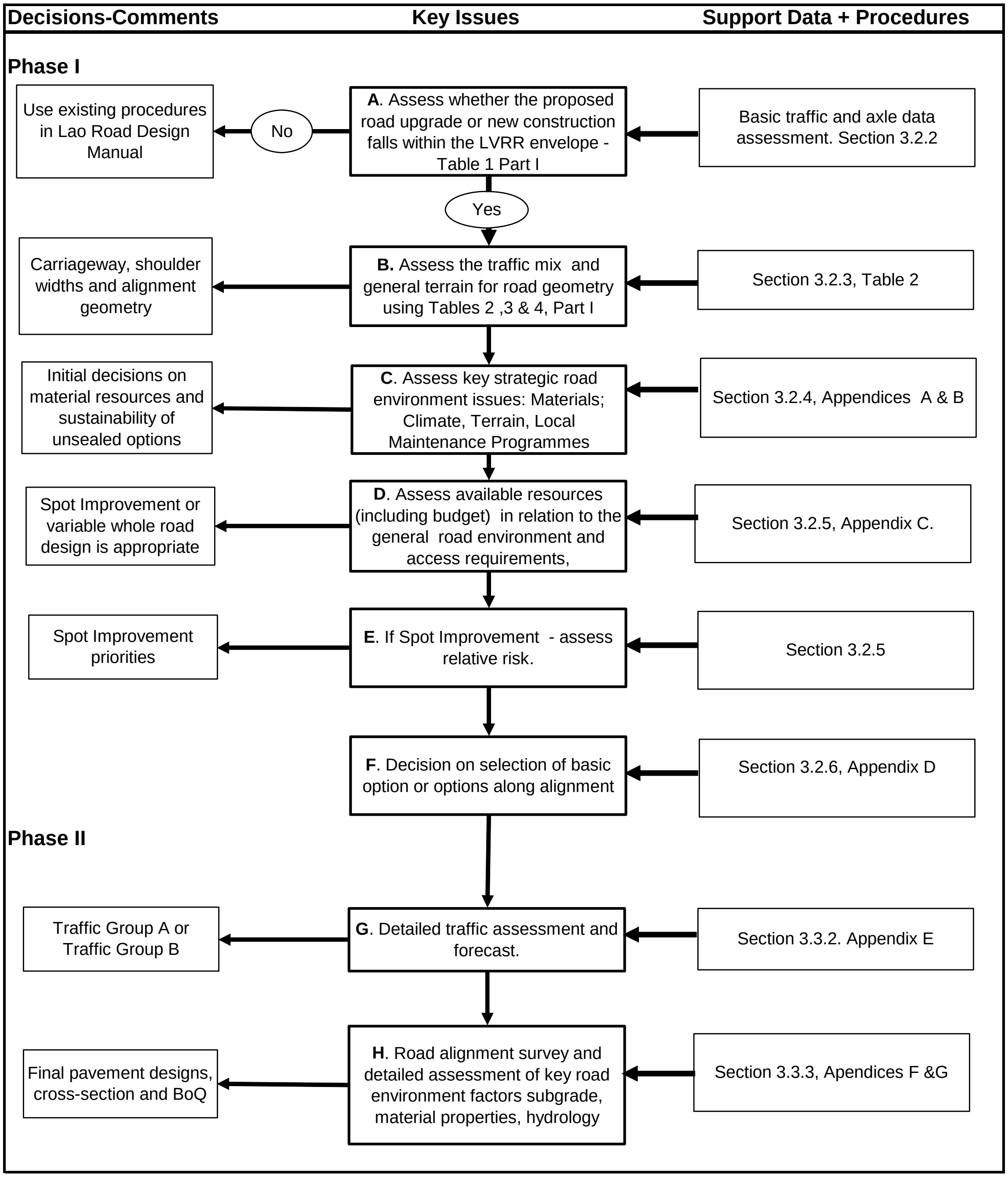
Impact Factor	Description
Construction Materials	The nature, engineering character and location of construction materials are key aspects of the road environment assessment.
Climate.	The prevailing climate will influence the supply (precipitation, water table), evaporation (temperature ranges and extremes) and movement (temperature gradients) of water. Climate impacts upon the road in terms of direct erosion through run-off, influence on the groundwater regime (hydrology), the moisture regime within the pavement, and accessibility for maintenance
Surface and sub-surface hydrology**.**	It is often the interaction of water, or more specifically its movement, within and adjacent to the road structure that has an over-arching impact on the road performance.
Terrain	The terrain, whether flat, rolling or mountainous reflects the geological and geomorphological history. Apart from its obvious influence on the long section geometry (grade) of the road, the characteristics of the terrain will also reflect and influence the occurrence and type of soil present, type of vegetation, availability of materials and resources.
Subgrade Conditions	The sub-grade is essentially the foundation layer for the pavement and as such the assessment of its condition is fundamental to an appreciation of the road environment.
Construction Regime	The construction regime governs whether or not the road design is applied in an appropriate manner. Key elements include: • Appropriate plant use • Selection and placement of materials • Quality assurance • Compliance with specification • Technical supervision
Maintenance Regime	All roads, however designed and constructed will require regular maintenance to ensure that the design life is reached. Indeed good maintenance can often extend the period that the road can function, well beyond the design life. Achieving this will depend on the maintenance strategies adopted, the timeliness of the interventions, the local capacity and available funding to carry out the necessary works
The "Green" Environment	Road construction and ongoing road use and maintenance have an impact on the natural environment, including flora, fauna, hydrology, slope stability, health and safety. These impacts have to be assessed and mitigated as much as possible by appropriate design and construction procedures.

3.2 Phase I: General Assessment of Pavement Options

3.2.1 General

This phase of the LVRR pavement design process is aimed at identifying the likely options in terms of both pavement type and EOD application – Spot Improvement or whole length construction. Figure 1 outlines a series of steps that may be used as a general guide to decision making. The following sections emphasise some key issues with respect to this general assessment phase

Figure 1, Framework for Pavement Design Selection



3.2.2 The LVRR envelope

The first step in the design process must be assessing whether or not a proposed road falls within the LVRR envelope as defined in Part I, Table 1. Selection of traffic group should ordinarily depend on survey of current traffic flows and AADT only.

The standard LVRR pavement designs are robust for the vehicle flows of up to AADT of 150. If surveys measure a current flow of AADT 50, then if traffic increases at 10% per year this would rise to about AADT 130 after 12 years; i.e. still within the capacity of the LVRR designs.

It is therefore suggested that if current AADTs 50 or less then no further traffic assessment is required before adopting the LVRR designs, provided that the types of vehicles comply with the limitations set out in Part I of the Standards and Specifications, i.e. no heavy trucks.

If current traffic flows exceed AADT 50 or there are grounds for believing that traffic growth will be higher than 10% year, then guidance should be sought from MPWT on traffic prediction. Detailed guidance on traffic surveys and prediction are provided in ORN5.

3.2.3 Road geometry assessment

LVRR road geometry as defined in Part I, Table 3, is assessed by reviewing the terrain with some additional modification based on general pavement type. Information on vehicle type and traffic mix is used to decide on carriageway and shoulder widths.

Consideration has 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 shoulders may be necessary. The increase in width will vary with the relative amounts of traffic, their characteristics and the terrain. In view of the relatively high costs normally involved in road widening care should be taken to ensure that only those sections of shoulder are widened which are justified by local demand.

For LVRRs, single lane operation is considered adequate as there will be only a low probability of vehicles meeting, and the few passing manoeuvres can be undertaken at very reduced speeds using either passing places or shoulders. 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.

A simple classification of "level", "rolling" and "mountainous" has been adopted and is defined by the number of five metre contour lines crossed per kilometre on a straight line linking the two ends of a road section, Table 2.

Table 2, Terrain classification

Terrain	Number of 5 Metre Contours/km	Description
Flat	0-10	Level or gently rolling terrain with largely unrestricted horizontal and vertical alignment.
Rolling	11-25	Rolling terrain with low hills introducing moderate levels of rise and fall with some restrictions on vertical alignment
Mountainous	>25	Rugged, hilly or mountainous terrain with substantial restrictions on both horizontal and vertical alignment

It is appreciated that there will be some severe constraints on horizontal and vertical geometry for some basic access alignments in mountainous terrain and that some relaxation of standards may be required in specific cases where alternatives of high embankment or deep cut are neither practicable nor economically appropriate.

3.2.4 Unsealed road sustainability

Engineers have traditionally relied on the use of unsealed natural gravel/laterite as a rural road surface, due to its initial low costs and simplicity of construction. However recent regional research confirms the serious problems relating to maintenance and sustainability of such surfaces in many road environment situations common in South East Asia. There are also health and environmental concerns regarding the widespread use of gravel as a road surface.

Gravel is a 'wasting' surface and as such material is lost from the surface of the road due to the erosive actions of traffic, flooding and rainfall. Unsealed gravel should ideally only be used for rural road surface applications in situations where sustainability conditions are fulfilled. These are summarized below:

1. **Adequate maintenance is guaranteed** – Gravel is a high maintenance surface requiring both routine reshaping/grading and expensive periodic re-gravelling. The regular maintenance of cross-sectional shape is a particular requirement that must form part of routine maintenance programmes.

2. **Gravel quality adequate** – Gravel should comply with grading and plasticity requirements and not break down under traffic, otherwise it will be lost from the surface at a high rate. Gravel quality varies substantially within each pit location. Great care is essential to ensure that only suitable material is selected, and that mixing in of marginal/unsuitable material is avoided.

3. **Adequate gravel deposits are available** – Gravel is a natural and finite resource, usually occurring in limited quantities. Once deposits are used up, subsequent periodic re-gravelling will involve longer hauls and higher maintenance costs.

4. **Compaction and thickness is assured** – Poorly compacted gravel will be less durable. Supervision arrangements should ensure that the full specified compacted thickness is placed.

5. **Haul distances are short** – Hauling gravel for construction and periodic maintenance causes damage or further maintenance liabilities to the haul routes.

6. **Low to moderate rainfall** – Gravel loss is related to rainfall and may be excessive with intense storms or where annual precipitation is greater than 2000mm.

7. **No dry season dust problems** – Long dry seasons can allow the binding fines to be removed from the surface by traffic or wind. This is a particular problem where communities live beside the road or their crops and property are regularly coated in dust. Inhalation of road dust is unhealthy and there are also safety-visibility issues.

8. **Low traffic levels** – Gravel loss is related to traffic flows. It is unlikely that a gravel surface will be cost-effective at traffic flows of more than 200 motor (2 or more axles) vehicles per day.

9. **Low Longitudinal Gradients** – Gravel should not be used in on gradients more than 6% (LVRR Standards and Specifications Part I: Table 3). In medium to high rainfall areas (1500-2000mm/yr) gravel loss by erosion will be high on gradients more than 4%.

Even in simple combinations of some of the above factors, gravel can be lost from the road surface at more than 30mm per year, leading to the need to re-gravel at very frequent intervals. The funding, resources and capacities are usually not available to achieve this and the surface will invariably deteriorate and revert to an earth surface.

A realistic assessment of the existing and future maintenance regimes is an absolute necessity at this stage of the design process. Over-optimistic assumptions as to maintenance deliverables are commonly made in the rural road sector leading to an inappropriate selection of a pavement option.

Appendix A outlines some key points in regard to maintenance and Appendix B highlights equally important issues with respect to appropriate use of materials.

3.2.5 Resource assessment

An assessment of available resources is generally required both to confirm the feasibility of a proposed LVRR and to identify sustainable and appropriate strategic design options. The assessment should include:

- Available budgets – for both construction and ongoing essential maintenance
- Available construction materials
- Likely contractor experience
- Local labour availability (skilled and unskilled)
- Condition of any existing road or track (residual asset)

These available resources can then be considered against the road objectives and a logical and realistic strategic design option identified within a sustainable EOD framework.

In practice the two approaches of Spot Improvement or whole length Variable Longitudinal Design define the extremes of a spectrum of possible options. The options within this spectrum will have a gradually increasing list of required works and cost, a gradually improving level of access, and a decreasing risk of failure to provide safe and reliable access. As more funds are available, additional Spot Improvements can be added. It is also possible to consider the spectrum extending below the spot improvement option to even cheaper works and a reduced level of access. Conversely, it is also possible to improve the level of service with more expensive options.. However, both these extensions of the spectrum move away from the EOD approach of meeting the needs of the road users for reliable access in a cost effective manner.

Key decisions are required however not only on the relative all-weather access risk along single alignments, but also between basic access requirements within the province or district network. Although a spectrum of options between whole length improvement and spot improvements is feasible, it is probable that the reality of prioritising a list of solutions according to a cost-benefit type estimate will not be easy or transparent and should involve extensive local consultation.

Part of this assessment process should include a whole life cost estimate of the available alternatives. There are two approaches to the assessment of whole life costs for rural roads, which each reflect discrete objectives, and may result in different conclusions depending on the local circumstances. These can be characterised as:-

a) Whole Life Asset Costs

b) Whole Life Transport Costs

The aim of Whole Life Road Asset Costs assessment is to minimise the costs of construction and maintenance of a particular road and pavement over a selected assessment period. This assessment would be of interest to an asset manager such as the OPWT, particularly in a severely constrained resource environment.

A Whole Life Transport Cost assessment brings in the component of user Vehicle Operating Costs (VOCs), and may include other economic or socio-economic factors (e.g. user time savings, socio-economic or environmental impact). This assessment is of more interest to, for example, national policy makers, planners and development agencies.

Any assessment will only be as good as the data and knowledge used in the relationships incorporated in the evaluation. For Lao the confidence in the cost data may be good for construction components for the various regions of the country. However, the knowledge and confidence may be less robust for both maintenance cost components of various road surface options and for user VOCs. The latter aspect is particularly uncertain regarding the effects of different road conditions in Lao. A draft Cost Model has been developed under SEACAP initiatives and this is further discussed in Appendix C.

3.2.6 Initial design decisions

Initial road design decisions are likely to concentrate on the following:

- To use unsealed options or not
- How extensively to use sealed options if required
- Identification of sections requiring concrete or similar option
- General drainage requirements

When the funds immediately available are limited, but more funding is reliably expected in the future, a 'Staged Construction' approach may also be considered. This involves providing a basic improvement of the surface initially, then providing further pavement layers later as resources permit.

Examples of this approach are:-

Stage 1: Engineered Natural Surface

Stage 2: Gravel surface

Stage 3 Sealed gravel or armoured gravel surface

The intention of armoured gravel, as described in Part II, Appendix A, is the cost-effective use of suitable natural gravels where they occur close to the road site, and to improve them sufficiently to accept a thin bituminous surfacing.

Appendix D presents an interim decision tree as an aid to the selection of appropriate pavement structures.

3.3 Phase II: LVRR pavement and surfacing option design

3.3.1 General

Phase II involves the detailed design of the general options identified under Phase I, including any Spot Improvement solutions. The LVRR Standards and Specifications (Part II) provides relevant pavement design Tables based largely on traffic and subgrade condition. This document also provides an initial pavement and surfacing matrix of 5 options with comments on selection and use.

It is likely that additional options will be added to this matrix as outcomes from ongoing rural road research feeds back into mainstream use. These additional options are likely to include:

- Bitumen emulsion seals
- Cement or fired clay-brick pavements
- Lime, cement or mechanically stabilised soils for base or sub-base

The following sections summarise some key points relevant to the use of the above guidance tables. Chapter 4 of this document provides background to the pavement design approach.

