MINISTRY OF PUBLIC WORKS AND TRANSPORT

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

Technical Paper 1
Background Review to Low Volume Rural Road Standards for Lao PDR

SEACAP 03.01

UNPUBLISHED PROJECT REPORT

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Technical Paper 1
Background Review to Low Volume Rural Road Standards for Lao PDR

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CONTENTS

ABBREVIATIONS & ACRONYMS

ACCESS	Microsoft database software
ADT	Average Daily Traffic
ASEAN	Association of South East Asian Nations
BRC	Bamboo Reinforced Concrete
CAFEO	Conference of ASEAN Federation of Engineering Organisations
CBR	California Bearing Ratio
CNCTP	Cambodia National Community of Transport Practitioners
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
EDCs	Economically emerging and Developing Countries
ENS	Engineered Natural Surface
esa	equivalent standard axles
EXCEL	Microsoft spreadsheet software
FHWA	Federal Highways Association (US)
FM	Fines Modulus
FWD	Falling Weight Deflectometer
GMSARN	Greater Mekong Sub-region Academic and Research Network
gTKP	global Transport Knowledge Partnership
HDM4	Highway Development and Management Model
HQ	Headquarters
IFG	International Focus Group
IFRTD	International Forum for Rural Transport Development
ILO	International Labour Organisation
IRF	International Road Federation
IRI	International Roughness Index
ITS	Indirect Tensile Strength
Km	kilometre
LCS	Low Cost Surfacing
LRD	Local Roads Division (DoR)

m	metre(s)
MCTPC	Ministry of Communication Transport and Construction
mm	Millimetre(s)
MERLIN	**M**achine for **E**valuating **R**oughness using **L**ow-cost **IN**strumentation
MPa	Mega pascals
NUL	National University of Laos
OM	Operations Manual
ORN	Overseas Road Note
PCU	Passenger Car Unit
Pen Mac	Penetration Macadam
PIARC	World Road Association
PTD	Planning and Technical Division (DoR)
QA	Quality Assurance
RED	Roads Economic Decision Model
Ref.	Reference
RRGAP	Rural Road Gravel Assessment Programme (Vietnam)
RRSR	Rural Road Surfacing Research (Vietnam)
RRST	Rural Road Surfacing Trials (Vietnam)
RTU	Rural Transport Unit
RT1	Rural Transport 1st Project, Vietnam
RT2	Rural Transport 2nd Project, Vietnam
RT3	Rural Transport 3rd Project, Vietnam
SBST	Single Bituminous Surface Treatment
SDC	Swiss Development Cooperation
SEACAP	South East Asia Community Access Programme
SIDA	Swedish International Developments Cooperation Agency
SOE	State Owned Enterprise
TRL	Transport Research Laboratory
UCS	Unconfined Compression Strength
UK	United Kingdom
UNOPS	United Nations Office for Project Services
VN	Vietnam
VOCs	Vehicle Operating Costs
VPD	Vehicles per day
WAN	Wide Area Network
WBM	Water Bound Macadam
WLC	Whole Life Costs

Executive Summary

Introduction

SEACAP 3 will contribute to the overall SEACAP goals of sustaining poverty alleviation through the development and mainstreaming of local resource-based standards for Low Volume Rural Roads (LVRRs). This will allow current regionally available rural road design and maintenance standards and guidelines to be improved for the specific circumstances of Lao PDR and permit more efficient and optimal use of the limited financial and physical resources available for the sector.

The SEACAP 3project seeks to achieve three key outcomes:

- Mainstream appropriate local road standards and specifications into the MCTPC together with an associated initial training programme.
- Develop an affordable and sustainable strategy for attaining the necessary road research capacity.
- Increase the awareness of good practice experience from this project by disseminating the outcomes at the national, sub-regional and international levels.

Documents Reviewed

More than 100 documents have been accessed either in hard copy or in electronic format as part of the process to review both the existing situation in Lao as regards LVRRs and relevant international Standards and Classification; a number of which have been identified as being of key importance to the project.

The Lao PDR Infrastructure Context and Poverty Alleviation

The Government of Lao PDR is engaged in a comprehensive infrastructure development plan encompassing all classes of roads in the country. This development plan has set the provision of villages with access roads by the year 2020 as an important target. The development plan is in line with the long term National Growth and Poverty Eradication Strategy (NGPES), established in 2004, which aims to eradicate mass poverty by 2010.

The Road law

The Road Law for Lao PDR (1999) defines its purpose as being to assure and facilitate traffic all year round between provinces cities and remote areas in order to contribute to the socio-economic development and to support the defence and securities of the country. Six classes of road are defined, namely: National; Provincial; District; Urban; Rural and Specific.

The road law defines the rights and duties of each of the above levels of governance in a hierarchical system. There appear however to be potential sources of conflict or confusion between directives from the MCTPC and directives from the Governors.

The Rural Road Network

The total road network is reported as comprising some 32,600 kms of which some 15,000 are described as District and Community. About half of the national roads, linking major towns and provincial capitals and providing connections to neighboring countries are now paved, with the remainder having gravel or earth surfaces. District and Community (or Rural) roads are essentially all unsealed.

The RTIP report in 2006 assessed that 19% of rural roads provide all year access and that 40% of villages have no access at all. The PRoMMS database of information on "maintainable" roads covers only around 5700km of rural road; which indicates that a further approximately 9,000kms of identified road are deemed to be in a non-maintainable condition.

A Road Maintenance Fund (RMF) has been in operation since 2002 and currently 10% is allocated to "local roads", however it is not expected that the fund will be able to fully cover local roads maintenance within the next 10 years.

Low Volume Road Standards and Classification

The Lao PDR Road Design Manual originally defined seven road design divisions; from Class I to VII based on decreasing traffic volumes (Class I with more than 8,000 vehicles per day to Class VII with less than 50 vehicles per day).

The current Lao Road Design Manual does not, however, address specific issues relating to the design of LVRRs which have been identified during the past 20 years of related research. Key to the success of these innovative solutions produced by this research is the recognition that conventional assumptions regarding road design criteria need to be challenged and that LVRR standards and designs need to support the function that the road is providing as well as recognising the important influences of the road environment on deterioration mechanisms.

LVRR Technical Specifications

Technical specifications and related designs need to be tailored to cater for specific circumstances, which implies that that the straight importation of solutions from standard highway designs manuals is not an appropriate approach. Alternative pavement and surfacing solutions for low-volume roads are now recognised and it is no longer acceptable in the context of sustainability and whole life costing to consider unsealed gravel as a total solution.

The current Lao PDR Road Design Manual is not tailored to the specific needs of LVRRs although it does offer some relaxation of pavement design standards for low volume roads. The only pavement specification include specifically for LVRRs is a gravel wearing course.

There is therefore a need for a range of appropriate LVRR specifications suitable for Lao PDR that can be handled by small contractors and local consultants with much more emphasis on engineering judgment and a simplified design process.

Lao PDR Road Environment Factors

The road environment factors likely to influence the construction and sustainable performance of LVRRs in Lao have been reviewed, with the key points being as follows:

Materials:. Principal material types are rock aggregate; alluvial sand and gravel; hill gravel and laterite gravel.

Climate: The Lao climate is essentially seasonally wet tropical with an annual rainfall of between 1500 and 3000mm occurring principally between May and October.

Terrain: The topography of Lao People's Democratic Republic can be related to the geological units with much of the terrain in the northern and eastern part of the country being mountainous, with lower lying more level ground and alluvial plains in the south and west.

Sub-Grade: The climate data shows a high rainfall environment where sub-grade conditions can be expected to be at least seasonally wet. It follows that the measurements to assess the strength of the sub-grade in the laboratory for use in design procedures should be undertaken in the soaked condition.

Traffic: An examination of the PRoMMs traffic information for maintainable rural roads shows them to be carrying either light to moderate traffic; that is up to 50 vehicles per day with up to 4 heavy vehicles, or up to 150 vehicles per day with 10 heavy vehicles per day.

Contracting Capacity: According to the register of contractors in the year 2005, 147 contracting firms are registered in Lao PDR, of which 140 are registered for road works. The information indicates that contractors would seem to be generally suitably equipped for routine works such as the construction of gravel wearing course road surfaces.

Maintenance Regime: The village based schemes for routine maintenance are in place in some provinces, they do however have some potential problems. These schemes rarely if ever include the vital capacity to maintain cross-fall on unsealed gravel roads and there remain some doubts as to their long term sustainability without external project support.

Knowledge Gaps

The cost-effective application of appropriate and sustainable standards and specifications for LVRRs requires that they be based firmly on local conditions. Local resource and task based roads strategy requires local knowledge. The review of existing documents under Module 1 of SEACAP 3, whilst being to access useful sources of local information has identified significant knowledge gaps.

The Way Forward: General

The key outputs from "Standards and Specification" component of SEACAP 3 can be summarised as follows:

1. A proposed LVRR Classification
2. A set of proposed Technical Specifications compatible with (1)
3. A matrix of pavement and surfacing options related to designated function
4. A guideline document associated with (1) and (2) above.

The Way Forward: Design Classification

There clearly has to be an upper limit to what roads may be included within the LVRR approach to rural road design and construction. In terms of current terminology in Lao it is proposed that the upper limit for the LVRR envelope would include Basic Access roads, with the following characteristics:

1. Less than 50 motorised VPD,
2. An ADT of 150-200 , all traffic included and factored
3. Low risk of vehicles exceeding the axle load limits (suggested as 4-6 Tonne)
4. A design life involving less then 250,00 esa.

The Way Forward: Standard Specifications

As a first step the project is assessing a limited number of pavement types covering the range of anticipated road classifications and considering the specification, cost and design options for these in relation to standard Lao environments.

The use of an Enhanced Section (Spot Improvement) approach utilising the above types, possibly together with an Engineered Natural Surface (ENS) option, will also be evaluated.

The Way Forward: Pavement Selection and Design

The proposed approach with respect to pavement guidance is currently being considered as two-phased. The first phase would be to identify pavement or surfacing options in relation to a number of standard Lao road environments.

The second phase involves the detailed design of the identified option or options. Key inputs at this stage of detailing pavement types would be; “Standard” Vehicles; Road function; Traffic and sub-grade.

It is proposed that the issue of LVRR structures be dealt with by considering the suitability of the DfID-funded draft Low Cost Structure Manual that is currently being reviewed as part of SEACAAP 19 in Cambodia. SEACAP3 will highlight the essential role of drainage and associated pavement crossfall in the Guideline Document. Standard detail from exiting specifications will be recommended.

A spreadsheet-based cost model was set up under SEACAP 1 in Vietnam and some initial work has been undertaken by putting in Lao materials costs. Some further work will be undertaken on the standard LVRR designs within the option matrix.

SEACAP 3.01 Technical Paper 1

1 Introduction

1.1 Project Summary

The SEACAP 3 project is part of the wider South East Asia Community Access Programme (SEACAP), whose strategic theme is 'livelihoods of poor and vulnerable people in SE Asia - improving sustainability'. SEACAP builds on existing knowledge, but also provides a research resource for filling gaps in knowledge, particularly in the local environment. Mainstreaming ensures that these solutions are accepted, adopted and applied on a large scale. This involves a process of dissemination through participatory workshops, guideline documents, demonstrations, training and implementation.

SEACAP 3 will contribute to this overall objective through the development and mainstreaming of local resource-based standards for low volume rural roads. This will allow current regionally available rural road design and maintenance standards and guidelines to be improved for the specific circumstances of Lao PDR and permit more efficient and optimal use of the limited financial and physical resources available for the sector.

Previous research has indicated that Low Volume Rural Roads (LVRRs) tend to respond to the dominance of a range of factors, collectively know as the "road environment", that together describe the matrix of road environment impacts that need to be addressed by design response factors such as pavement type and strength, road geometry, and earthwork and drainage arrangements. The road performance is a direct function of the road environment and its interaction with an appropriate design. For low volume rural roads it is now believed that the relative influence of traffic on road deterioration is much less than that for other roads. One of the implications from this is that appropriate Standards and Specification need to be specially adopted for LVRR regimes.

SEACAP work in Vietnam has highlighted an apparent mis-match between the pavement options currently being used, their road environment, and many of the materials being used to construct them. Given the potential for overlap of road environments between Lao PDR and Vietnam it is likely that a similar mis-match situation occurs in within the LVRR sector in Lao, particularly if a gravel wearing course is the predominant option, hence the importance of the current SEACAP 17 project and the links to similar trials in Vietnam and Cambodia.