3.3.2 *Traffic and traffic growth*

The proposed LVRR pavement design process utilises a simplified division of traffic impacting within the road design life, into Traffic Group A and Traffic Group B, with the former being essentially light traffic with an esa of up 10,000 and the latter incorporating slightly larger vehicles (up 4.5T axle load) with an esa up 100,000. Although the road designer is therefore left only with the task of deciding into which of these two groups his road falls, there still remains a number of important decisions involving the following:

- The volume and make-up of traffic on an existing road
- The estimated traffic for a new road
- The increase in traffic and change in traffic mix within the designated design life
- The risk of axle loads above 4.5T

The measurement of existing traffic is a standard and straightforward process that should be carried out, where possible, prior, to any detailed design process. LVRR traffic count procedures together with methods of interpretation and forward estimations are outlined in Appendix E

The risk of high axle loads can probably best be assessed on the basis of local knowledge of, for example, likely logging or quarrying operations that could involve heavy truck operations.

3.3.3 *Detailed alignment assessment.*

Some form of investigation or assessment of the condition of the existing road or proposed LVRR alignment will be necessary to provide required information for the detailed design of the pavement, drainage and any required earthworks. Data sets that should be collected include the following:

- Condition of any existing pavement or road surface
- Subgrade strength – the worst case soaked condition measured by in situ testing or by fully representative sampling and laboratory testing
- Existing or required side drainage
- Existing or required cross drainage
- Water table information including likelihood of flooding
- Terrain as it impacts on horizontal or vertical geometry
- Detailed construction material properties

Typical standard forms and outline procedures are included in Appendices F (Road Environment Assessment.

4 LVRR Key Pavement Issues

4.1 General

The following sections highlight key issues with regard to the selection and design of the initial LVRR pavement and surfacing options currently considered), namely:

Unsealed: Gravel Wearing Course

Flexible: Sealed Gravel; Sealed Armoured Gravel; Sealed Macadam

Rigid: Non Reinforced Concrete

There are key differences between the situation in Lao and that of other countries and regions where low volume road guidelines have been published, especially where those guidelines promote the use of marginal materials. Essentially Lao has higher rainfall and lower evaporation such that road subgrades and pavements may be wetter, and therefore weaker in terms of bearing the weight of cumulative traffic loading.

For the gravel and the concrete pavements, those layers form the surfacing and the upper structural layer. For the sealed roads the bituminous surfacing provides the vitally important role of protecting the structural layers below from wet weather but it does not provide any structural strength. The upper structural strength is provided by the roadbase and the sub-base.

In developing the pavement thickness designs the gravel surfacing and the sealed surfacing have been treated in a similar fashion in that both have been designed to protect the subgrade from excessive stresses imposed by traffic. Suitable thickness designs have been achieved fairly readily for the sealed pavements. The process has been more difficult for the gravel surfaced designs. This is because, for the sealed roads, the pavement thickness remains constant throughout the life of the pavement, but for the gravel pavement, the gravel is gradually worn away and the stresses on the subgrade gradually increase as gravel thickness is lost. This has been taken into account as much as possible by specifying a minimum cover that must be retained to protect the subgrade.

The current Lao Road Design manual (LRDM) covers all aspects of road design, including geometry, materials, pavements, drainage, road safety, road signs, junctions and water crossings. However, although the LRDM is appropriate for National and Provincial roads it is in a number of respects inappropriate for LVRR pavement design. These include the following:

- There is over-reliance on the two solutions: gravel, which may not be suitable for many roads in Lao; and sealed gravel, which may not be feasible with the gravels available in most areas
- When alternatives are available, their design tends to be conservative and therefore expensive
- The LRDM does not allow the use of ‘marginal’ materials which do not meet normal specifications, or use of materials which are weaker than those normally accepted
- The LRDM takes less account of the wide range of non-traffic or environmental factors that affect the performance of LVRRs
- The volume, style and complex nature of the design guidance is not targeted at engineers and technicians working in OPWTs.

4.2 Unsealed Gravel

The structural design of the LVRR unsealed gravel roads has been based on the work carried out by the research station of the United States Army Corps of Engineers. For the armed forces the traffic carrying capacity of a soil is critical. An army needs to know whether a soil will carry vehicles for long enough for all of its equipment to pass through a critical point or whether a strengthened road needs to be built. Much of the knowledge concerning the relationship between soil strength, wheel loads, tyre pressures, and traffic carrying potential of soils and aggregates derives from this research. The latest publication on this subject is entitled *'Aggregate surfaced roads and airfield areas'* and was published as part of the Unified Facilities Criteria (UFC 3-250-09FA) in 2004.

A summary of the procedure together with key tables is included in Appendix G to this document.

The thicknesses derived from this procedure do not take account of gravel that is lost during use and therefore an additional thickness is required to ensure that the subgrade is protected throughout the life of the surfacing before re-gravelling is carried out. Table1 in Part II of the LVRR Standards and Specifications has included an allowance of 100mm and the gravel layer has been divided into a surfacing component and a capping layer. Furthermore, the subgrade categories have been combined for practical purposes. This means, in effect, that for subgrade strengths greater than the minimum in each subgrade class, there is a small safety margin. If the thicknesses of gravel that are selected exceed the values in Table 1 in Part II, then the road will not require to be gravelled so soon.

4.3 Sealed Flexible Designs

For the sealed roads, thinner pavements have been achieved by examining the international literature for permissible subgrade stresses for empirically proven pavements under full traffic loading (8.2T), and then designing thinner pavements, by reducing the thickness until the limited permissible strain in the subgrade is reached for the LVRR design vehicles. To do this a mechanistic or theoretically based method has been used, employing accepted criteria. A computer program was used to assist in determining the stresses at various levels in the pavement and the subgrade; Bitumen Stress Analysis in Roads (BISAR 3.0).

Permissible subgrade strains for empirically proven pavements under full standard traffic loading have been examined and limiting conditions found. Thickness has then been reduced, for the reduced loading, until the limiting permissible strains are again reached. To do this a mechanistic, or theoretically based method has been used, employing accepted criteria and reasonable assumptions.

To address the issue of pavement material quality and how it might be reduced, the use of both normal and lower standard materials have been considered. Unfortunately, the stresses at the top of the pavement are very similar to the tyre pressures of the vehicles using the road. While these are lower for the LVRR design vehicles they are not in direct proportion to the reduction in load, and therefore there is only limited scope for reducing materials quality. However, it has been possible to reduce the quality of materials used in the uppermost structural layer of the flexible sealed pavements for the lowest levels of traffic.

4.4 Rigid Pavement Design

For the concrete (rigid) pavements, the AASHTO (1993) approach for low volume roads has been adopted for these Standards. It is not possible to make substantial thickness reductions for concrete roads for these standards because concrete pavements are prone to cracking if loaded near the longitudinal edges. For single lane roads as in the standards, there is a particular problem because vehicles will be required to enter or leave the concrete pavements to permit other vehicles to pass. For this reason a single thickness concrete pavement of 150mm has been specified which will readily tolerate the stresses imposed by vehicles travelling entirely on the pavement and will resist the stresses imposed where they enter or leave the pavement. It will also resist the environmental stresses imposed by the climate.

4.5 Shoulders

A number of shoulder options have been trialled under the regional SEACAP programmes, all of which had one or more disadvantages. The issues of shoulder design, mode of construction and whether or not they should be sealed require further attention within the regional road environment. Key points to arise out of the trials programmes so far are:

- Unsealed macadam shoulders are unlikely to be suitable for most road environments, particularly those with moisture susceptible road-bases or sub-grades.
- Adequate earthwork support to the outside shoulder edges is necessary.
- Construction of shoulders should be integrated with carriageway construction where possible.
- There are potential mixing difficulties with lime or cement stabilised shoulders constructed separately after the carriageway.
- Earth shoulders should not be used with gravel or unsealed stone macadam surfacing, as surface water is prevented from draining from the road surface as soon as any surface deformation/wear occurs and surface re-shaping or grading is inhibited.

Key advantages and disadvantages of shoulder options that have been trialled regionally by SEACAP are summarised in Table 3.

Table 3, Trialled shoulder options

Description	Principal Advantages	Principal Concerns
Natural gravel	Appropriate where suitable sources of specified quality gravel are locally available and where suitability criteria of rainfall and gradient are met.	Should only be used with great care and knowledge of performance for surface applications, due to expected material losses in service.
Un-stabilised local soil	Potential low cost alternative in some road environments.	Not generally recommend due to low strength and high erosion potential; consequently high maintenance costs and safety concerns.
Quarry-run	Appropriate where suitable sources of specified quality material are locally available.	Material likely to be highly variable in terms of grading and plasticity, hence would require adequate control testing and site monitoring of delivered material. Oversize material particles likely to be a significant problem.
Unsealed stone macadam	Strong robust option when shoulders can be built as an extension of similar base construction.	Difficult to construct as shoulders separate from carriageway construction. Requires adequate edge buttressing by earthworks to allow adequate aggregate compaction. Can cause deterioration of moisture sensitive base/sub-base by easy ingress of run-off water.
Single chip sealed macadam	Strong robust option when shoulders can be built as an extension of similar base construction.	Difficult to construct as shoulders separate from carriageway construction. Requires adequate edge buttressing by earthworks to allow adequate aggregate compaction. In higher traffic environments in conjunction with a 3.5m wide carriageway, encourages motor vehicles to use and damage shoulders. Can add significantly to the cost.

4.6 Capping Layer

The LVRR principals require the maximum use of locally available materials and the minimum use of more expensive high quality pavement materials. This requirement has been met by using the thinnest roadbase and sub-base that is possible and making up the required total thickness for the protection of the subgrade by using a capping layer. The capping layer uses a material quality that is significantly lower than the sub-base requirement. These materials are typically about one third of the cost of sub-base materials and are expected to be readily available near the alignment or as overburden or lower quality material at the material sites. In this way, the thickness of the sub-base and road base materials and thereby their costs have been kept at a minimum.

It is strongly recommended that a capping layer is used. However, if suitable material cannot be obtained, the sub-base (or gravel wearing course) thickness must be increased by 65% of the thickness of the capping layer shown in the Tables, rounded to the nearest 25mm.

4.7 Subgrade,

The subgrade is defined as the top 300mm of the existing or prepared ground, on which the capping layer (as required) or the sub-base will be placed. Assessment of subgrade strength should be in its worst case (soaked condition); that is, for in situ testing at the end of the rainy season and for CBR laboratory testing in its 4-day soaked condition.

4.8 Crown Height and Water table

The depth of the water table may strongly influence the strength of the road and will give an indication of the potential for flooding. It is also possible that it fluctuates during the year. It is necessary to determine its shallowest depth. If the water table is within 0.5m of the ground surface, ensure that the top of the subgrade is 0.65 above the ground level or the invert level of the ditch in cut sections. Seasonal and maximum water table and flood levels should be carefully confirmed with various people living in the area if possible.

The pavement designs for both sealed and gravel roads assume that the capping layer and the upper pavement, road base and sub-base, are all either 0.45m above the invert level of the side-drain and that in flooded areas or where the water table rises to within 0.5m of the ground level they are placed 0.65m above the highest water level or the invert level of the drain whichever is greater.

Any areas adjacent to the road which are prone to flooding either naturally or intentionally for irrigation must be determined. The presence of the road will potentially impede the natural flow of water and cross drainage must be provided for the former. For the latter the road must be raised on an embankment such that the height of the top of the subgrade is not less than 0.65m above the highest water level expected, often known as the “freeboard”.

4.9 Earthworks

The minimum CBR requirement for earthworks is 4%, tested in the soaked condition.

Where embankments are required to meet the height conditions given above, they should be made up of the local subgrade soils of the same or higher strength. If the embankment height before the placement of the capping layer is 300mm or greater the strength of the embankment material becomes the subgrade strength for the pavement design.

In cuttings the top 300mm of the remaining natural material can form the subgrade and effectively becomes the subgrade material for the design. The strength of this top 300mm must be proven to ensure the pavement design is correct. If its density is below specification, then the top 150mm must be removed and the exposed surface thoroughly compacted. Thereafter the temporarily removed material should be replaced and compacted.

5 Drainage and Structures

5.1 Road drainage

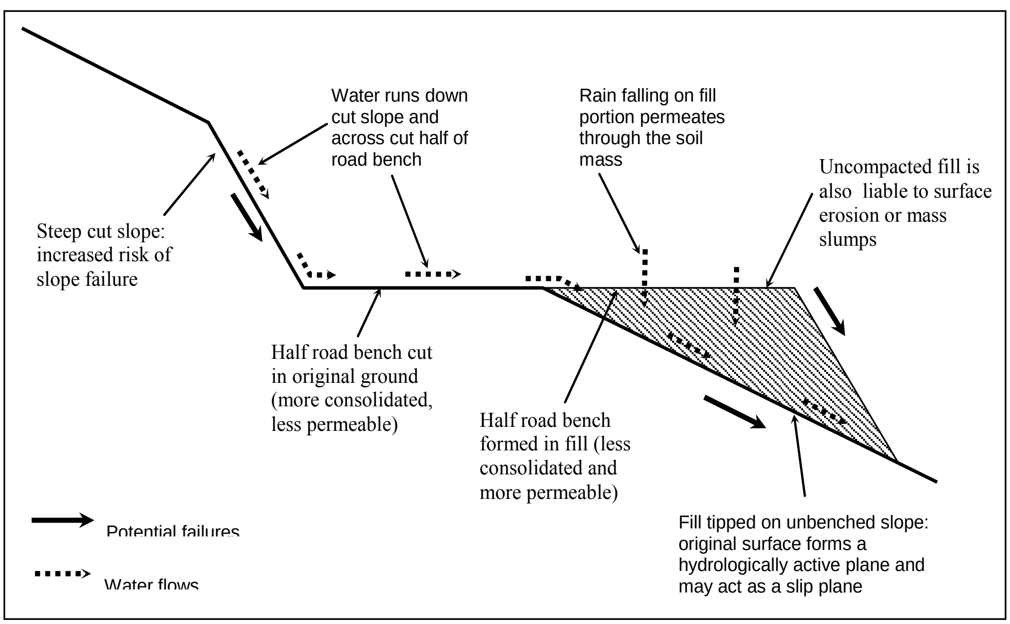
The importance of drainage has been emphasised in Parts I and II of the LVRR Standards and Specifications. However, regional SEACAP research has confirmed that although this importance is widely recognised by rural road practitioners there is a significant problem in applying drainage principles in construction and maintenance practice. Commonly observed problems include:

- Inappropriate “boxed-in” pavement design
- Missing and poorly maintained side drainage
- Insufficient or badly sited cross drainage (culverts)
- Lack of maintained road shape (cross-fall) on unsealed roads
- Build–up of vegetation and debris on shoulders preventing adequate run-off.

Any one of the above factors will adversely impact upon perhaps the most important single aspect in road design; the protection of the road from surface or ground water.

In addition to the direct impacts on the performance of the pavement by weakening its component layers, there are also significant drainage issues related to the maintenance of earthwork stability. This is of particular importance in hilly or mountainous terrain where poor drainage can have severe consequences on the provision of all-year access, with significant consequences for the rural communities for which the LVRRs are designed to serve, Figure 2.

Figure 2, Typical Water Impacts on Mountainous Road Section



5.2 Structures

There is a perceived need for updated structures guidance aimed specifically at the rural road sector. To this end DfID is assessing the relevance of a draft Low Cost Structures Manual (LCSM) developed under a previous research programme. This LSCM is a practical planning, design, construction and maintenance guide for rural road, small structures in developing countries and economies in transition. It was designed to supplement the recognised available documents such as the Overseas Road Note 9, and the inspection guidance provided by Overseas Road Note 7. This document is aimed primarily at those responsible for the design and construction of low volume road structures in developing countries.

The focus is particularly on relatively simple technologies that are suitable for construction by local contractors and communities using local skilled and unskilled labour. However, relevant issues are also raised that would be of interest to any practitioners concerned with the provision of sustainable rural transport infrastructure.