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

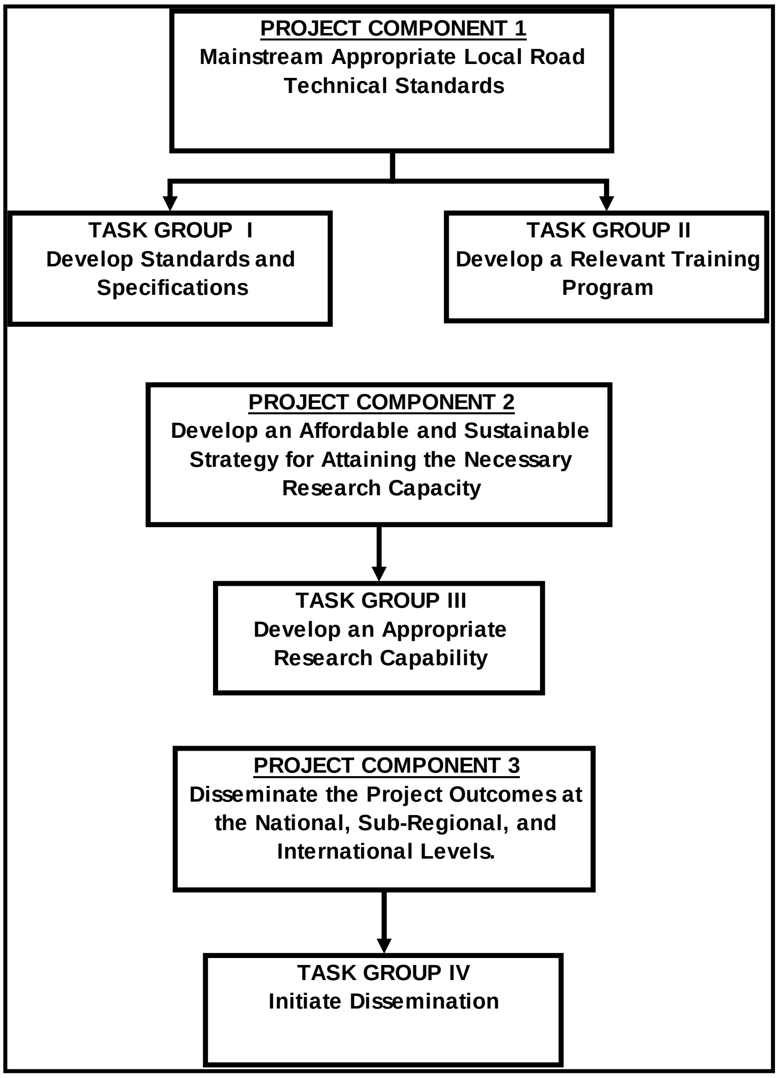
The SEACAP 3 project seeks to achieve three key outcomes:

- Mainstream appropriate local road standards and specifications into the MPWT together with an associated initial training programme.
- Develop an affordable and sustainable strategy for attaining the necessary road research capacity.

- Increase the awareness of good practice experience from this project by disseminating the outcomes at the national, sub-regional and international levels.

These project components have been assembled into Modules with a number of Task Groups as shown in Figure 1

Figure 1, SEACAP 3 Modules



1.2 Document Aims

This paper is an updated version of the working Review Document drafted and use by the SEACAP 3 team during April-July 2007 and presented at a Progress Workshop on 26th July 2007 . Its aims are derived form the SEACAP 3 Terms of Reference (ToR) which call for a document that synthesizes the Module 1 review and assessment phase of the project. The objectives of this report are therefore to provide a concise summary of the outcomes from this work.

1.3 Content

In line with the general requirements of the ToR and the associated Technical Proposal this document contains the following key elements:

- A summary of the current status of local road technical standards and specifications including their administrative framework
- A summary of the general local road environments
- Definition of knowledge acquisition needs
- A summary of the proposed way forward for the project

Comments on research and training are included in separate Technical Papers 3 and 4 respectively.

2 Documents Reviewed

2.1 Scope of Review

More than 100 documents have been accessed either in hard copy or in electronic format as part of the process to review both the existing situation in Lao as regards LVRRs and relevant international Standards and Classification.

The main general categories of document accessed were :

Infrastructure background (Lao)

Road Administration (Lao)

Rural road environment data (Lao)

Road Standards and Classifications (general)

Rural road design (general)

Rural pavement specifications (general)

Project specific documents (Lao)

2.2 Key Technical Documents

A number of documents were identified as being of key strategic importance in the review of LVRRs particularly with regard to the adoption standards and specification appropriate to the Lao environment. These were:

- Lao PDR Road Design Manual, which provides the current road standards in Lao and contains detailed methodology for road design in Lao together with relevant background information
- MCTPC, (2003), Specification for Local Roads (District and Rural Roads): provides a good starting point the SEACAP 3 LVRR standards
- SEACAP 1 Final Report (3 Volumes), contains draft specifications for a range of LVRR options as well as recommendations on cost modelling and approaches to design selection
- World Bank Guidelines on Basic Access: presents clear recommendations on basic access standards and general design approaches
- ARRB Sealed Local Roads Manual and ARRB Unsealed Roads Manual; together these documents provide a substantial amount of information applicable to LVRRs in terms of both standards and approaches to design and specification of materials for road pavements
- SEACAP 17: Module 1 Report: contains details of trial road specifications and designs as well as a useful summary of the Lao rural road sector.

In addition to the above documents the LSRP-2 PRoMMS database provides a valuable overview of the Lao rural road network. The ProMMS is a tool for Road inventory and Maintenance Planning for local roads. Data tables are available which provide,

1. Administrative data, road referencing system. Province, District, Road class, Road number, Link number, section number, start and end point of the road and road length.
2. Technical data such as road width, surface type, last year surfaced, traffic, Topozone, Structure type and structure size

3. Condition data surface condition, drainage condition shoulder condition for paved road, structure condition, accessibility, access constraint, road roughness for paved roads.
4. Road environment in population and social and political importance.

3 The Lao PDR Infrastructure Context

3.1 General

Lao PDR is administered from national government through provincial, district and village authorities. There are 18 Provinces, 129 Districts and approximately 11,000 villages.

Some 80% of the population live in rural areas, where less than two thirds of the villages benefit from all-year motorable access.

3.2 National Infrastructure Strategy

The government is engaged in a comprehensive infrastructure development plan encompassing all classes of roads in the country. It has set the provision of villages with access roads by the year 2020 as an important target with in this plan. This provision is seen as a major positive impact on the development of the country as a whole.

3.3 Poverty Alleviation

The GoL has a long term National Growth and Poverty Eradication Strategy (NGPES), established in 2004, which aims to eradicate mass poverty by 2010. There is expected to be an increasing shift of resources towards the NGPES priority of strengthening the provincial-district-community road network to all-weather access standard.

Seventy two districts are identified in the NGPES, the poorest 47 being identified for priority investments in the 2005-10 period. The promotion of Kum Ban planning is a priority for the NGPES; each Kum Ban should have all-year access among the constituent villages and to the district centre.

Warr (2007)[1] in an important paper clearly states that reducing transport costs through rural road improvement generates significant reductions in poverty incidence by improving the income earning opportunities of rural people and by reducing the costs of the goods they consume. A feature of his results was that when no vehicle access areas were provided with dry season access roads (earth and gravel), the reduction in poverty incidence is about 17 times the reduction that occurs when dry season access only roads are upgraded to all weather access roads. The ratio of the effect on GDP is about 6. Reducing transport costs for households without road access is highly pro-poor.

Whilst Warr notes that the results do not demonstrate that road improvement should be shifted away from upgrading dry season access roads to providing road access to villages currently lacking it, but rather that both forms of road improvement are important and both contribute to overall poverty reduction. And importantly he states that ".. the costs of road building in the two cases need to be taken into account in determining the most appropriate road building strategy and that it is likely that the cost per kilometer of providing road access where there is currently none is bound to be significantly higher than upgrading existing roads".

Warr concludes that results confirm that "there is considerable scope for reducing poverty incidence in Laos by reducing rural transport costs through improving the quality of rural roads".

[1] Warr P, 2007, Road Improvement and Poverty Reduction in Laos, Australian National University
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3.4 Road Law

The Road Law for Lao PDR (1999) defines its purpose as being to assure and facilitate traffic all year round between provinces cities and remote areas in order to contribute importantly to the socio-economic development and to support the defence and securities of the country to link the national economy to the other regional countries.

Six classes of road are defined, namely:

1. **National Road**: A road of strategic importance for the overall interest of national and international economy and includes:
    a. Road connecting the national capital to the provincial and special zone capital
    b. Road to international borders
    c. Road of importance with regard to socio-economic and national defence security purpose.

2. **Provincial Road**. Prefecture and Special Zone Road; a road of importance for the economic, political socio-cultural development and for the national defence and security purposes at the provincial level including:
    a. Inter-provincial road
    b. Road connecting a provincial capital to district centres, river ports, tourist and importance historic sites of the province.

3. **District Road**: a road of importance for the economic political socio-economic development and for the national defence and security purposes at the district level including:
    a. Inter-district road
    b. Road connecting the district centre to the village, river ports tourist and historic sites and special economic zone of the district.

4. **Urban Road** a road used by traffic within urban areas
5. **Rural Road**: a road connecting villages and to various production and service centres of the village
6. **Specific Road**: a road used specifically for the production and service of a sector of activities the national defence and security and the forest **preservation** zone.

The formal organization responsible for monitoring public roads comprises

1. The Ministry of Public Works and Transport (MPWT), formerly known as the Ministry of Communication, Transport, Post and Construction (MCTPC)
2. The Departments of Public Works and Transport (DPWT) at Province level
3. The Offices of Public Works and Transport (OPWT) at District or Municipality level
4. The Village Authorities.

Thus a hierarchical system of governance appears to exist exists though the Ministry to DPWTs, OPWTs and Village Authorities. However a recent report commissioned by the ADB noted that in fact the DPWT Directors report also to Provincial Governors and that there were a potential sources of conflict or confusion between directives from the MPWT and directives from the Governors; particularly as funding to the DPWT comes from provincial sources.

The road law further defines the rights and duties as each level of governance; these are summarised in Table 1

Table 1 Right and Duties of Governance Levels

Authority	Duties
MPWT	1. Make strategic plan and long, medium and short term plans related to the development of the road network; 2. Set up the organization, management, control, planning, survey, design, construction, maintenance, repair and use procedure of the road throughout the country; 3. Elaborate the technical specifications; 4. Elaborate the policy and road construction cost, maintenance to be submitted to the Government for consideration; 5. Record the statistical data of public roads; 6. Maintain International relation and cooperation for the development of the road network; 7. Execute the rights and duties related to the road activities as delegated by the Government.
DPWT	1. Develop the strategic plan and the road network development plan for which the DPWT is responsible; 2. Issue the authorization to follow up the activities of Road Construction Companies and the Consulting Engineering Companies operating within the limit of the province; 3. Record statistical data and regularly submit reports on the situation of roads under the DPWT's responsibility to the Ministry of Public Works and Transport; 4. Execute the rights and duties related to the road activities as delegated by the Ministry.
OPWT	1. Support and follow up the construction, maintenance, repair of roads under its responsibility; 2. Manage and assure the maintenance of the roads within the limit of the district or Municipality under its responsibilities; 3. Record statistical data and regularly submit reports on the situation of roads under its responsibilities to the Department of Public Works and Transport, of the a community level province, Prefecture and Special Zone; 4. Execute the right and duties as delegated as by the Department of Public Works and Transport, of the province, Prefecture and Special Zone,
Village	1. Regularly submit reports on the situation of the roads within the limit of the village and under its responsibilities to the Office of Public Works and Transport of the District or Municipality; 2. Incite the population to contribute to the construction, maintenance and repair of roads within the limit of the village; 3. Coordinate with neighbouring villages for sharing out responsibilities for road maintenance; 4. Execute the right and duties as delegated as by office of Public Works and Transport of the district or municipality.

3.5 The General Road Network

The road network comprises some 32,600 kms and Lao has one of the lowest road densities of 0.14 km pre square kilometre. The network is broken down as follows

National 7107

Provincial 7214

Urban	1,304
District	4986
Community	15411

Of these about 4,823kms are paved. Much of the community road network consists of only tracks navigable in the dry season and may not provide access to 4 wheeled vehicles.

Motorized vehicles are the dominant mode of transport in Laos, carrying 91 per cent of total freight ton-kilometers and 95 per cent of total passenger-kilometers. The road system in Laos is mostly in poor condition. At present, less than 20 percent of this total network is paved. Only about half of the national road network is now paved, with the remainder having gravel or earth surfaces.

With assistance form World Bank, ADB, SIDA and others a concerted effort is being made to restore or upgrade roads to a "maintainable" standard and generate the funds to maintain them thereafter.

3.6 Rural Roads

The paper by Warr noted three types of road access within rural areas:

> No vehicular access; This means that the pathways through which the village is normally reached cannot accommodate conventional motorized vehicles. This does not necessarily mean that the village is completely isolated from commodity trade. It may still be able to accommodate some forms of transport. These include human-powered vehicles such as shoulder poles, backpack frames, handcarts and bicycles, animal-powered devices such as carts and sledges and possibly two-wheeled motorized vehicles such as motorcycles.
>
> Dry season only access; Roads consist predominantly of unpaved roads that are accessible to conventional motorized vehicles during the dry season but not necessarily throughout the year. During the wet season, such roads will at times be impassable. At other times, vehicles will be required to use alternative routes that may facilitate passage but would result in higher transport costs due to a change in travel distance, road roughness, and speed. This category includes most, but not all, earth and gravel road surfaces.
>
> All weather access. Finally, all weather access roads can be used by conventional motorized vehicles during the dry and wet seasons. In other words, unlike dry season access roads, these roads would not be subject to frequent closure as a result of flooding during the wet season. This covers almost all paved roads.

In 2002-03 almost one third of all rural households still lived in villages without roads that support motorized vehicle access.

The RTIP report (2006)[2] assesses that 19% of rural roads provide all year access; this leaves around 9,200km of rural road need an upgrade. It also estimates that 40% of villages have no access at all and at an average of 3km per road this would mean around 11,000km of additional basic access road construction.