The manual is both a practitioner’s handbook and a basis to update existing national standards and specifications to include the improved and more sustainable use of local resources. The draft LCSM also contains sets of standard drawings and Bills of Quantities suitable for incorporation into national guidelines or documentation. The designs are based on extensive field experience and offer possibilities to reduce the design costs on commonly used structure types.

It is hoped that this LCSM will be available shortly for adaptation for Lao LVRR conditions.

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6 Construction

6.1 General

Local and regional research has indicated a number of issues that may need to be addressed in regard to local contractor performance on rural road programmes:

1. Clear training and guidance will be required for contractors using options other than unsealed gravels.

2. A straightforward contractor assessment procedure is recommended for LVRR construction programmes. In particular there is need to ensure that the contractors have read and understood the technical specifications.

3. Small contractors are generally not used to following technical specifications closely and may require a combination of easy-to-follow guidelines and initial close supervision.

4. There is likely to be a wide range of contractor quality, from very good to incompetent. This reinforces the need for an effective review of contractor capability before contracts are awarded.

5. Experience indicates that there may be a general initial resistance to new procedures, with many contractors tending to use locally established practice as default procedures without reference to contract specifications.

6. Small contractors generally have limited plant resources; for example, they rely heavily on the standard 8-10 tonne, 3-wheel, static rollers for compaction, which have limitations for certain types of materials. Yet there is an apparent reluctance to consider plant-hire options within the existing small contractor environment.

7. Contractor performance and progress may be inhibited by severe cash-flow difficulties, which are not helped by unrealistic delays in processing agreed payment certificates. This may partly explain the reluctance to consider the plant-hire option.

8. Some new option procedures are likely to be best controlled by a tightly overseen "method specification" approach. This is particularly true of operations where control testing may involve significant delays.

9. Simplified guidelines or handbooks on the important features and precautions/requirements for each surface/paving layer type would assist both technical and non-technical personnel involved with the planning, approval, design, construction supervision, and maintenance of rural roads.

10. Appropriate materials testing is a very cost-effective way to assure value-for-money for the considerable investments made in road surfacing and paving. There is a noticeable problem in ensuring contractors undertake the required sampling and testing of as-used materials. One solution may be the use of a provisional lump sum in the contract for payment of laboratory work to encourage contractors to undertake this testing. This should be considered as a standard practice.

6.2 Construction procedures

Construction procedures should be in accordance with the technical specifications, included as appendices within Part II of the LVRR Standards and Specifications, together with any constraints required as a consequence of the Environmental Impact assessment.

Some additional guidance may be obtained from the Rural Road Construction Guidelines document issued as part of the SEACAP 1 project (Intech-TRL, 2007).

Consideration has been given to the thickness of layers to assist in meeting compaction requirements. None of the flexible pavement layers exceed 150mm compacted thickness and many are 100mm. The subgrade, where it is necessary to work it in depth (as in cuttings) can be compacted in layers of 150mm. This approach is consistent with the use of the lighter compaction equipment that is likely to be available.

As envisaged, the road pavement can be successively built-up of increasingly better quality materials such that a construction platform is immediately formed by the placement of the first capping layer and a gradually stronger structure is progressively achieved, better able to support construction equipment and promoting higher densities in the layer above. For the concrete pavements, a good quality well formed support layer will be attained suitable for accurate and adequate thickness control of the concrete pavement.

One particular point to emphasise is that it follows when constructing road pavements intended for only light commercial traffic that the movements of heavy construction trucks must be limited and avoided as much as possible. This can be achieved by “back-dumping” construction materials for each pavement layer and by being especially cautious when building the capping layer over weak natural subgrades. Back dumping is a construction process where heavy construction equipment does not unnecessarily travel on the completed construction layer.

6.3 Supervision and quality control

The following issues have been identified with regard to supervision of works involving various surfacing options:

1. The role of site supervisors in controlling the contractors’ procedures and material usage is not yet generally accepted in the rural road sector in the region. Current practice appears to be concerned largely with observation and reporting of progress rather than technical control.
2. As with the contractors, there was a wide range in supervision performance. In general there was a lack of experience in the application of specifications and associated testing requirements.
3. There may be a significant lack of awareness of the importance of Quality Assessment in the rural road sector and a consequent lack of a quality control ethic and a lack of appreciation of the importance of as-used materials testing, in situ testing and daily records.
4. The above issues highlight the need for appropriate training and guidelines on construction supervision.
5. There are potential difficulties with supervisors being unable to exert influence on the contractors to abide by specifications and the unwillingness of contractors to heed advice from supervisors.

6.4 Quality assessment

Quality control in construction has a significant affect on the performance and life of any pavement surface, whether it is gravel, reinforced concrete or any other material. A greater awareness of this fact is required to be imparted to political, administrative and engineering personnel through improved awareness creation, training and project management. This issue is of substantial importance even for gravel road investments, and will be increasingly significant as the rate of investment per km increases with the adoption of the more durable surfaces.

Quality Control should not be an onerous administrative burden within the rural road sector, but rather it should comprise a few simple straightforward procedures as set out in the table below.

Table 4, Quality control procedures

Ref.	Quality Control Procedure	Comment
1	Assessment of proposed material sources combined with control on as-delivered materials	Quality control research has demonstrated problems with contractors apparently changing materials between original approvals and actual construction. The principle of testing of construction materials as delivered and placed on site must be adhered to.
2	Use of simple on-site observational and testing procedures to control construction quality	The combination of simple standard sheets, on-site measurements and simple tests such as DCP and the concrete slump test will give good quality control. Annotated and dated site photographs are also very useful.
3	Survey of final as-built quality	Research has demonstrated the effectiveness of this approach. Superficial "drive-over" surveys cannot be considered an alternative if QA is to be taken seriously as part of the contractual signing-off procedure.

7 Environmental Impact Considerations

7.1 General

All rural road construction projects in Lao PDR have to comply with existing regulations on environmental impact, which define road projects into two main categories:

- **Category I**: Projects with potentially no environmental impacts. These are projects that only involve routine maintenance, periodic maintenance or minor improvements of roads within the existing constructed width (roadway) without involving a change of class or category of the road and are not located in "environmentally sensitive areas".
  - **Category II**: Projects with potentially adverse environmental impacts. These are **all other construction/improvement/rehabilitation projects** whether on the existing or modified alignment within the existing "right of way" or reconstruction/new roads that require the acquisition of new right-of-way. All projects involving improvement/construction outside the existing "roadway" especially all roads located in, or affecting, "environmentally sensitive areas" must be included.

All Category II projects require an Initial Environmental Examination (IEE) which will then determine whether or not a full Impact Assessment (EIA) is required. Category I projects do not normally require to go through this process although compliance with general environmental good practice is required.

7.2 Likely Impacts

The key topics to be considered for an EIA relevant to the life cycle of a road are summarised in Table 5.

Table 5, Likely Environmental Impacts

	Pre-construction	**Construction**	**Associated development**	**Operation**	**Maintenance**
	Quarries Borrow pits	Earthworks; drainage Site clearance Equipment/Site camps	Ribbon development Commercial development	Traffic	Resurfacing Quarries Borrow pits
Water resources	1	1	1	1	2
Soil usage	1	1	1	2	2
Air pollution	2	1	1	1	2
Natural resources	1	1	1	2	2
Safety	2	2	3	1	2
Noise and vibration	1	1	2	1	2
Biodiversity	2	1	1	3	2
Resettlement	2	1	1	3	3
Socio-economic impacts	2	2	1	1	3
Cultural heritage	1	1	1	3	3

Notes: 1: Potential major impact; 2: Potential minor impact; 3: Impact unlikely

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SEACAP 3

Low Volume Rural Road Standards and Specifications: Part III

Application of LVRR Standards and Specifications

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B: Road Construction Materials

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APPENDICES

A: Maintenance Issues

APPENDIX A: MAINTENANCE ISSUES

A1 Introduction

Appropriate maintenance is fundamental to the sustainability of any road provision, and this Appendix has been included to specifically provide an introduction to LVRR maintenance issues. As noted in the main text, maintenance factors should be considered as part of the process of determining the most appropriate surface or paving treatment for any particular section of a LVRR.

Some surfaces are more demanding of maintenance and sensitive to the timing of its provision than others. Therefore before coming to a final decision on the selection of a pavement or surface type, it is advisable to assess the future maintenance requirements of the options being considered and to decide whether or not there is a likelihood of this level of maintenance being resourced (financially and physically) and being arranged in a timely manner.

This assessment should also form part of any Whole Life Costing of the pavement/surfacing option.

A2 Importance of Maintenance

From the day a road is constructed, it starts to deteriorate under the influence of traffic and weather and other influences. The rate of deterioration depends on factors such as:

- selected or intrinsic design period,
- appropriateness of design,
- cross section (width, shoulders etc.),
- type of construction,
- quality of construction,
- moisture factors (rainfall, flooding, moisture movement etc.),
- drainage arrangements,
- traffic,
- alignment (gradient, curvature).

Maintenance is required on a regular basis to counter the deterioration and keep the road close to its intended and as-constructed condition in order to fulfil its intended role as an important part of rural transport infrastructure. Rehabilitation is not maintenance, and its requirement is an indication that the maintenance regime has failed and that more extensive and costly restoration works are necessary. It is not cost-effective to skimp on maintenance and then, later, have to rehabilitate a road. In Whole Life Cost terms this is more expensive to those responsible for the provision and upkeep of the road and certainly leads to more expensive Vehicle Operating Costs and restricted access for road users.

In general LVRRs tend to be of low investment cost and have relatively high maintenance characteristics. High maintenance surfaces include earth and gravel. Bitumen seal pavements generally have more modest maintenance requirements and concrete pavements usually require the least maintenance.

LVRRs do not generally have the resources allocated to them to justify a sophisticated, computer-based, maintenance management system such as those sometimes used on main road networks. In Lao, however, the SIDA supported Second Lao Swedish Road Sector Project (LSRP2) has produced a practical software tool which does have relevance to LVRR maintenance. This is discussed further in section A1.6.

Fortunately, adequate maintenance of LVRRs can be achieved without such systems and with some basic understanding of the essence of maintenance and how to carry it out, and with simple observations and record keeping, for example; LCS Working Paper No 5 (Gongera & Petts, 2003).

A3 Types of Road Maintenance

Maintenance for LVRRs can be categorised principally as *Routine* and *Periodic*.

Routine maintenance comprises a range of small scale and simple activities – usually carried out at least once a year - but usually widely dispersed. Typical activities include roadside verge clearing and cutting back encroaching vegetation, cleaning of silted ditches and culverts, repairing minor erosion, patching and pothole repair, and light grading/reshaping of unsealed surfaces. This maintenance may be able to use unskilled as well as skilled labour, or labour-based methods supported by light equipment. Conventional or community contracting may be appropriate. These regular operations are a good opportunity to identify periodic maintenance needs.

Periodic maintenance occurs less frequently – usually after a number of years. Works can include regravelling, resurfacing, resealing and repairs to structures. These works can be expected and planned to a degree. They are normally large scale and may require standard or specialist equipment and some skilled resources.

Spot Improvement, pavement strengthening overlays or pavement reconstruction are normally not considered to be ‘maintenance’ and are often funded separately under ‘development’ or ‘capital’ budgets. As discussed previously rehabilitation is also not considered to be maintenance.

Occasionally urgent, unplanned, maintenance works may also be required – sometimes known as *Emergency Maintenance* - for example because of particularly severe weather conditions, floods, unexpected deterioration, landslips or exceptional damage caused by over-size/weight vehicles.

A4 Guidance on Assessment of Future Maintenance Needs

There has been little research on the maintenance needs in the Lao environment of the various types of surface/paving options included in these LVRR guidelines. The following guidance is based on research elsewhere with appropriate adaption/interpretation and is therefore necessarily of a provisional nature only. Local experience and further investigations should be used to augment this guidance.

The following guidance is indicative only. The operational arrangements for maintenance will have a major influence on the actual cost of maintenance depending on who provides each resource and the management arrangements. For example, the labour inputs may be paid for or provided by the community, materials and technical and quality guidance may be provided by a government or agency, or other interested stakeholder.

As discussed elsewhere in this document, a particular route may have a range of surface options. Each surface will generate maintenance requirements that will vary depending on the factors listed in A1.2 above. Even the level and quality of maintenance itself will ultimately affect future route conditions and maintenance liabilities.

In the following Table A1.1, BASIC Maintenance includes all off-surface items such as shoulder repairs, vegetation control and drainage system cleaning and erosion repairs, which will be of similar quantity for all surfaces on LVRRs. There will, however, be more drainage cleaning required on unsealed sections of road as surface materials will be washed into the side drains.

Table A1.1 Provisional LVRR Maintenance Assessment

Pavement Option	Maintenance Needs Rating	Expected Routine Maintenance	Expected Periodic Maintenance
Engineered Natural Surface (baseline comparison)	High	BASIC plus pothole repairs and camber reshaping (1 – 6 times per year). More frequent on weaker soils and with higher traffic and rainfall. Camber reshaping can be achieved manually or by simple grading equipment.	Raising embankment or camber when worn down, using local material.
Unsealed Gravel	Very High	BASIC plus pothole repairs and camber reshaping (1 – 3 times per year). Camber reshaping can be achieved manually or by simple grading equipment.	High-cost re-gravelling to replace material lost due to traffic and weather. Typically from 2 to >5cm of surface material loss per year depending on the road environment The timing of re-gravelling is critical, otherwise the surface may quickly revert to an earth standard.
Sealed Natural Gravel	Moderate	BASIC plus pothole repairs	Reseal of the surface after maybe 8 – 12 years (depending on various road environment factors).
Sealed Armoured Gravel	Moderate		
Sealed Macadam	Moderate		
Non Reinforced Concrete	Low	BASIC only	Crack sealing and joint repairs

When costing maintenance it is important to include the following components, whether charged for or provided free of charge:

- Labour
- Materials
- Equipment
- Supervision, testing and quality control.

A5 Maintenance Capability

Maintenance capability can be a major factor in the sustainability and therefore selection of a surface/paving option for a specific section of LVRR.

Assessing maintenance capability usually requires expertise in organisational or management matters. However, a good indication can be obtained by looking at the condition (and therefore maintenance performance) of similar existing roads in the locality. If more than 50% of the roads are in poor condition, there is little likelihood that the maintenance of the 'new' road will be any better unless specific initiatives are taken to actively improve maintenance performance.

In a poor maintenance environment, it is preferable to opt for lower maintenance designs, otherwise there will be a high risk that any investment in improvements will be wasted or short-lived.

In Lao a Road Maintenance Fund (RMF) has been in operation since 2002 which obtains most of its internal revenue from a fuel levy, tolls and road-fines. More than half its revenue however comes from Donor support. Currently only 10% is allocated to "local roads" and the actual amount generated for LVRR maintenance is very small. It is not expected that the fund will fully cover local road's maintenance within the next 10 years.

The Road Law specifically calls for the inclusion and involvement of village community groups in the implementation of routine road maintenance works, particularly on Rural Roads, and a number of donor-funded village-based schemes for routine maintenance are in place in some provinces in Lao. However these schemes do not appear to include any capacity to maintain shape (cross-fall) on unsealed gravel roads. Without regular maintenance of road shape, the ability of a road to shed water is lost and the consequent ponding of water during the wet season will inevitably escalate its deterioration and eventually it will fail in its function to provide an all-weather rural access route.

The almost complete lack of any road shaping capacity in existing routine maintenance schemes is one the fundamental contributory reasons for the poor performance of unsealed LVRRs in the region.