The PRoMMS database also yielded useful information on rural roads and their condition. It should be noted however that this project dealt only with what were deemed to "maintainable" roads. It covered a wide range of road types that are very similar to but do not follow the national administrative classes exactly. Six classes are given where classes 1, 2 and 3 are National, Provincial, and District roads, and thus follow the hierarchy. Class 4 is for urban roads. Class 5 is rural roads where these are defined as "a road connecting village to village and to various production areas and service facilities for the villages" As such they appear to include Kum Ban satellite type roads, but do not, it is anticipated, include roads that form links from one part of the network to

[2] Lan Xang International, Development of rural transport infrastructure policy for the Lao PDR. Final Report

another. Thus they terminate and they would not carry through traffic. This is an important consideration as through roads would attract diverted traffic.

Links in the database are usually up to 40km, but terminate at Provincial and District boundaries (a new link is declared if the road continues). Links are split when road width, surface type traffic group or topographic zone changes. Sections are not usually longer than 5km and roads shorter than 2km are not split into sections. Table 2 shows the number of sections of road within each class in the PRoMMS database. It is emphasised that the database contains information only on maintainable roads. It can be deduced that here are a further 9,000kms of road which are not maintainable and are not in the database.

Table 2 Road Classes of Road Sections by Province

Province	Number of sections in road classes:			
	Provincial	District	Rural	Total
Vientiane Capital city	52	88	68	208
Bokeo	36	5	41	82
Luangnamtha	38	2	38	78
Phongsali	37	11	62	110
Oudomsay	45	71	18	134
Huaphan	44	37	26	107
Xiengkhuang	33	0	98	131
Luangprabang	120	39	52	211
Sayabuly	152	37	25	214
Vientiane	161	89	128	378
Bolikhamsay	48	57	53	158
Khammuan	67	43	121	231
Savannakhet	139	37	46	222
Saravan	18	51	129	198
Champasak	67	59	145	271
Sekong	12	6	63	81
Attapeu	16	2	34	52
Total sections	1,085	634	1,147	2,866
Representing Kms:	5,425	3,170	5,735	14,330
Note: correct if each section is 5kms				

Table 3 summarises information extracted from the database and illustrates some of the main characteristics of the rural roads. Key points to emerge from an examination of the data are

1. Road formation widths are predominantly 4-5m (single lane) with some variation to 6m in the south and one mountainous province (Huaphan) having 30% or roads at 3m.
2. Drainage is recorded as fair to poor almost throughout the rural road network. With variable ditch depth (fair is more than 200mm and poor is less than 200mm), erosion is commonly noted..
3. Surfacing is predominantly unsealed gravel, with a minority being earth and only very small percentage being paved; for example the Provinces of Xiengkhuang, Vientiane and Attepue have some sections with a paved surface, probably a surface dressing.
4. The overall surface condition is generally fair to poor in these maintainable sections. Fair condition considers that some water may be retained in ruts and potholes (the latter are less than 3 per kilometre), some corrugated areas and some erosion. Poor condition records that the camber is too low at less than 2% there is significant retention of water on the road and a poor riding comfort.

Table 3 Some Characteristics of Rural Roads (PRoMMs, 2006)

		Rural road widths				Drainage condition				Surface type				Surface condition			
Province	Rural	Highest		Next		Highest		Next		Highest		Next		Highest		Next	
	Links	m	%	m	%		%		%		%		%		%		%
Vientiane Capital city	68	5	50	4	22	Poor	63	Fair	32	Gravel	91	Earth	7	Poor	65	Fair	31
Bokeo	41	4	56	5	24	Fair	71	Poor	12	Gravel	73	Earth	27	Fair	76	Good/Poor	24
Luangnamtha	38	4	55	5	24	Fair	50	Poor	40	Gravel	100			Fair	61	Poor	37
Phongsali	62	3	76	4	13	Fair	53	Poor	37	Gravel	84	Earth	16	Fair	53	Poor	45
Oudomsay	18	4	83	5	17	Fair	56	Good	44	Gravel	100			Good	56	Fair	44
Huaphan	26	4	58	3	31	Poor	46	Fair	27	Gravel	92	Earth	8	Fair	50	Poor	31
Xiengkhuang	98	4	64	5	26	Good/Poor	52	Fair/Bad	48	Gravel	94	Earth/Paved	6	Poor	31	Fair	26
Luangprabang	52	5	58	4	19	Fair	58	Poor	29	Gravel	85	Earth	15	Fair	77	Bad	12
Sayabuly	25	5	52	4	28	Poor	72	Bad	28	Gravel	65	Earth	35	Poor	80	Bad	16
Vientiane	128	5	72	4	26	Poor	42	Fair	33	Gravel	87	Earth/Paved	13	Poor	40	Fair	39
Bolikhamsay	53	4	81	5	11	Poor	64	Fair	21	Gravel	100			Poor	72	Fair	13
Khammuan	121	4	50	5	41	Fair	76	Poor	12	Gravel	93	Earth	7	Fair	69	Poor	21
Savannakhet	46	5	52	6	35	Poor	46	Fair	43	Gravel	93	Earth	7	Poor	59	Fair	33
Saravan	129	4	49	5	25	Bad	44	Poor	33	Gravel	84	Earth	16	Poor	50	Fair	25
Champasak	145	5	45	4	30	Poor	36	Fair	34	Gravel	98	Paved	2	Fair	54	Good	27
Sekong	63	5	32	5	32	Poor	62	Fair	37	Gravel	79	Earth	21	Poor	52	Fair	44
Attapeu	34	5	53	6	21	Poor	75	Bad	16	Gravel	93	Earth/Paved	7	Poor	71	Fair	24
Total sections	1,147																
Representing Kms:	5,735																

3.7 Maintenance

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. The principle is that road users should pay the full costs of maintaining the national road network and progressively contribute to maintaining all roads; currently 10% is allocated to “local roads”. It is not expected that the fund will be able to fully cover local roads 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. It is understood, however, that current Ministry of Finance regulations do not allow for direct contracting with village communities and this is an issue requiring urgent attention. It appears however that there is a DPWT contract document which has been prepared for use between DPWT and Village Maintenance Committees (VMC) and that the village community elects the members of the VMC who then undertake to perform routine maintenance activities.

A number of maintenance variations on a Community Road Model (CRM) have been introduced by SIDA, KfW[3] and others in a number of provinces. Under these schemes the communities are asked to contribute to the routine maintenance of their local roads through organizations such as Village Maintenance Committees (VMCs) . This contribution is usually in the form of providing labour whilst supporting projects provide training, tools and materials. In some more prosperous areas the villagers may opt to pay a cash contribution to employ local maintenance workers.

Village Road Maintenance Committees (VMC) with representatives from the villages along a road is a model proposed by the LRD as a forum for coordination and agreements on the maintenance of the road in question. It is essential to establish this organisational level as otherwise the district OPWT would have to handle too many villages. The delegation of decisions to the VMC will also mean that road issues will be handled closer to the villagers.

Village Road Maintenance Units (VMU) are being established, in some provinces at least within the Village authorities, with the task of informing and discussing with villagers the importance of access to the main road network and to organise maintenance and construction of roads.

All these maintenance schemes, however, are concerned only with routine maintenance and do not address the issues of road shape (cross-fall) or re surfacing, which are fundamental to sustaining un-sealed road networks.

[3] KfW Workshop, March 2007

4 Low Volume Road Standards and Classification

4.1 The Low Volume Rural Road Sector

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

Key to the success of these innovative solutions is recognition that conventional assumptions regarding road design criteria need to be challenged and that the concept of an appropriate or environmentally optimised design, approach provides a way forward. Low volume road standards and specifications need to support the function that the road is providing as well as recognising the important influences of the deterioration mechanisms.

Key issues which define the need for a different approach to LVRR design and construction are:

Materials: 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 LVRRs. 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

Costs: The consideration of all present and expected future costs involved with an investment in rural road infrastructure is an important issue in the consideration of LVRR designs, particularly so when assessing unsealed versus sealed pavement options. 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.

Maintenance: Appropriate maintenance is a fundamental and frequently neglected issue relating to the sustainability of rural roads, particularly unsealed options. Therefore before coming to a final decision on the selection of a pavement or surface type, it is essential to pragmatically assess whether or not there is a likelihood of maintenance being resourced (financially and physically).

Safety: Conflicts between motorised vehicles and pedestrians or bicycles are a major safety problem on the type of mixed traffic rural roads that occur in Laos where separation is generally not economically possible. There may actually be a good argument on safety grounds for keeping traffic slow (30km/hr) in mixed traffic environments rather than seeking higher design speeds. The use of wider shoulders in standards designs is suggested as a possibility. ORN 5 highlights bus-stop areas as particular danger areas

4.2 Current Lao PDR Situation

4.2.1 Road Classification

The current Lao PDR Road Classifications are contained within the Lao Road Design Manual, (MCTPC 1999). Seven road design classes were specified in the original manual, from Class I to VII based on decreasing traffic volumes from Class I with more than 8,000 vehicles per day to Class VII with less than 50 vehicles per day.

The Road Classifications were amended in subsequent proposals (MCTPC, 2003) for several reasons in recognition of (i) the experience gained in practical works, (ii) the fact that many of the population live far from each other creating a wide range of small and isolated communities, (iii) the government is bringing development to rural people, and closing the gap of isolation, (iv) the government is trying to bridge rural areas with urban areas where all services are available (v) the current reality in terms of economy and society of Laos which is focused on the alleviation of poverty of the rural regions.

In essence, Class VII was split into two classes VII and VIII for traffic categories 21 to 50 ADT and less than or equal to 20 ADT, respectively. This permits alternative designs more suitable for low volume roads.

The RTIP report (2006) suggests a two-fold division of road based on administration:

1. Community roads maintained by local villages
2. State rural roads maintained by provinces or districts.

This is a purely administrative proposal and is not related to a roads function or task.

The current Lao Road Design Manual does not address specific issues relating to the design of LVRR

In a report in 2004[4] related to the Road Maintenance Programme (RMP) the Authors noted that the 2003 reclassification of roads resulted in a net 14% rise in the length of rural roads at the expense of provincial and district roads. They reported a mismatch between the administration of roads and their function. They recommended a rationalisation of the road classification system.

4.3 Regional and International Examples

4.3.1 SADC –southern Africa

Guidelines for the pavement design of low volume rural roads have been developed for the SADC regions of southern Africa. This document provides a very useful guide to all the considerations faced by the challenges of low volume road development. Being a guideline, it does not prescribe, and is not a specification.

The pavement design guidelines have been produced after extensive research and performance analysis of trial roads and existing pavements. They consider sealed roads with unbound pavement layers. Traffic level down to the lowest realistic ranges of concern to a pavement engineer (0.05million esa's) are considered and the pavement design merges onto ORN31, 4th Edition (1993) pavement designs for traffic levels above 0.5 million esa's.

Relaxation of material quality is permitted especially for dry areas usually by widening the particle size distribution, fines content and plasticity of natural unbound road base materials, and it permits a bearing capacity for the road base as low as CBR 45%,(soaked) for traffic loading levels of 0.1million esa's. This bearing capacity is declared to be suitable for both wet and dry areas, but the design guide emphasises the importance of keeping the pavement moisture content, especially the road base, below saturation level. This is achieved by sealing the shoulders and specifying minimum road widths of about 7 metres to keep the outer wheel track at or lower than the optimum moisture, and by ensuring the minimum height from invert level of the ditch to the crown of the road is at least 0.75metres. Given these dimensions, the actual CBR in-situ is expected to be above the conventionally specified value of CBR 80%. It should also be noted that the strength of the sub-base is set rigidly to CBR30% and no relaxation is permitted.

Unfortunately the climate of Lao is much wetter than that of the SADC region and the simple transference of guidance is not appropriate.

[4] Bray D, & Johnson J, 2004. Transport sector issues review; Final Report to MCTPC.

4.3.2 Australia

The Australian local roads manual presents pavement designs for low traffic roads and includes comprehensive design and construction information. The range of suitability is wide, give that it is for use throughout the varied climates found in Australia. Pavement designs for traffic levels as low as 0.1million esa's are presented.. Pavement design charts are presented which consider the use of variable strengths in the lower layers with a stringent limitation being applied at the road-base level of CBR 80% as it approaches the surface. This approach permits a wider use of materials in the lower layers than is usual, effectively making more use of locally available materials than might otherwise be permitted. Both unbound and cemented pavement types are permitted and there is a useful section on the use of segmental block paving.

4.3.3 Vietnam

The Vietnam rural road sector benefits from a number of documents that give guidance on the design of low volume rural roads, for example Mot 1992[5] and Mot 2006[6]. Some of the definitions and classification lack clarity and there is some conflict and overlap between documents; nevertheless the Vietnam rural documentation is a valuable source of information from a country that shares many road environment characteristics with Vietnam.

4.3.4 India.

Indian Roads Congress 2001 issued uniform guidelines on rural roads which provide geometric standards, pavement standards and other construction practices to achieve planned development of rural roads in India. The manual based on codes, practices and standards prevailing in different the Roads' Departments of various states which have been proved effective and tested by experience

The rural roads manual comprises a complete document for the use of Engineers and Planning Authorities engaged in rural roads planning construction and maintenance including both guidelines and the code of practice with type design, tables, type drawings etc.

Road classification is administration based rather than road function based and such there are only two classes for rural road; Other District Road and Village Road. The road geometric parameters are limited to these two classes depending on the terrain regardless the traffic volume. The design parameters recommended are absolute minimum and they should be applied only where serious restrictions are implies from technical or economical consideration.

The Indian pavement design focuses on the use of the local material and recommends a flexible pavement as a typical option, in particular 20 mm bitumen seal on water bound macadam base.