A6 The Provincial Road Maintenance Management System (PRoMMS)

The PRoMMS project has been developed under the Lao Swedish Road Sector Project 2 (LSRSP2). The software is a tool for determining maintenance needs and costs from surveyed road data and it assists in prioritising, planning and budgeting maintenance activities of roads and structures. Although the range of roads covered by LSRSP2 includes LVRRs, the principal focus is on roads with a higher traffic standard. The LSRSP2 project does not currently include any roads which are designated as "unmaintainable", most of which are likely to be in the lowest (LVRR) category.

The project has also involved appropriate training and practical mainstreaming according to "The Maintenance Procedures for Road Networks" (MPRN). The MPRN recognizes that it is important to know the condition of the road network when planning maintenance activities and recommends that a condition survey should be done once a year and condition ratings should be collected for each *section* of a road and all structures along the road.

Detailed procedures are described in the PRoMMS manual and the associated database holds data collected since 2004.

The outputs from the LSRSP2 are therefore both an important guidance document for OPWT engineers in assessing LVRR maintenance requirements and also a valuable source of existing LVRR conditions and maintenance costs.

A7 Further Information

Further information on road maintenance may be obtained from the following international and regional sources. Most of these documents may be downloaded from www.gtkp.com

Gongera & Petts (2003). LCS working paper 5 : A tractor and labour based routine maintenance system for unpaved rural roads.

PIARC (1994). International Road Maintenance Handbook.

SweRoad, 2004. Provincial Road Maintenance Management System (PRoMMS) User Manual. Produced for the Department of Roads, MPWT, Lao PDR.

TRL (1985). Overseas Road Note 2: Maintenance Techniques for District Engineers (2rd Edition).

TRL (2003). Overseas Road Note 1: Road Maintenance Management for District Engineers (3rd Edition).

TRL (2003). Overseas Road Note 20: Management of Rural Road Networks.

Low Volume Rural Road Standards and Specifications: Part III

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APPENDICES

B: Road Construction Materials

APPENDIX B: ROAD CONSTRUCTION MATERIALS

B1 General

The materials used in road construction and maintenance are an important and expensive resource that are not limitless and are largely non-renewable. This, together with the need for the management of scarce financial resources, means that widespread use of local materials is essential for Low Volume Rural Roads (LVRRs). Where reserves are limited or of marginal quality, as they may be in certain rural areas of Lao, their appropriate usage is a priority and it is important to use materials appropriate to their role in the road, that is, to ensure that they are neither sub-standard nor wastefully above the standards demanded by their engineering task.

The ability of the materials to perform their function in the road is normally assessed by their compliance, or non-compliance, with construction material specifications. These specifications, are applied to control the impacts of excavation, transportation, compaction and placing, and the in-service impacts of both the traffic and environment depending on the nature and position of the materials in the pavement structure.

B2 Assessment Criteria

There is a clear need for an assessment of available materials in terms of quality, quantity, variability and cost as part of the LVRR pavement option selection and design process. It is recognised, however, that there may be limited resources available for comprehensive materials investigations at OPWT level. The following sections are aimed at providing some guidance on basic procedures of material assessment.

The types of construction materials normally requiring some form of assessment before being approved for use in road works are:

- Common fill
- Capping layer (imported subgrade)
- Filter and drainage aggregate
- Sub-base
- Base
- Surfacing aggregate
- Concrete aggregate.

Specific requirements for pavement materials are included as part of the pavement specifications in Appendix A of Part II of the LVRR Standards and Specifications. Their assessment criteria are generally based on easily measurable attributes of the materials, such as grading, plasticity and strength, see Table B1 below.

Information for construction materials assessment is normally obtained in a number of ways:

- From existing records
- From field evaluation of potential sources
- By laboratory testing of potential sources
- By evaluation of placed materials.

Table B.1 General Criteria for Assessing Construction Materials

	Material Characteristic	Description of the Material Property	Main Laboratory Tests Designed to Evaluate the Property.
1	Particle Size Grading	The relative proportions of each size fraction from gravel to clay size	Sieve Analysis Hydrometer analysis
2	Plasticity of Fine Fraction	The characteristics of the particles smaller than 0.425mm to behave as a plastic/ cohesive material at different moisture contents	Liquid Limit Test Plastic Limit Test Linear Shrinkage Test
3	Load bearing capacity of compacted material	The capacity of the compacted materials to support imposed loads under saturated conditions	4-day soaked California Bearing Ratio (CBR)
4	Volume Stability	Volumetric response of the compacted material to swell on soaking.	Swell measurement during 4-day soaked California Bearing Ratio Test (CBR)
5	Particle Strength and Durability (Granular materials)	The existing strength of individual particles and the ability of the particles to maintain this strength during the life of the road.	10 % Fines Aggregate Crushing Test (10% FACT) and wet/dry ratio Los Angeles Abrasion Test (LAA) Magnesium or Sodium Sulphate Soundness Test
6	Particle Shape (Granular materials)	The angularity and flakiness of the aggregate particles and their ability to interlock together	Visual description Flakiness Index Test Elongation Index Test

B3 Existing Records

Significant data on materials sources and their geotechnical properties are normally collected during the construction, maintenance, rehabilitation or reconstruction of roads. This is frequently extremely useful and relevant information comprising not only as-produced material properties but also related costs.

The benefits of being able to access as built records are:

- Full scale information on the performance of the materials in the road enabling a crosscheck on, for example, assumptions regarding the relationship between in-situ, as-dug and service performance.
- Identification of resource deficiencies in terms of quantity or quality.
- Identification of any construction problems with particular materials.
- Identification of in-service performance deficiencies.

For Lao the principal material groups likely to be used in LVRR construction are summarised in Table B3.

Table B2, Lao Material Groups

Resource Group	Description	Comment
I Hard-Rock	Strong to very strong igneous (granite, basalt), sedimentary (crystalline limestone) and metamorphic (schist) rock types normally requiring drill-and blast quarrying techniques for excavation.	Likely to provide good quality aggregate although there are potential shape problems for sealing aggregate using metamorphic rock types. Potentially high quarry development and production costs mean that only existing quarries are likely to be used for LVRR projects.
II Weak-Rock	Weak to very weak mainly sedimentary rocks such as shale, mudstone and non-crystalline limestone. This group includes rock types from the above group that have been weakened by weathering processes.	Unlikely to be suitable for use in the upper pavement layers or as concrete aggregate, although some of the Lao sandstones may be of marginally suitability. Even when used as sub-base or earthworks there are potential degradation problems with some shale and mudstones.
III Hill Gravels	Hill gravels (colluvium) derived from a combination of hard rock weathering and down-slope accumulation. Materials generally excavated by borrow-pit techniques	Appropriate material can be used both as a wearing course material and as possible shoulder, sub-base and capping layer materials. Requires careful assessment as to variability with potentially significant variations in grading within a deposit.
IV Laterites	Soil-like materials with a clay-silt- sand-gravel nature with small nodules or concretions that have been formed largely in situ by tropical and sub-tropical weathering processes. Occasional forms more continuous hardened layers Materials generally excavated by borrow-pit techniques.	Good quality laterites are well suited for use as a wearing course and also as sub-base. Less common high quality materials are suitable for sealed roadbase layers. Requires careful assessment as to variability and thickness. Suitable deposits may only be 0.5-1.5m thick with weaker unsuitable materials both above and below.
V Residual Soils	Formed by the in situ weathering of Group I and II materials these may grade into and be closely associated with Group III and IV materials, but do not contain significant granular material. Red residual soil is frequently confused with true laterite.	Generally low strength plastic materials suitable only for earthworks. Some material may be suitable as capping layer.
VI Alluvial Materials	Sand, gravel and cobble derived mainly from Group I materials that have undergone processes of erosion, transportation and deposition in addition to weathering. Materials generally excavated by borrow-pit techniques	Plentiful supplies of alluvial sands and gravels occur adjacent to the Mekong and its main tributaries. Coarser gravel and cobbles likely to require crushing and processing to achieve specifications for aggregate. May require detailed investigation of rock content if high quality concrete is required.

Construction records may be kept either by relevant government departments and local authorities or by road construction supervising organisations and contractors. Typical information sets that should be gathered are summarised in Table B3.

For recent large projects much of these data may already be in spreadsheet format and hence readily transferred to a central information system. The review process for SEACAP 3 indicated that this was the case for Lao. However, older project data are likely to be in hard copy that would have to be transferred to electronic format.

Table B3, Materials Information Sets

Information Set	Description of Potential Information Sets
Location	Location of materials sources by co-ordinates, by road chainage or by representation on maps. Identification of resources; distances for material haulage; mass haul calculations
Material Quantities	Amounts of potentially available material. Reviewed in conjunction with volumes required, stockpiled quantities achievable and wastage.
Geological Character	Classification: rock types, sand and gravel; laterites etc..
Geotechnical Character	Index or behaviour properties. In form of individual results, project reports or database files. Previous records of performance. Also, the identification of possible problems associated with these activities.
Economic Factors	Costs of material processing; of haulage; and of any required modification. Cost limitations imposed by project budget.
Environmental Impact Factors	Impacts on the environment: pollution - dust, noise etc; health – water borne disease; loss of productive land etc.

B4 Field Assessment of Potential LVRR Material Sources

The field assessment should be done by a field team visiting and evaluating the sites previously identified during the desk study phase. An ideal exploration team would include a materials engineer and a road engineer with support from local community representatives who know the location of exposures and ownership boundaries etc..

The team should be prepared to undertake the following:

- Sketch map key geological features
- Sketch map key physical features; e.g. access tracks, source boundaries, rivers etc.
- Dig shallow exploration pits or use hand augers
- Describe materials
- Field assessment of geotechnical properties
- Take representative samples.

The field descriptions and assessment of properties may be aided by using a number of simple field tests, Table B4.

The principal outcome from the fieldwork work should be a clear identification of material resources. Reporting on the exploration phase should include:

- Details of resource locations
- Access information
- Estimates of available quantities
- Sketch maps of each source
- Evaluation of types of construction material available; aided by laboratory test results
- Assessment of any plant required for excavation and processing
- Indicative assessment of problem, or non-standard materials
- Ownership details of existing or potential sources
- Assessment of costs

Table B4, Simple Field Tests for Material Assessment

Field Test	Description
Fines Content	Relative percentages of silt/clay. Hand shake dilatancy test Jar settlement test
Schmidt Hammer	Use of Schmidt hammer on solid rock exposure or large boulder can be correlated to estimated compressive strength.
Hand Sample Index Strength	Use of small geological type hammer on hand or core sample Very weak: easily broken in hand Weak: broken by leaning on sample with hammer Moderately weak: broken in hand by hitting with hammer Mododerately. strong: broken against solid object with hammer Strong: difficult to break against solid object with hammer Very strong: requires many blows of hammer to break sample Extremely strong: sample can only be chipped with hammer
Field Durability	Immerse samples in still water for 30 minutes and observe behaviour: no effect noticeable drop in strength slowly breaks into pieces under light finger pressure slowly crumbles to small blocks under light finger pressure rapidly breaks into pieces under light finger pressure rapidly crumbles to small blocks under light finger pressure rapidly crumbles to small blocks disintegrates to sediment
Aggregate Pliers Test	Take 100-200 pieces of air dry material in the 12 to 20 mm range. The operator then attempts to break the pieces between finger and thumb. The remaining pieces are then tested by trying to break them with a pair of 180-mm pliers. The maximum strength should be applied in both experiments. The percentage unbroken by the pliers is termed the Aggregate Pliers Value and is broadly comparable to 10% Fines value of over 100 kN.
Field Plasticity	Prepare a ball 20 or 30 mm in diameter. Moisten so that it can be modelled without being sticky. Roll to a 3mm thread adding water if necessary. At 3mm the material should start to break, then remould into a ball and carry out the following: - Ball is hard to crush – does not crack/crumble = high clay content. - Tends to crack/crumble = low clay content - Impossible to make a ball = high sand or silt content, very little clay - The ball has a soft or spongy feel = organic soil

B5 Laboratory Testing

Materials testing programmes vary greatly in size and scope depending on the type of road project and associated works. Even for limited scope LVRR projects, materials testing should not be commissioned on an arbitrary basis but should be rationally programmed with clear objectives. Within an overall aim of assuring that selected materials and designs are capable of carrying out their function, laboratory testing is undertaken for a number of reasons.

- Identification of potential material resources
- Proving quality and quantity of actual material reserves
- Monitoring quality of as-won or processed materials
- Construction quality assurance

- In service monitoring

Table B5 lists the more common laboratory tests likely to be required in the assessment of a potential construction material, together with suggested minimum sizes of required sample.

Table B5, Standard Materials Tests and Required Sample Sizes

Test Procedure	ASTM	Minimum Sample Required Fine	 Medium	 Coarse
Moisture Content	D2216	0.05kg	0.35kg	4.00kg
Liquid Limit (Cone /Casagrande))	D4318	0.50kg	1.00kg	2.00kg
Liquid Limit (one point Cone)	D4318	0.10kg	0.20kg	0.40kg
Plastic Limit	D4318	0.05kg	0.10kg	0.20kg
Shrinkage Limit	D427	0.50kg	1.00kg	2.00kg
Linear Shrinkage	(BS1377)	0.50kg	0.80kg	1.50kg
Particle Size (Sieve)	C136 - 117	0.15kg	2.50kg	17.00kg
Particle Size (Hydrometer)		0.25kg		
Particle Density	D854	0.30kg	0.60kg	0.60kg
Compaction – CBR (Modified)	D1883		80.0 kg	
Mg/Na Soundness	C88	150g	600g	850g
Chemical Tests (Organic, Chloride, carbonate etc.)	C40, D1411, D4373	150g	600g	350g
Point Load Test	(ISRM)		Ten identical samples	
Los Angeles Abrasion (LAA)	C131		5.00-10.00kg	

A number of common soil indices are derived from relationships between, Atterberg limits and particle size. and are used to characterise unbound granular materials and soils. These can be useful for characterising general engineering and geotechnical behaviour.

Commonly used grading indices are defined below:

Fines Ratio (FR) = P 0.075/P 0.425

Grading Coefficient (GC) = (P 26.5 – P 2.00) x P 4.75/100

Grading Modulus (GM) = [300 - (P 2.00 + P 0.425 + P 0.075)]/100

Coarseness Index (IC) = (100 – P 2.36)

Fineness Index (IF) = P 0.075

(Where P 0.425 = percentage of material passing the 0.425mm sieve etc, and P is the percentage passing the sieve size given)

Parameters defined to evaluate the relationship between plasticity and fines content include:

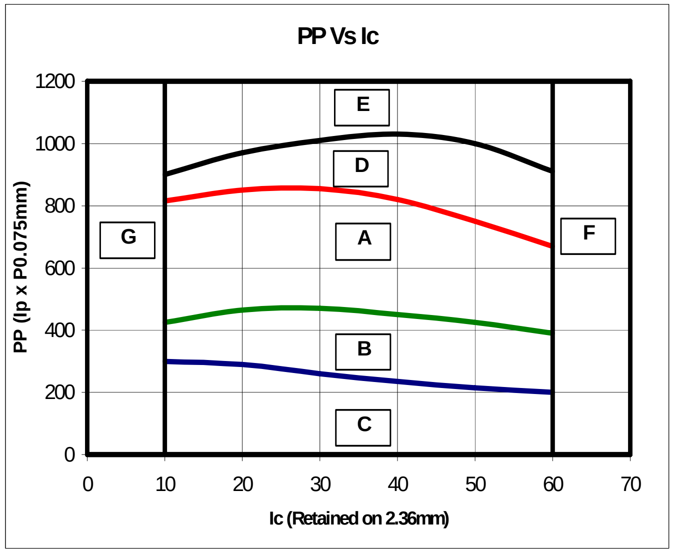
Plasticity Modulus = Plasticity Index x % passing 0.425 mm sieve

Plasticity Product = Plasticity Index x % passing 0.075 mm sieve

Shrinkage Product = Linear Shrinkage x % passing 0.425 mm sieve

Figure B1 illustrates the practical application of the indices in indicating general trends in wearing course performance related to changes in particle size and plasticity characteristics.

Figure B1, Wearing Course Performance Trends



A:	Good performance under wet and dry conditions
B	Good performance under wet conditions; corrugates in dry conditions
C	Lacks cohesion: rapid deterioration with trafiic
D	Good in dry conditions; slippery in wet; potholes/erosion
E	Poor in both wet and dry conditions
F	Too coarse: erodes badly; difficult to maintain
G	Too fine; trafficability problems in wet and very dusty when dry

B6 Approval for Use and Quality Control

It is not realistic to attempt to force contractors to meet inappropriate or unobtainable material standards. For overall cost-effectiveness and minimization of environmental impact, the LVRR road designs and specifications have taken into account, where possible, locally available materials. Hence the use of flexible material specifications that acknowledge local material variations and the use of a capping layer to minimise the use of what may be scarce good quality materials.

Material approval for use should be accompanied by clear guidelines laying out the limits within which the approval is valid. These limits may take a number of forms, namely:

- Material characteristics after compaction (material specification)
- In situ moisture regime
- Sub-grade design value and in situ moisture condition
- Pavement layer thickness design
- Construction methodology
- Traffic level, type and loading.

Where genuine material problems or shortages exist, it is the responsibility of the road designers to overcome the issue by a combination of:

- Adapting the specification and road design to suit local materials, or

- Adapting or modifying the materials to suit a realistic specification.

Sub-standard or marginal quality materials can be, under appropriate conditions, effectively improved by mixing with another material to produce a blend with better characteristics (mechanical stabilisation) or by treatment with an additive such as cement, lime or bitumen or a proprietary chemical (chemical stabilisation). This topic has yet not been addressed fully by the SEACAP programme in Lao, but regional and international experience indicates that the following additives could be considered for use to treat potential road aggregates:

- Granular materials (mechanical stabilisation).
- Portland cement.
- Cementitious blends (cement and lime, cement and bitumen etc).
- Lime (hydrated lime).
- Bitumen (including emulsions).
- Synthetic chemicals.

The principle factors to be considered when selecting the most suitable method of treatment are,

- Type of material to be treated
- Climatic conditions
- Proposed use of the stabilised material
- The capabilities and experience of the construction personnel
- The availability of specialist construction plant
- The availability of testing facilities for investigation and subsequent quality control
- Relative costs

Figure B1, General Guidance on Stabilisation Method (ARRB, 1999)

	MORE THAN 25% PASSING 75µm			LESS THAN 25% PASSING 75µm		
Plasticity Index	PI≤10	10<PI<20	PI≥20	PI≤6 PI x % passing 75µm≤60	PI≤10	PI>10
FORM OF STABILISATION						
Cement and Cementitious Blends	✓	✓		✓	✓	✓
Lime		✓	✓	✗		✓
Bitumen			✗	✓	✓	✗
Bitumen/ Cement Blends	✓		✗	✓	✓	
Granular	✓	✗	✗	✓	✓	
Miscellaneous Chemicals*	✗	✓	✓	✗		✓
KEY	Usually suitable	✓	Doubtful		Usually not suitable	✗

Low Volume Rural Road Standards and Specifications: Part III

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APPENDICES

C: Whole Life Cost

APPENDIX C: WHOLE-LIFE COSTS

C1 Introduction

This Appendix provides an introduction to Whole Life Costing (WLC) for Low Volume Rural Roads (LVRRs) in Lao.

There are a number of accepted and documented techniques to assess the costs and effectiveness of road investments. Some methods require substantial amounts of data that may not be available, would be costly to collect for routine management decisions, would be difficult to analyze with confidence, and may not justify the levels of investment funding available, especially for LVRRs.

Whole Life Costing is preferable to simply considering only the initial design and construction costs of a range of surfacing or paving options for a complete route or a route section. The consideration of all present and expected future costs involved with an investment in rural road infrastructure should be an integral part of the design process, including Maintenance aspects, as discussed in Appendix A.

As noted in Section 3.2.5 of the main text, there are two basic approaches to the assessment of whole life costs for rural roads which can each reflect discrete objectives, and may result in different conclusions depending on the local circumstances. These can be characterized as:-

- Whole Life Costs for the Road Asset
- Whole Life Transport Costs

This Appendix outlines a simple approach to Whole Life Costing for LVRRs in Lao. This is initially based on Whole Life Road Asset Costs but, as reliable data becomes available, then Whole Life Transport Costs may be confidently introduced.

C2 General Approach to WLC Assessment

Whole Life Asset Costing is a process of assessing all costs associated with an investment over its intended (initial) or design lifetime. The aim is to minimize the sum of these values to obtain the minimum overall expenditure on the asset, yet achieving an acceptable level of service of the asset. The principal cost components are the initial investment or construction cost and the future costs of maintaining (or rehabilitating) the asset over the assessment period selected (for example, 12 years from construction). In adverse scenario costing, any rehabilitation costs will need to be included (for example, if maintenance is deficient and the road will need to be reconstructed during or at the end of the assessment period). Usually an assessment of the residual value of the asset at the end of the assessment period is included to incorporate the possible different consequences of construction and maintenance strategies for the surface options investigated.

Whole Life Transport Costs will also include a component (usually substantial) for the savings in Vehicle Operating Costs for the various investment and maintenance strategies. After all, the purpose of the road is to cost-effectively transport the local road users. Other socio-economic factors may also be included in the assessment. The aim is to minimize the overall transport costs (infrastructure and means of transport) over the assessment or design lifetime and will usually incorporate cost savings or other benefits to the road users and community.

From an economic evaluation viewpoint, an important decision is the reduction in value that is assigned to future costs. A discount rate is usually used to reduce future costs and benefits (for example by 10% per year). In this way a dollar spent after one year is only valued at 90 cents at a discount rate of 10%. Similarly, a dollar expected to be spent after two years is valued at only 81 cents in current terms. The decision on discount rate selection is usually based on a combination of policy and economic considerations.

Whole Life Costing is a process requiring informed application of the combination of financial, management and technical skills and knowledge, and is best performed by specialists at regular intervals on behalf of local LVRR decision makers.

Further advice on cost-benefit assessment can be obtained from documents such as Overseas Road Note 5 – A Guide to Road Project Appraisal.

C3 Construction Costs

Construction costs are available from previous contracts throughout the country. For Whole Life Costing purposes it would be very useful to regularly compile these costs on a regional basis, and broken down for each surface and paving option. In view of the high variability of energy/transport and materials costs the data should also be compiled by year so that any inflation cost adjustments can be made. Refinements could later be incorporated for such factors as size of contract, remoteness from main administrative centres, etc., as these aspects usually influence the overall cost of works.

C4 Maintenance Issues

The Lao and regional experiences have shown that the capacity and delivery of maintenance on LVRRs is generally far from adequate. This is due to a complex range of factors, as discussed in Appendix A. These factors result in a generally inadequate provision of effective routine maintenance on LVRRs and, in addition, a serious inability to make adequate provisions and arrangements for the necessary periodic re-gravelling required for the considerable network of gravel roads.

When Whole Life Costing is carried out, a pragmatic assessment of the expected maintenance resources and capacity should also be carried out to achieve a realistic WLC assessment.

C.5 Vehicle Operating Cost Issues

Whole Life Transport Costs of LVRRs include an assessment of vehicle costs savings for road interventions or maintenance strategies i.e. with the aim of minimizing the sum of construction, maintenance and vehicle (user) operating costs (VOC) over the selected assessment period.

Various economic models have been developed to help decision makers assess the balance of road construction and maintenance investments and road user costs, including HDM4 and the World Bank's RED model. There are a number of constraints to be considered for the application of these models for the situation of LVRRs in Lao, particularly with regard to the evaluation of VOC:-

1. HDM4 is primarily motor vehicle and roughness driven and is more appropriate for assessment of the higher category routes.
2. VOC relationships for HDM4 and RED have been developed primarily from experience in Africa and South America, not South East Asia, where there are climatic, traffic, environmental, operational and cultural differences.
3. "The models are limited in their ability to deal with the problems of very basic access; many of the key road deterioration and VOC cost relationships tend to break down for rough earth roads and tracks and very poorly maintained roads".
4. The models do not have VOC relationships for motorcycles and bicycles, which account for most of the traffic on the rural roads.
5. There is a substantial component of pedestrian traffic on some rural roads.
6. The "commercial" vehicles commonly used on rural roads are mainly light and slow moving trucks and agricultural vehicles, for which VOC-road condition relationships are not locally researched.

7. Robust VOC versus road condition knowledge is not available for the Lao conditions[1].

VOC-road condition relationships can vary by substantial factors[2]. It is likely that the fundamental factors of the local Lao environment regarding driver behaviour, vehicle life and depreciation, vehicle repair capability, spares availability, value of time, load carrying, and personal/commercial decision making, vary substantially between the previously researched regions of the world and Lao, thereby influencing VOC relationships in a different and very significant way.

The issue of seasonal passability is particularly relevant for roads that become flooded for short or long periods, and for gravel roads on weak subgrades that can become impassable to motorized traffic when severely deteriorated.

C.6 Conclusions

Limitations with local research and data availability mean that there are a number of constraints to carrying out realistic Whole Life Costing of LVRR investments in Lao. Reasonable data exist to enable Whole Life Asset Costing to be done despite limited knowledge on maintenance needs and costs.

C7 Typical Worked Example

The following example is taken from the SEACAP 03 Training Course to illustrate a typical comparison of Whole Life Asset Costing between a sealed and an unsealed option in a mountainous, high gravel loss environment, Table C1. Some of the key points are as follows.

- The road options are designed and construction quantities of each material are calculated from the unit cost of each material.
- The maintenance needs (routine and periodic) of the road are then estimated and the maintenance costs are calculated. Because these costs occur in the future, it is necessary to discount them at an agreed discount rate to give their Net Present Value (NPV). A discount rate of 10% was used.
- The residual value of the road at the end of the analysis period is calculated. Residual values were assumed to be the discounted value of the construction cost of the lower layers of the pavement and half the construction cost of the surfacing. This assumption is based upon the pavement layers being still in good condition but the surfacing layer having lost half its initial value.
- The analysis period is 12 years.

The costs for construction and maintenance were taken from locally available sources, however, it is worth noting that the applied routine maintenance costs for gravel are lower than regional experience indicates. Nevertheless the advantage of using this approach is well illustrated by clearly indicating the WLC advantage of sealed option over and unsealed option despite the apparent initial attractiveness of the latter's construction costs.

[1] Outline regional data only - Analysis of Vehicle Operating Costs on Rural Roads, Rural Transport Strategy Study, Vietnam, I T Transport, 1999.

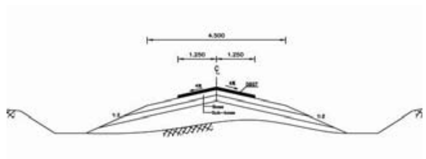
[2] Research by TRL found that unit road freight transport costs varied by factors of 4 to 6 between some African countries and Pakistan. Rizet, C and J L Hine, 1993.

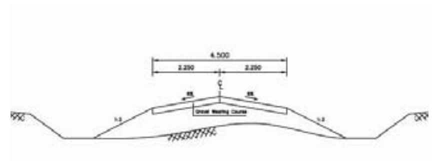
Table C1, WLC Work Sheet

EXAMPLE OF WHOLE LIFE ASSET COST CALCULATION AND COMPARISON

Pavement option	Pavement design			
	Capping	Sub-base	Base	Surface
1. Gravel Wearing Course	25cm	-	-	20cm
2. Double seal on gravel	10cm	10cm	10cm	DBST

Region: North
Terrain: Mountainous
Gravel loss : 50 mm/year
Subgrade CBR : 4%
Traffic :10,000 ESA





Work Description	Pavement Option (Cost per km)									
	Seal on gravel					Gravel surface				
	Unit	Qty	Rate (USD)	Amount (USD)	NPV (USD)	Unit	Qty	Rate (USD)	Amount (USD)	NPV (USD)
1. Construction										
1.1 Capping Layer	m3	510	4.00	2,040.00		m3	1275	4.00	5,100.00	
1.2 Sub-base	m3	480	6.50	3,120.00		m3	0	6.50	0.00	
1.3 Base	m3	470	22.00	10,340.00		m3	0	6.50	0.00	
1.4 Surfacing	m3	50	59.75	2,987.50		m3	900	6.50	5,850.00	
Sub -Total:				18,487.50	18,487.50				10,950.00	10,950.00
2. Routine Maintenance										
2.1 Year 1				889.34	808.49				664.99	604.54
2.1.1 Grass cutting	m2	400	0.16	64.00		m2	400	0.16	64.00	
2.1.2 Bush cutting	m2	200	0.02	4.00		m2	200	0.02	4.00	
2.1.3 Clearing of ditches	m	800	0.39	312.00		m	800	0.39	312.00	
2.1.4 Grading of shoulders	m2	450	0.39	175.50		m2	450	0.39	175.50	
2.1.5 Filling pothole of Amoured	m3	3	22	66.00		m3	0	22	0.00	
2.1.6 Filling pothole of Natural grave	m3	0	4.37	0.00		m3	5	4.37	21.85	
2.1.7 Patching of pothole	m2	20	4.37	87.40		m2		4.37	0.00	
2.1.8 Filling along edges with grave	m3	8	3.38	27.04		m3	8	3.38	27.04	
2.1.9 Edge repairs, patching	m2	10	3.46	34.60		m2	10	3.46	34.60	
2.1.10 Crack sealing, minor arears	m2	60	1.98	118.80		m2		1.98	0.00	
2.1.11 Grading of gravel surface	m2		0.26	0.00		m2	100	0.26	26.00	
2.2 Year 2				889.34	734.99				664.99	549.58
2.3 Year 3				889.34	668.17				664.99	499.62
2.4 Year 4				889.34	607.43				664.99	454.20
2.5 Year 5				889.34	552.21				664.99	412.91
2.6 Year 6				889.34	502.01				664.99	375.37
2.7 Year 7				889.34	456.37				664.99	341.25
2.8 Year 8				889.34	414.88				664.99	310.22
2.9 Year 9				889.34	377.17				664.99	282.02
2.10 Year 10				889.34	342.88				664.99	256.38
2.11 Year 11				889.34	311.71				664.99	233.07
2.12 Year 12				889.34	283.37				664.99	211.89
Sub -Total:					6,059.69					4,531.04
3. Periodic Maintenance										
3.1 Year 1										
3.2 Year 2										
3.3 Year 3										
3.4 Year 4									6,339.50	4,329.96
3.4.1 Regravelling						m3	675	7.54	5,089.50	
3.4.2 Scarifying of existing road						m2	2,500	0.5	1,250.00	
3.5 Year 5										
3.6 Year 6										
3.7 Year 7									6,339.50	3,253.17
3.7.1 Regravelling						m3	675	7.54	5,089.50	
3.7.2 Scarifying of existing road						m2	2,500	0.5	1,250.00	
3.8 Year 8				4,400.00	2,052.63					
3.8.1 Resealling	m2	2500	1.76	4,400.00						
3.9 Year 9										
3.10 Year 10									6,339.50	2,444.15
3.10.1 Regravelling						m3	675	7.54	5,089.50	
3.10.2 Scarifying of existing road						m2	2,500	0.5	1,250.00	
3.11 Year 11										
3.12 Year 12										
Sub -Total:					2,052.63					10,027.28
Residual Value (= cost of the pavement + half of the surfacing cost)				16,994.00	5,414.81				8,025.00	2,557.01
NPV net cost @10%					**21,185.01**					**22,951.31**

Low Volume Rural Road Standards and Specifications: Part III

Application of LVRR Standards and Specifications

APPENDICES

D: Selection of Pavement Options

APPENDIX D: SELECTION OF PAVEMENT OPTIONS

D1 Introduction

Section 3 in the main text of this document highlights the main factors that govern the initial selection of LVRR pavement options. This Appendix seeks to take this advice a stage further by relating specific road environment scenarios with appropriate LVRR pavement or surfacing options. Other Appendices within this document are also closely involved in this process, namely;

Appendix A: Maintenance Issues

Appendix B: Construction Materials.