4.3.5 Summary

Table 5 provides a summary of the key aspects from a representative range of LVRR classifications

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[5] Rural Road Design Standards, 22TCN 210-92, MoT, 1992, Viet Nam.
[6] Design & Construction guidelines of rural & mountainous roads, MoT, 2006, Viet Nam.

List of international LVRR classifications and their key points.

No.	Source	Classification Basis	Traffic Divisions	Terrain	Roadway Width (m)	Design Speed (km/h)	Vertical Gradient %
1	India	1 .Other District Roads (ODR). 2. Village Roads (VR).	Definition	Plain Rolling Mountainous Steep	7.5, 4.75 & 4.35 for ODR. 6.0, 4.0 & 3.75 for VR.	20 to 50 for ODR. 20 to 40 for VR.	3.3 to 8 for both ODR and VR.
2	Vietnam	A & B	By axle Load 6T for A & 2.5T for B	Mountainous Upland Hilly Lowland Deltaic Sandy Coastal	5.0 for A 4.0 for B	25 for A 15 for B	15% for A 20% for B
3	Cambodia	A&B	ADT 201-2000 for A. 0-200 for B.	Flat Rolling Mountainous	5.0 for A 3.5 for B.	50 to 70 for A. 40 to 60 for B.	4 to 15 for A. 6 to 20 for B.
4	World Bank	Basic Access	Less than 50 VPD	Flat Rolling Mountainous	3.5 to 5.0 for Flat 3.0 to 5.0 for Rolling 3.0 to 4.0 for Mountainous	Less than 30 km/h	N/A for Flat 12% for Rolling 12 to 15% for Mountainous
5	Southern Africa Development Community (SADC)	D and E	AADT Less than 200 50-200 for D <50 for E	Flat Rolling Mountainous	8.0 m for D. 6.0 m for E.	70 km/h: flat. 70 km/h: rolling. 50 km/hr mountainous .	N/A

No.	Source	Classification Basis	Traffic Divisions	Terrain	Roadway Width (m)	Design Speed (km/h)	Vertical Gradient %
6	Australia	Minor, Local Access without buses, Local Access with buses and Local Access Industrial.	AADT	N/A	N/A	80 km/h: flat. 70 km/h: rolling. 50 km/h: mountainous .	N/A
7	USA	Rural Major Access Roads, Rural Minor Access Roads, Rural Industrial / Commercial Access Roads, Rural Agricultural Access Roads, Rural Recreational and Scenic Roads and Rural Resource Recovery Roads.	Access function and ADT less than 400.	N/A	5.4 m to 8.0 m depending on the selected speed.	From 20 Km/h to 100 Km/h for all road classification.	Calculate from Equation.
8	Thailand	4 and 5	ADT 300-1,000 for class 4 <300 for class 5	Flat-moderately rolling Rolling or hilly Mountainous	9.0 m for 4 8.0 m for 5	70-90, 55-70 and 40-55 for 4 60-80, 50-60 and 30-50 for 5 (depending on terrain).	4% for flat 8% for rolling and 12% for mountainous.
9	ORN 6	D, E and F	ADT 100-400 for D. 20-100 for E. <20 for F	Level Rolling Mountainous	7.0 for D 6.0 for E 2.5-3.0 for F.	50, 60 and 70 km/h for D 40, 50 and 60 km/h for E . N/A for F. (depends on terrain)	10% for D. 15% for E. 15-20% for F.
10	Lao PDR (Current Standard)	V, VI, VII and VIII	ADT in 20 years. 101-300 for V. 51-100 for VI 21-50 for VII. <20 for VIII.	Flat Rolling Mountainous	6.5-7.0 m for V 6.0-6.5 m for VI 4.5-5.5 m for VII 3.0-4.0 m for VIII	20-60km/h for V 20-60km/h for VI 20-40km/h for VII 15-30km/h for VIII.	8% for 60 km/h 9% for 40km/h 10% for 25 km/h 12% for 15 km/h.

5 Low Volume Road Technical Specifications

5.1 General Requirements

There is an increasing recognition of the need to improve the sustainability of rural network construction by ensuring that the technical specifications are appropriate to the function of the road, the resources available and the complex interactions other road environment factors. Technical specifications and related designs need to be tailored to cater for specific circumstances rather than generalised to cover wider national or even international situations. This approach is likely to mean that the straight importation of solutions from standard highway design manuals is not appropriate

There is also now an appreciation that more attention needs to be paid to assessing the circumstances appropriate for gravel surfacing and the consideration of other options for low volume roads, particularly for rural communities. There has emerged over the last 10 years a proven suite of alternative pavement and surfacing options that can provide appropriate and sustainable solutions for low-volume roads within sub-tropical and tropical regions. It is no longer acceptable in the context of sustainability and whole life costing to consider unsealed gravel as the total solution; particularly in high rainfall; flood prone or mountainous terrain.

There is therefore a need for a range of appropriate LVRR specifications that can be handled by small contractors and local consultants with much more emphasis on engineering judgment and a simplified design process.

5.2 Current Lao PDR Situation

5.2.1 Pavements

The Lao PDR Road Design Manual offers some relaxation of pavement design standards for low volume roads. The main pavement type is a gravel wearing course.

Gravel wearing courses are designed to wear and so maintenance costs for this road type are high, but construction costs are low. They are known to function well in some environments and not so well in others. Road user costs are usually high because of the unevenness of the road surface and other defects. Dust is an environmental problem especially for roadside communities.

Poor performance of gravel roads is usually caused by excessive gravel loss due to combinations of traffic, and erosion due rainfall, flooding and geometry (gradient). Basically, high rainfall and steep gradients increase the rates of deterioration to unsustainable levels on low volume roads where the deterioration caused by traffic maybe a less severe problem. It will be apparent that the reductions in geometric designs to save costs will require that road designs in rolling or mountainous terrain will have steeper gradients which is likely to make the use of gravel pavements even less durable and therefore less suitable when all other factors oar equal. However this is inevitable as it will usually be necessary to avoid expensive cut or fill operations. The solution is to offer the road design community alternative pavements, as is the purpose of this project.

The current main alternative to providing a gravel wearing course in Lao is to simply seal the surface using a bituminous using a single or double seal (a surface dressing). However, one has to be cautions in the widespread application of this approach because the supporting base material (of gravel wearing course quality) may retain insufficient strength once sealed and may fail. One of the technical reasons for this is that once sealed the clayey materials suitable for wearing courses may draw in water though the process of pore suction which will increase its moisture content which cannot then evaporate because of the seal. In essence, materials that are perfectly suitable for unsealed roads may not necessarily be suitable for adjacent sealed roads.

There is anecdotal evidence that in Lao PDR the seals only last for 2-years whereas in normal use (with fully specified pavements) they would be expected to last for approximately 5 to 9 years for a single or a double seal respectively. However, there is little research-based evidence on this problem within the Lao environment.