Appendix C: Whole Life Costs

D2 Pavement and Surfacing Options

Although the current LVRR specifications deal with only a very limited number of pavement or surfacing options, it is likely that additional options will be added to this list as information from ongoing national and regional research is taken up by the MPWT.

A listing of potential LVRR options for Lao is given below in Table D1.These options are used for illustrative purposes in the following selection framework.

Table D1, Potential LVRR options

Type of pavement	Materials
Unsealed	Gravel Hand-packed stone
Sealed Flexible base and sub-base	Dry-bound Macadam Water-bound Macadam Gravel Mechanically stabilised local materials Chemically stabilised local materials
Block Sealed or unsealed	Fired clay bricks Stone setts/cobble stones Concrete blocks
Rigid pavement	Non-reinforced concrete

D3 Selection

The identification of suitable pavement options is, firstly, a filtering process whereby unsuitable or unsustainable options are removed from consideration. This is outlined below as a series of steps

1. Consider available materials – Figure D1
2. Consider maintenance impacts – Figure D2
3. Consider erosion issues (rainfall-gradient-flooding) Figure D3
4. If sealed options are being selected – consider seal types – Figure D4.

This process should highlight those options that are most suitable on physical environment grounds. The remaining options can then be assessed on the basis of:

- Budget – Whole Life Cost
- Contractor capability
- Local stakeholder opinion

Figure D1, Available Materials

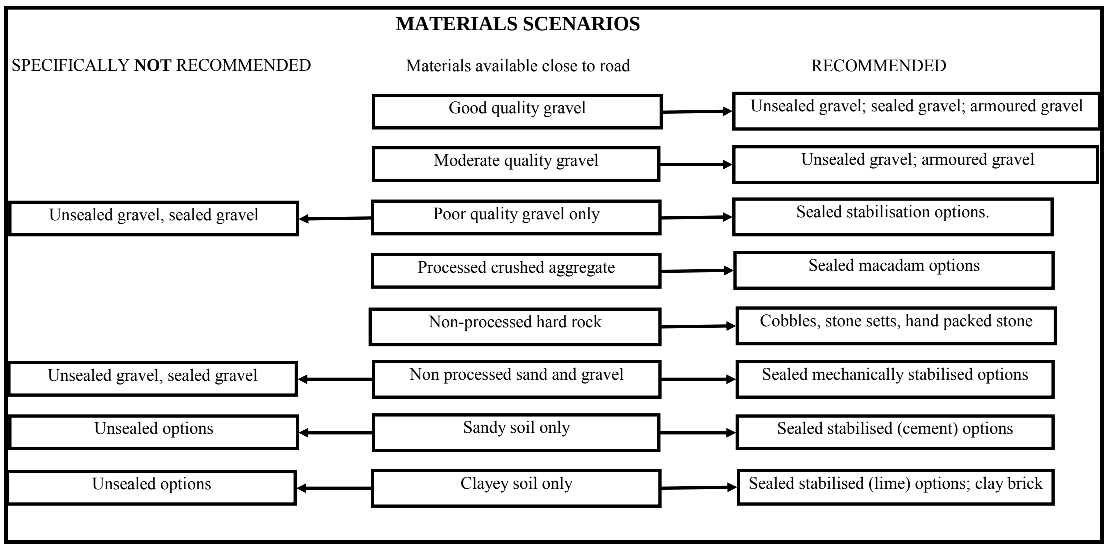


Figure D2, Maintenance

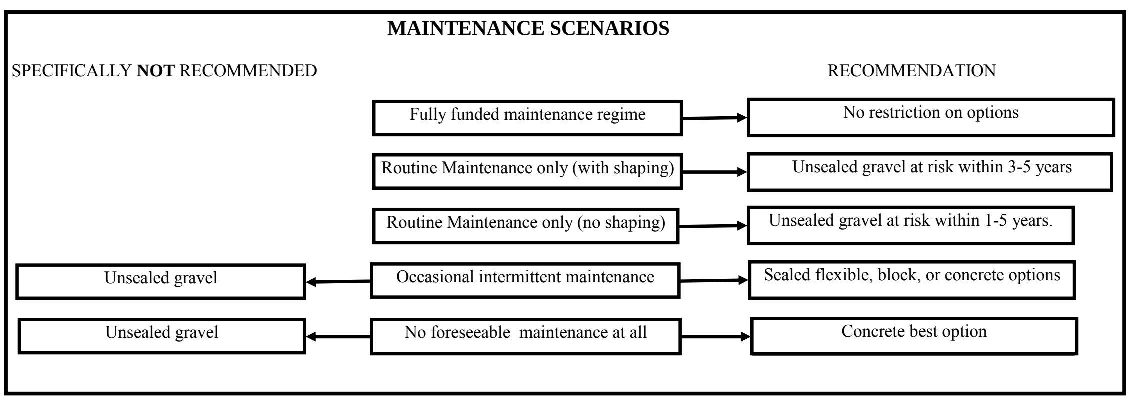


Figure D3, Erosion Impact

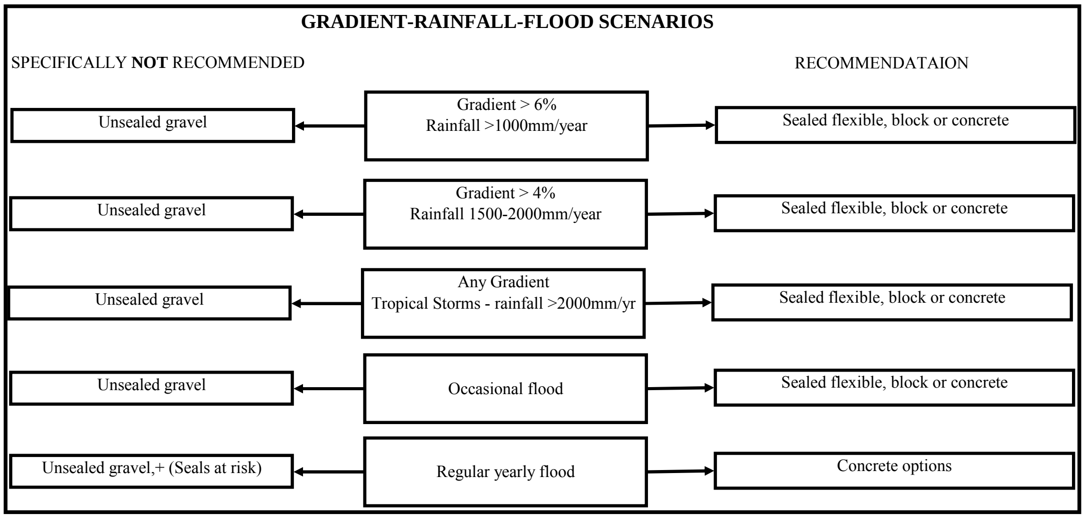
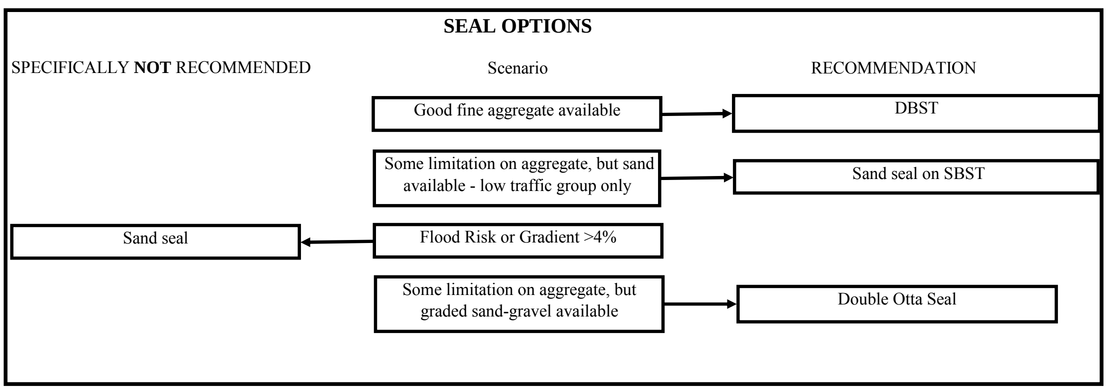


Figure D4, Seals



Low Volume Rural Road Standards and Specifications: Part III

Application of LVRR Standards and Specifications

APPENDICES

E: Traffic Assessment

APPENDIX E: TRAFFIC ASSESSMENT

E1 General

For pavement design we are interested in the number of commercial vehicles only. These are the small and medium trucks with up to about 4.5Tonnes on the rear axle. Heavy vehicles have been excluded from this standard. We are also interested in the smaller commercial vehicles as well. They add volume and some loading to the road.

The traffic loading is determined by summing the AADT traffic in each of the two classes (small and medium trucks) in the design period and applying growth and loading factors. It should be remembered that these are single-lane roads and the traffic is expected to be channelled. This means that the AADT is used, instead of the loading in the most heavily loaded direction, and the result is increased further to account for the channelling. Finally the sum of the traffic in the small and medium truck classes is summed to obtain the number to enter into the pavement design chart.

Table E1, Calculation for Cumulative Equivalent Standard Axle Loading, esa

AADT	Traffic Growth	Channelling	Loading Factor (esa/vehicle)	Total esa's
Total of small trucks (<1.8m body width).	Apply growth factor and obtain total for design period (12 years)	Multiply x 1.5	0.01	Result
Total of medium trucks (>1.8m body width)		Multiply x 1.5	0.1	Result
Total for pavement selection				Sum of the above two results

In the calculation for the design traffic, lighter 4-wheeled vehicles are ignored in the calculation (as shown in the table above) because they do not contribute significantly to pavement loading.

If necessary the traffic can be calculated more accurately by applying the commonly used equation to determine the cumulative axle loading, namely

$$\text{esa for an axle} = (\text{measured axle load}/8.16\text{T})^{4.5}$$

This process should be carried out if significant overloading is suspected.

E2 Traffic Counts to Determine AADT

The normal LVRR traffic surveys are undertaken by means of a standard classified manual traffic counts. In some circumstances, for example where there is a suspected risk of heavy vehicle overloading on light pavements, it may necessary to undertake more detailed commercial traffic counts. These classified counts may be undertaken in conjunction with axle load surveys.

The procedures in this document refer primarily to standard manual traffic counts, although suitable forms are include for use in classified traffic counts as well.

Manual counts are carried out by observers situated at an observation point at the side of the road from where they record each vehicle on a survey form according to the vehicle type, Form E1.

For tertiary rural roads a minimum survey period of three days is recommended. A 7-day count is recommended where significant variability of traffic is suspected. Traffic should be counted in each direction for a 12-hour period, (6am to 6pm). A survey team should consist of at least two people to allow for a shift system to be adopted.

Periods of *abnormal* traffic flow should be avoided, (i.e. periods when relatively rare short-term events occur such as public holidays). In locations where a large *seasonal* variation occurs, surveys may be necessary at different times of the year to reduce errors in estimating annual traffic.

For more detailed commercial traffic counts Form E2 should be used.

Figure E1 shows a typical traffic form. From completed forms the average daily traffic for each vehicle type is calculated and then they are converted into an equivalent daily traffic (esas) using either Table E1 or calculated from the results of a more accurate axle load survey.

The ADTs calculated directly from the results of the traffic count (Form E1) require several corrections.

a) If traffic is known to pass at night, the 12-hour count must be multiplied by 1.2 to estimate the 24-hour count. If no traffic passes at night, the 24-hour count equals the day count.

b) Traffic along most roads varies during the year depending upon aspects such as the weather, harvest periods, festivals and so on. The adjustment factors should be derived when possible from official Lao factors. The seasonal factor is used to convert a traffic count made in a specified month into a figure which represents the average during the entire year. The result is known as the AADT – Annual Average Daily Traffic.

c) For pavement design it is necessary to estimate the traffic that will use the road in the future. This will comprise not only the traffic that uses the existing road but also traffic that may be diverted from other roads when the new road is built and traffic that may be generated as a result of the construction. These two estimates must be added to the existing traffic to give the total.

d) Finally pavement design requires the cumulative total traffic that will use the road during the design period hence a traffic growth factor needs to be used to calculate this total. Growth rates can be quite high if other investments are being made in the area of the road and normally advice needs to be sought from central authorities.

E3 Worked example (Form E3)

Form E3 illustrates the analysis. Fifteen vehicle categories are shown but this level of detail is not normally required for LVRR pavement design. For example, there should not be any large trucks otherwise the road will be defined as a higher category. Each row of the Form is summarised below.

1. Rows 1 and 2 show the traffic count in each direction
2. Row 3 shows the total traffic count, namely the sum of Rows 1 and 2
3. Row 4 shows the adjustment factor to take account of traffic that uses the road between 6.00pm and 6.00am and Row 5 shows the result of this adjustment.
4. Row 6 shows the adjustment factor, if any, to account for the season that the traffic count took place and the result of this adjustment is shown in Row 7. This is the best estimate of the AADT of the existing traffic.
5. Row 8 shows an estimate of traffic that will be diverted from other roads and generated by the new road when it is completed.
6. Row 9 is the sum of existing, diverted and generated traffic and is the best estimate of the traffic that will use the road immediately after it is built.
7. Row 10 shows the estimated growth rate per year and Row 11 shows the factor by which the traffic will increase by the final year of the analysis period.

The next stage of the analysis is to determine the total cumulative esas over the analysis period. Here we assume that there are no large trucks and that the road category is a LVRR. Therefore we assess the esas of the small and medium trucks only, the other lighter vehicles having no significant effect. The esa estimate is shown in the bottom left of Form E3.

8. Row 1 of the mini Table is the previously calculated AADTs for the small and medium trucks
9. Row 2 is the factor (S) by which Row 1 must be multiplied to determine the total cumulative traffic over the design period. Row 1 multiplied by 365 gives the initial *annual* traffic but this has to be scaled up using the growth rate and the number of years. The formula for calculating the factor S is,

$$S = [(1+r)^n - 1]/r$$

Where *n* is the number of years and *r* is the growth rate expressed as the percentage /100. That is 60% is expressed as 0.60 for example.

10. Row 3 is the result of the calculation and gives the total traffic over the design period.
11. It is assumed (Row 4) that 70% of the trucks are fully loaded and the remainder are only partially loaded. The partially loaded trucks contribute very little to the overall loading and are ignored. Row 5 is the total number of fully loaded trucks.
12. Row 6 is the channelling factor mentioned previously to take account of the extra loading that occurs on relatively narrow roads by virtue of the narrower wheeltracks that develop. Row 7 is the result of applying this adjustment.
13. Finally the average esa of a loaded truck is shown in Row 8 (based on typical load levels) and the total loading for each truck type is shown in Row 9.
14. Row 10 shows the sum for both truck sizes and is the figure needed for pavement design.

It is important to understand that such a calculation is not very precise. Numerous assumptions have been made, specifically at steps 3 (night traffic), step 4 (seasonal adjustment), step 5 (diverted and generated traffic), step 7 (growth rate), step 11 (assumed percentage of fully loaded trucks), step 12 (channelling factor), step 13 (average esa per loaded truck). Many of these assumptions can be verified or modified by collecting more data. For example an axle load survey will improve knowledge of several of them and a night count will provide information on night traffic. However, additional data collection is not usually justified for LVRRs. Furthermore, data on loading collected for higher standard roads can often be used to improve the assumptions made herein.

Form E1 LVRR Traffic Count

Province					SURVEYOR	
District					LOCATION	
Daily 12 hour counts	*DATE*					
Traffic Class	0600-0900	0900-1200	1200-1500	1500-1800	Total	24 hr Daily Average
PEDESTRIAN,						
BICYCLE						
ANIMAL						
CART						
MOTORCYCLE						
TRICYCLE/TRACTOR						
CAR,						
4WD, PICKUP						
MINI-BUS						
MED BUS						
LARGE BUS						
LIGHT TRUCK =<4.5 TAL W=1.8m						
MED-TRUCK =<4.5 TAL, W=2.3						
LARGE TRUCK >4.5 TAL						
TOTALS						
Rain This Period?						
Daily Survey Period:	6.00 hours to 18.00 hours					

Form E2

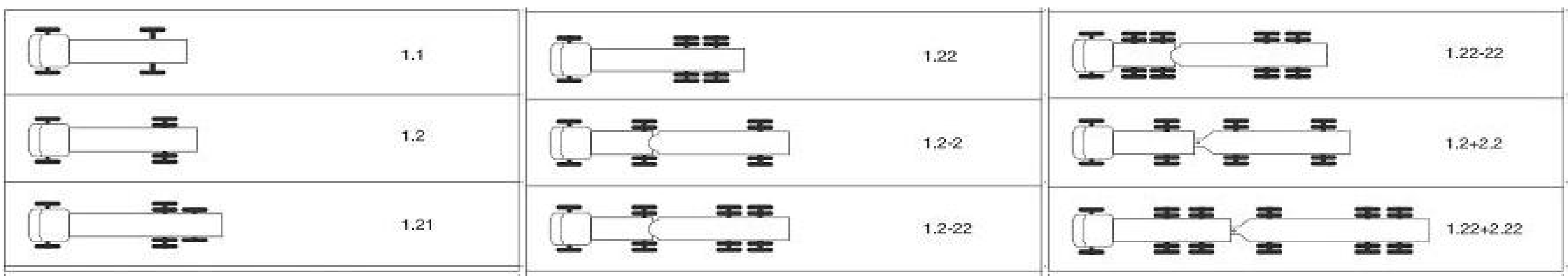
Commercial Vehicle Observation Survey Form

Observer/Surveyor: . . . . Location: . . . . Date: . . . .

No	Vehicle type	Truck/bus axle configuration	Make/of truck	Estimated "rated" gross vehicle weight	Actual loading status	Estimated body size (m3)	Description of payload	Vehicle Direction
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								

Notes:

1. This Survey form is intended to be used for observations of commercial trucks and buses **WITHOUT** stopping traffic or interfering with their natural flow. Some familiarization by the Observer will be required before the surveys commence to allow him/her to quickly and accurately assess the data to be recorded.
2. Traffic type: Information to be inserted in this box i.e. truck or bus.
3. Truck/bus axle configuration: insert number code i.e 1.2 etc. - see chart below



4. Make/Manufacturer of truck: if known.
5. Estimated "rated" gross vehicle weight: i.e. what the plating notice on the vehicle states
6. Actual loading status: Whether Empty/Part Full/Full Load.
7. Estimated body size: in cubic metres
8. Description of payload: stone/aggregates/earth/logs/timber/agricultural crops/building materials/other/unknown etc.
9. Vehicle Direction: coding for each direction.

If the Observer is unsure about any entry, he/she should enter the data within brackets. It is appreciated that in some circumstances it will not be possible to record the data accurately and these incidences should be identified to assist with the survey analysis.

Form E3

Count duration	6.00 - 18.00
Design Life (yr)	12

	Vehicle category		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Directions	Vehicle description		Pedestrian	Bicycle	Guided animal	Cart	Motorcycle	Tuk-tuk, Jambo Motorized tricycle, farm tractor	Passenger car	Jeep or 4WD vehicle	Small bus: <12 passengers	Medium bus: 12-25 passengers	Large bus: >25 passengers	Small truck: 2 axles, 1.8m width	Medium truck: 2 axles, 2.3m width	Large 2 axle truck: >2.3m width	Large >2 axle truck: >2.3m width
Traffic count … to …		A	24	14	6	2	18	15	3	2	2	1	0	5	8	0	0
… to …		B	20	13	4	3	16	20	2	1	2	1	0	6	7	0	0
Total two-way count		C = A + B	44	27	10	5	34	35	5	3	4	2	0	11	15	0	0
Daily factor		D	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
x Daily factor		E = C x D	52.8	32.4	12.0	6.0	40.8	42.0	6.0	3.6	4.8	2.4	0.0	13.2	18.0	0.0	0.0
Seasonal factor		F	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
x Seasonal factor = AADT		G = E x F	52.8	32.4	12.0	6.0	40.8	42.0	6.0	3.6	4.8	2.4	0.0	13.2	18.0	0.0	0.0
Estimate generated + diverted traffic		H	17.4	10.7	4.0	2.0	13.5	13.9	2.0	1.2	1.6	0.8	0.0	4.4	5.9	0.0	0.0
Total AADT		J = G + H	70.2	43.1	16.0	8.0	54.3	55.9	8.0	4.8	6.4	3.2	0.0	17.6	23.9	0.0	0.0
Annual growth rate (%)		K	2	2	2	2	7	7	7	7	7	7	7	7	7	7	7
DL growth rate		L	1.27	1.27	1.27	1.27	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
x DL growth rate = Final year AADT		M = J x L	89.2	54.7	20.3	10.1	122.1	125.7	18.0	10.8	14.4	7.2	0.0	39.5	53.9	0.0	0.0

ANALYSIS OF TRAFFIC GROUPS

Traffic groups		1	2	3	4	5
Traffic group description		Large buses and large trucks	Medium trucks	Small trucks	4+ wheeled motorised vehicles	Non-motorised road users
Categories		11, 14 & 15	13	12	7 to 15	1 to 4
Total DL year AADT	M + M + M	**0**	**54**	**40**	**144**	**174**

TRAFFIC ANALYSIS FORM

ESA ESTIMATE

Vehicle category		13	12
Vehicle description		Medium trucks	Small trucks
AADT	J	23.9	17.6
Cumulative DL factor	N	6990	6990
x Cumulative DL factor	P = J x N	167341	122716
Loaded proportion	Q	0.7	0.7
x Loaded proportion	R = P x Q	117138	85902
Channelling factor	S	1.5	1.5
x Channelling factor	T = R x S	175708	128852
ESAs per truck	U	0.1	0.01
x ESAs per truck	V = T x U	17,571	1,289
Total ESAs (Medium + Small)	W = V + V	**18,859**	

DAILY FACTOR

Duration of count	6.00 to 18.00	1.2
Daily factor = D	0.00 to 24.00	1

TRAFFIC GROWTH

Annual growth rate = K	1	2	3	4	5	6	7	8	9	10
DL = 12 yr --- Growth rate = L	1.13	1.27	1.43	1.60	1.80	2.01	2.25	2.52	2.81	3.14
Cum factor = N	4675	4993	5335	5704	6100	6527	6986	7481	8013	8586
DL = 15 yr --- Growth rate = L	1.16	1.35	1.56	1.80	2.08	2.40	2.76	3.17	3.64	4.18
Cum factor = N	5934	6438	6992	7601	8270	9005	9814	10703	11681	12757
DL = 20 yr --- Growth rate = L	1.22	1.49	1.81	2.19	2.65	3.21	3.87	4.66	5.60	6.73
Cum factor = N	8117	9046	10102	11304	12673	14232	16011	18039	20354	22996

SEASONAL FACTOR

Month in which count was made	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seasonal factor = F	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Low Volume Rural Road Standards and Specifications: Part III

Application of LVRR Standards and Specifications

APPENDICES

F: Road Environment Assessment

APPENDIX F: ROAD ENVIRONMENT ASSESSMENT

F1 Objective

The main text of this document indicated the importance of collecting road environment information from along the alignment for the upgrade or construction of LVRRs. This Appendix provides an outline methodology for the systematic collection of this information, in conjunction with Appendix B, *Road Construction Materials* and Appendix E, *Traffic Assessment.*

F2 Road Environment Data Sheet

Form F1 is a proposed Road Environment Data Sheet that should be completed as part of the road walk-over survey on candidate roads. The basic sheet may be modified to meet specific project requirements, however the key data sets are:

Junctions (roads, dykes, canals etc)

Location of existing bridges, culverts

Location of buildings likely to be effected by road construction

Existence of any side ditches.

Existing road widths

Existing shoulder width

Existing pavement material type

Existing sub-grade material

Existing pavement or sub-grade strength (see following section)

Estimate of existing access conditions:(index).

1. Excellent, 2-Wheel Drive car in all weather
2. Good, 2WD car in dry season
3. Fair, 4WD in all weather
4. Poor, 4WD in dry season only
5. Failed, Not passable by 4WD.

Description of any road damage

Earthworks – is road in cut or on embankment

Indication of potential or existing borrow areas or quarries

Current alignment gradient

Estimation of groundwater level (eg observation of rice field, river, pond, lake)

Flooding: estimation of depth and how often this happens

Sampling should be in line with the following guideline (see also Table B5)

- Small soil samples at every section: about 2kg.

- 5 kg sample for clay, sandy clay. (Check enough for grading and plasticity)
- 15kg sample for gravel, sand.
- Large bulk soil sample when sub-grade laboratory CBR testing required.

Form F1

Initial Road Survey | **Sheet number /**

Chain	General	E'Work	Shoulder L	WTL	WTR	Shoulder R	E'Work	General	Condition	Material	Gradient	Curve

Road Name

GPS Start	N		
	E		
GPS End	N		
	E		
Surveyor		Date	

LEGEND

Houses

Bridge

Culvert

Road

W Surface water

R Rice field

Ditch

E'Work
E - Embankment
C - Cutting
N - None

D DCP
S Sample

M Material source

Material
E - Earth
S - Sand
Cl - Clay
Gr - Gravel-cobble
BS - Bitumen

Access Condition
1 - Excellent 2WD
2 - 2WD in dry season
3 - Fair 4WD all weather
4 - Poor 4WD in Dry
5 - Failed - Not passable

Gradient
a - <0%
b - 0-2%
c - 2-4%
d - 4-6%
e - 6-8%
f - >8%

Comments

F3 Subgrade Strength –

F3.1 In situ Testing by Dynamic Cone Penetrometer (DCP)

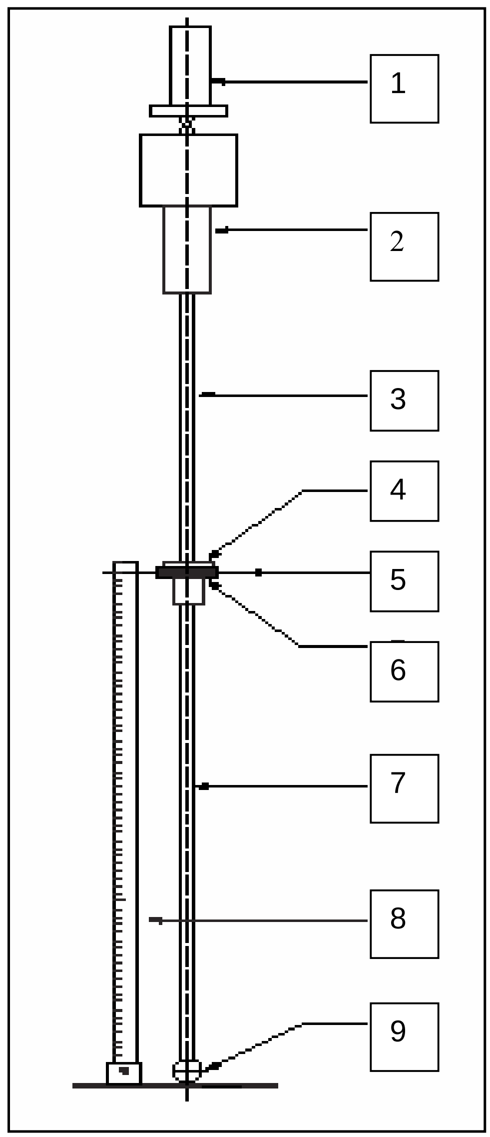
When available the DCP may be used to estimate the sub-grade conditions along the road. The DCP values correlate well with CBR values. If DCP equipment is not available then obvious areas of possible weak sub-grade should be identified.

The DCP is an instrument designed for the rapid in-situ measurement of the structural properties of existing road pavements constructed with unbound materials (Figure F1). Continuous strength measurements can be made down to a depth of approximately 850mm or, when extension shafts are used to a recommended maximum depth of 2 metres. Where pavement layers have different strengths the boundaries can be identified and the thickness of the layers determined.

Correlations have been established between measurements with the DCP and CBR (California Bearing Ratio) so that results can be interpreted and compared with CBR specifications for pavement design. A typical test takes only a few minutes and therefore the instrument provides a very efficient method of obtaining information.

Figure F1 The Assembled DCP

1. Handle
2. 8kg Hammer
3. Hammer shaft
4. Coupling
5. Handguard
6. Clamp ring
7. Standard shaft
8.1m rule
9. 60 degree cone



DCP readings should normally be taken every 250m (2 at each chainage sunk at least 500mm or refusal). This spacing may be increased to 500m in cases where there is no change in terrain, earthworks or general environment. Samples should be taken for examination and possible testing at DCP section locations.

The design of the DCP uses an 8Kg weight dropping through a height of 575mm and a 60^{0}. cone having a diameter of 20mm.

After assembly, the first task is to record the zero reading of the instrument. This is done by standing the DCP on a hard surface, such as concrete, checking that it is vertical and then entering the zero reading in the appropriate place on the test sheet (Form F2).

The DCP needs three operators, one to hold the instrument, one to raise and drop the weight and one to record the results. The instrument is held vertically with the weight just touching the handle, but not lifting the instrument. The operator then lets it fall freely. If during the test the DCP leaves the vertical, no attempt should be made to correct this as contact between the bottom shaft and the sides of the hole will give rise to erroneous results.

It is normal practice to take a reading after a set number of blows. It is therefore necessary to change the number of blows between readings according to the strength of the layer being penetrated. For good quality granular bases readings every 5 or 10 blows are normally satisfactory but for the weaker sub-base layers and sub-grade readings every 1 or 2 blows may be appropriate. There is no disadvantage in taking too many readings, but if too few are taken, weak spots may be missed and it will be more difficult to identify layer boundaries accurately hence important information will be lost.

Little difficulty is normally experienced with the penetration of most types of granular materials. It is more difficult to penetrate granular materials with large particles and very dense, high quality crushed stone. The instrument has been designed for strong materials and therefore the operator should persevere with the test. Penetration rates as low as 0.5mm/blow are acceptable but if there is no measurable penetration after 20 consecutive blows it can be assumed that the DCP will not penetrate the materials. If only occasional difficulties are experienced in penetrating granular materials it is worthwhile repeating any failed tests a short distance away from the original test point.

If the DCP is used extensively for hard materials, wear on the cone itself will be accelerated. The cone is a replaceable item and it is recommended by many authorities that replacement be made when the diameter has reduced by 10 percent. However other causes of wear can also occur hence the cone should be inspected before every test. Typically the cone will need replacing after about 10 holes in hard material and in the absence of damage other than shoulder wear this is the recommended practice

The results of the DCP test are usually recorded on the field test and the results can then either be interpreted by hand calculator or transferred to a standard EXCEL-type spread-sheet and processed by computer, Figure F2. Alternatively, there is now available a DFID funded TRL computer programme that can now be used to calculate not only layer depths and CBRs but other related relationships and plots. This programme may be downloaded via www.transport-links.org,

The boundaries between layers are easily identified by the change in the rate of penetration. The thickness of the layers can usually be obtained to within 10mm except where it is necessary to core (or drill holes) through materials to obtain access to the lower layers. In these circumstances the top few millimetres of the underlying layer is often disturbed slightly and appears weaker than normal.

Several similar relationships between the DCP readings and CBR have been obtained; the one currently used by the TRL is as follows:

TRL, Overseas Road Note 18 (60^o cone) $\quad \text{Log}_{10}(\text{CBR}) = 2.480 - 1.057\ \text{Log}_{10}(\text{mm/blow})$

Agreement is generally good over most of the range but differences are apparent at low values of CBR, especially for fine grained materials. It should be remembered that DCP-CBR figure refers to a specific index strength for specific in situ conditions of moisture and density and great care needs to be taken in relating this to laboratory based CBR values. Therefore if precise values are needed, it is advisable to calibrate the DCP for the materials in question. Nevertheless, if the testing is undertaken at worst case soaked (rainy season) conditions it will give a reasonable representative picture of existing actual pavement or sub-grade strength conditions.

F3.2 Laboratory CBR Testing

Laboratory testing of samples from the alignment will index strength values related to particular moisture-density conditions, rather than existing in situ conditions. The subgrade of a potential sub-section should be sampled at initially, say, 0.5km intervals and near to the boundary of every visible soil change. At every test location remove topsoil and take individual samples of each layer that is visually different. The test pits will never be less that 0.3m depth and more usually 0.5m depth. Classification compaction and soaked CBR tests should be carried out on each sample.

From at least three CBR results within any selected section, compare the results of the classification and compaction tests to confirm on that the materials are similar. Then select the lowest soaked CBR value as the subgrade CBR for pavement design. If they are not similar then reassess and change the selection of the sub-sections along the alignment, obtain more samples for laboratory testing as necessary, and repeat the process.

Form F2: Standard DCP Field Sheet

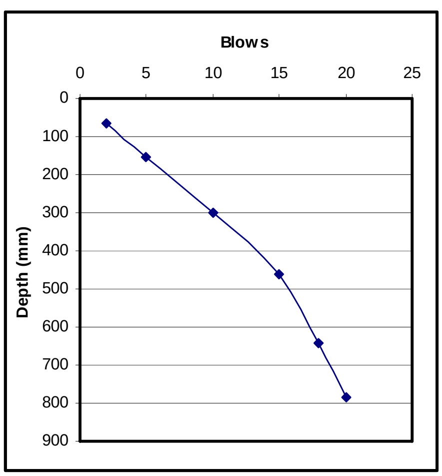
SITE/ROAD	DATE
	TEST NO
SECTION NO/CHAINAGE	DCP ZERO READING mm
DIRECTION	TEST STARTED AT
WHEEL PATH	

No OF BLOWS	TOTAL BLOWS	READING mm	No OF BLOWS	TOTAL BLOWS	READING mm	No OF BLOWS	TOTAL BLOWS	READING mm

HUE DCP FIELD SHEET								
Site/Road		Phu Loc Road			Date		19/11/2002	
Test No.		PL.07			Operator		Ph¹m Gia TuÊn	
Site Location					Zero Reading (C0)		107.0	
Test Location		RS			Depth of Start		0.0	
No.Blows	Total Blows	Total Penetration (mm)	Total Corrected Penetration	ΔPen	Pen/blow	LogP	No	CBR
a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**j**
		107						
2	2	174	67	67	33.5	1.5250	0.8680	7.4
3	5	259	152	85	28.33333	1.4523	0.9449	8.8
5	10	406	299	147	29.4	1.4683	0.9280	8.5
5	15	570	463	164	32.8	1.5159	0.8777	7.5
3	18	750	643	180	60.0	1.7782	0.6005	4.0
2	20	890	783	140	70.0	1.8451	0.5297	3.4

Formulas for Excel

a	b	c	d	e	f	g	h	i
Input	$b_n=a_n+a_{n-1}$	Input	$d_n=c_n-c_0$	$e_n=d_n-d_{n-1}$	f = e/a	$g=\log_{10}(f)$	h=2.48-1.057*g	i=10*h



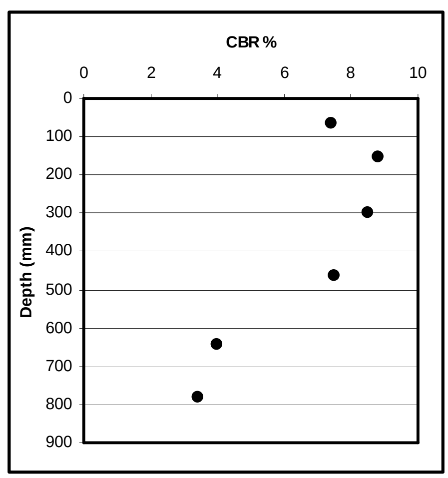


Figure C4: Typical EXCEL Calculation Sheet and Plots for DCP Data

F4 Useful Equipment

The following equipment is recommended for an alignment survey:

- Camera
- DCP
- GPS
- Shovel, hoe, trowel,
- Tape-measure 50m,
- Straight edge 2m, spirit level (?)
- Small plastic bags (2kg).
- Big plastic bags (5kg, 15kg).
- Pens, papers for sample cards.
- Forms (Survey, DCP, traffic)
- Bulk sample jute bags.
- The map of road location

Low Volume Rural Road Standards and Specifications: Part III

Application of LVRR Standards and Specifications

APPENDICES

G: Pavement Design Issues

APPENDIX G: PAVEMENT DESIGN ISSUES

G1 Objective

This Appendix provides some background to the LVRR pavement design matrices presented in Part II and elaborated in Part III of the LVVR Standards and Specifications.

G2 Gravel Wearing Course Design Approach

As noted in Section 4.2 of the main document, the structural design of gravel roads has been based on the work carried out by the research station of the United States Army Corps of Engineers (USACE). The design procedure in their research consists of five steps,

a) Defining the class of road based on overall traffic volume,

b) Deciding on the category of traffic that will use the road based on traffic composition i.e. the types of vehicles, their weights and their percentage in the traffic stream,

c) Combining (a) and (b) into a design ‘index’,

d) Estimating the subgrade strength

e) Using (c) and (d) in a design chart that determines the gravel thickness directly

The class of road used in the USACE research is defined in Table G1.

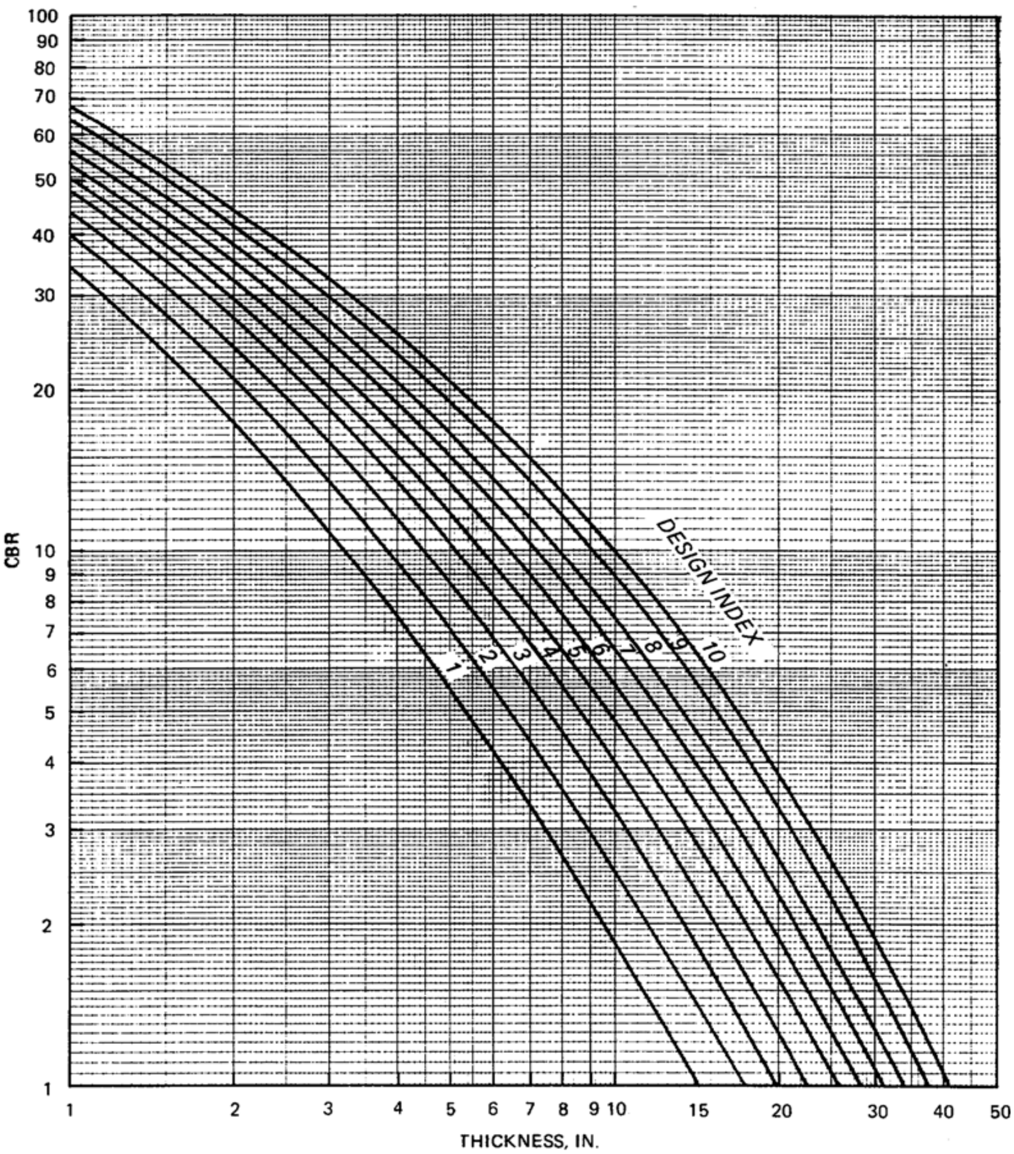
Table G1, USACE Road Classes

Road Class	AADT
A	10,000
B	8,400-10,000
C	6,300-8,400
D	2,100-6,300
E	210-2,100
F	70-210
G	< 70

For Lao the LVRRs fall into classes F and G only.

The USACE traffic categories based on composition are divided into three Groups, but more importantly, also into four categories as shown in Table G2. Finally the design ‘index’ is selected from Table G3 and the thickness from Figure G1.

Figure G1, USACE Design Chart



DESIGN CURVES FOR
GRAVEL SURFACED ROADS

Table G2, USACE Traffic Categories

Traffic Group	Category	Description
1		Cars and pick-ups
2		2- axled trucks
3		3, 4 and 5-axled trucks
	I	Mainly Group 1. Less than 1% Group 2
	II	Mainly Group 1. Less than 10% Group 2
	III	As much as 15% Group 2 and <1% Group 3
	IV	As much as 25% Groups 2 and 3 but < 10% Group 3
	IVA	> 25% Groups 2 and 3 or >10% Group 3

Table G3 USACE Design Index

Road Class	Category I	Category II	Category III	Category IV
A	3	4	5	6
B	3	4	5	6
C	3	4	4	6
D	2	3	4	5
E	1	2	3	4
F	1	1	2	3
G	1	1	1	2

The traffic categories representing the traffic composition on the rural roads in Lao are categories I, II and III. The basic design indices are therefore '1' and '2'. The resulting thicknesses are shown in Table G4. If the thicknesses fall below these levels then the subgrade will deform and more extensive deterioration will occur.

Table G4, Gravel road minimum thicknesses

Subgrade CBR	Index 1	Index 2
2	240	300
3	190	230
4	155	190
5	135	165
6	115	145
7	105	130
8	100	120
9	100	115
10	100	110
>12	100	100

The thicknesses in Table G4 are the basis, together with an additional “wearing allowance’’, for the LVRR recommended unsealed gravel thicknesses in Part II of LVRR Standards and Specifications.

G3 Gravel Wearing Course (GWC) Loss in Service

SEACAP regional research has indicated the variable levels of in-service gravel loss that are likely to be experienced in Lao. This loss has to be made-up by appropriate regravelling during the life of an unsealed road if the minimum wearing course thickness is to be maintained.

As discussed in Section 4.2 of the main text, a standard additional of 100mm of wearing course has been allowed for over and above the minimum required thickness. The amount and frequency of required regravelling is dependant on the rate of gravel erosion and Table G5 presents a summary potential gravel loss based on SEACAP research in Vietnam (Cook and Petts, 2005).

When the residual thickness state of the gravel road is reached, it will then very rapidly deteriorate both at the surface by punching into the capping layer and at the subgrade. Therefore, if the anticipated gravel loss is unlikely to be matched by appropriate regravelling, then consideration should be given to an initial thickness of construction greater than the minimum recommendation of 200mm.

While it is expected that rates of gravel loss in Lao will be similar to the Vietnam experience, Table G5, it should be noted that an additional gravel loss may arise from the regional factor if marginal materials are used in the GWC.

Table G5, LVRR Gravel Loss matrix

Terrain Region	**River plain Subject to flood**	**River Plain Minimal flood**	**Flat**	**Rolling small hills**	**Hilly and mountainous**
1. Basic Gravel Loss (mm/year)	40	25	30	20	35
2. Key Regional Factor **Adjustment to Basic Loss for Regional Factor**	Marginal material Add 15mm/year	Marginal material add 5 mm/year	Marginal material add 10 mm/year	Gradient 2-4%: add 5 mm/year 4-6%: add10 mm/year Gradient above 6% not recommended	Sheet erosion (See Note 1) A: add 5mm/year B: add 15 mm/year C: add 30 mm/year
Note 1. Sheet erosion	A = Gradient <2% subject to minor sheet flooding		Sheet flooding means that water covers the road surface due to flooding from surrounding ground and not just the rainwater that falls directly on the road surface.		
	B = Gradient 2-4% subject to regular sheet flooding				
	C = Gradient >4% subject to regular sheet flooding				
3. Additional loss of +15% for Traffic Group B					

G4 Macadam Definitions

SEACAP research has indicated some regional variability in the definitions of Water Bound Macadam (WBM) and Dry Bound Macadam (DBM). The following are the definitions relevant to the SEACAP 3 LVRR documentation:

Dry Bound Macadam: Comprises essentially a skeleton of single sized angular stone with voids in-filled with a dry cohesionless fine aggregate. The voids are filled to achieve a dense, stable matrix through the use of vibratory compacting plant with little or no use of water.

Water Bound Macadam: Internationally the term "waterbound macadam" implies a layer constructed with similar materials to dry bound macadam with, in this case , the fine aggregate being washed in and compacted by steel drum roller. In some regional projects, however, "water bound macadam" is specified as comprising a single sized angular stone skeleton with voids being in-filled by a series of varying single sized stone aggregate placements, with compaction by steel drum roller aided by the addition of water. For SEACAP 3 LVRR purposes the international definition applies.

G5 Bitumen Emulsion Seals

The use of bitumen emulsion sealed surface options in comparison with hot bitumen has been a key aspect of programmes parallel to SEACAP 3 in Cambodia and Vietnam. They concentrated on the trialling of bitumen emulsions seals as an alternative to the use of hot bitumen for a number of reasons:

- Application is more suitable for labour oriented methods because of low health and safety risks
- Suitable for commune based maintenance operations
- Better site control on small rural contracts on application compared with hot bitumen

It is appreciated however that currently there are issues of bitumen emulsion availability in Lao and for that reason the LVRR specifications have concentrated on hot bitumen seals. Nevertheless there are significant environmental, construction and maintenance advantages in using bitumen emulsion when it becomes more generally available in Lao.