There is also some evidence that some basic access roads are being designed using material qualities at levels far below the limits of the existing design manual. This may be acceptable and allow welcomed savings in construction costs but on the other hand it may lead to premature failure if there is no engineering justification for the reductions .

Currently in Lao PDR and the only pavement option available to the engineer for low volume roads are gravel or sealed gravel, neither of which may perform well.

To seek other alternatives, the review has considered the trial pavement research constructed in Vietnam and Cambodia under other SEACAP projects. Although the long-term performance of these is still being assessed, the studies offer a significant number of alternative pavement types and sealing techniques that would greatly increase the options available. Some are suitable for labour intensive operations while others re suitable for mechanised construction, or both.

An important factor will be to assess the engineering suitability of these alternative pavements with respect to Lao PDR conditions and to their construction cost. An ideal solution would be the replacement of gravel pavements with one of these options at similar whole life costs and retain the same or greater durability. Some road user costs have been made assessed but further work is needed to examine the basis of these and the appropriateness of using the usual processes used for obtaining whole life costs.

6 The Lao PDR Local Road Environments

6.1 Road Environment Factors

It is now generally accepted that an effective LVRR design process should take into account the whole road environment if it is be cost effective and sustainable in engineering, social and economic terms. Table 6 presents the key elements of this road environment that impact most directly on the road design process.

Table 6 Road Environment 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 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.
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 LVRR 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.
Sub-Grade Conditions	The sub-grade is essentially the foundation layer for the pavement and as such knowledge of its condition and variability are fundamental to an appreciation of LVRR environment.
Traffic Patterns and Axle Loads	Findings from recent research indicate that the relative influence of traffic is often less than that from other road environment parameters in low volume roads. However, even for these roads due consideration still needs to be given to the influence of traffic on the performance of the structure. In particular the engineering risk from heavy trucks or overloaded vehicles needs to be assessed.
Construction Regime	The construction regime governs whether or not the road design options can be 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 at least some regular maintenance (routine and periodic) to ensure that the design life is reached. 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. For some LVRR options (eg unsealed gravel) an established and effective maintenance regime is essential prerequisite for sustainability.
Socio-economic Issues	Issues that need to be taken into account when identifying appropriate pavement solutions include: • Local employment on construction/maintenance • Development of local contracting capability • Use of local resources (keeping funds in-district) • Health and safety in construction and design • Environmental degradation of resource development

6.2 Materials

6.2.1 General

In terms of general geology, terrain and engineering geology Lao PDR can be considered as comprising three main systems; Northwest Laos; Truongson, and Kontum-Savannaket, with a fourth smaller one, the Bolevens Plateau to the South East. Natural materials available for road construction occur as a function of the controlling geological and geomorphological influences within these systems. Preliminary assessment of the geology and likely predominant materials of the systems is summarised in Table 7.

Table 7 Engineering Geological Systems

System	General Geology	Predominant Materials
North West Laos	A generally NNE-SSW trending fold belt of sedimentary rocks (mudstones to sandstone) with some volcanic tuffs and localised low grade metamorphics. Gniess and associated granite in the extreme NW , otherwise only isolated igneous intrusions (granite)	Alluvial sands and gravels adjacent to the Mekong and tributaries Isolated granite/rhyolite aggregate and laterite gravel sources. Poor quality colluvial gravel. Marginal quality sandstone aggregate
Truongson	A generally NW SE trending sequence of sedimentary rocks including limestone with major acid igneous intrusions (granite/diorite).	Igneous aggregate – mainly granite, but also localised diorite and basalt. Limestone aggregate Associated hill gravel (colluvium) Localised laterite gravel and some alluvium
Kontum-Savannaket	Generally undeformed sedimentary rocks (sandstone). Recent alluvial deposits adjacent to the Mekong	Alluvial sand and gravel adjacent to Mekong Marginal quality sandstone aggregatel
Bolovens Plateau	Basic lavas and sandstones with occasional quartzites.	Basalt aggregate, alluvial sand and gravel. Laterite gravel

The available materials can be considered falling into the broad groups which are discussed below.

6.2.2 Crushed Rock

The following material types are commonly reported by material engineers as being used in Lao.

Sandstone is available around Vientiane Province and to the south within the Kontum Savannaket system. This has been used for road base construction but it is reported to perform poorly as it is too weak or degradable and breaks down in the pavement. Its performance is reported as better for use as riprap and gabions for example.

Limestone is also widely available and is reported to be strong and durable

Acid igneous rocks (Granites and Rhyolites) are quarried and reported to be available for use as road construction materials, principally in the North and West of Lao.

6.2.3 Alluvial Sands and Gravels

River gravels and sands are abundant in the vicinity of the Mekong river and its main tributaries, their use as construction materials is locally very common. A wide range of sand and gravels sizes are available, these generally well rounded. Larger gravel sizes are crushed as required.

6.2.4 Laterite Gravels

Lateritic gravels are reported as being extremely common in the mid and southern regions of Lao (Kontum Savannaket) and are used extensively for gravel wearing courses. The plasticity of these gravels appears to be greater than normally specified and in general appear to be lower standard than usually specified for sub-base. On unsealed roads they are reported as being excessively dusty in the dry season and form a slush of clay fines on the surface in the wet season

6.2.5 Hill Gravels

Hill gravels (colluvium) derived from a combination of hard rock weathering and down-slope accumulation are likely to be widespread in upland areas of Lao. Appropriate material can be used both as a wearing course material and as possible shoulder, sub-base and capping layer materials. They require careful assessment for potentially significant variations in strength, plasticity and grading within a deposit.

6.2.6 Bricks

There is an extremely extensive fired clay brick small scale industry and this forms a major form of building construction. Portland cement construction blocks are also common, made from fine river gravels and sands. Although the commonly used fireclay bricks and building blocks would have a low compressive strength, segmental paving is commonly used for footpaths in Vientiane city and is (can be formed to provide a high strength block of road pavement quality.

6.2.7 Cement and lime

Cement and building lime is manufactured at two major enterprises centres located in Naliam in Khamonnom Province and Vientiane Province. Small scale lime burning production in local kilns does not seem to have been established. The effectiveness of lime or cement stabilised bases and sub-bases for LVRR pavements in Lao is a research topic worth pursuing.

6.2.8 Bitumens

Imported bituminous materials of the types commonly used for road construction are available, for prime, tack coats and for surfacings. A major supplier is TIPCO of Singaporean origin.

6.3 Climate

6.3.1 Data Sources

The Department of Meteorology and Hydrology weather observation network (DMR, 2006) consists of a total of 50 stations, of which 17 are the main synoptic surface stations, and 33 are secondary stations. Rainfall is recorded at a further 113 stations. The main synoptic stations record parameters such as temperature evaporation, humidity, wind speed and sunshine hours. Records are available for long-term (say 20 years) for the majority of these stations.

The Hydrological Network consists of staff gauges at 109 stations and 49 discharge stations. Recently (2006) Band Doppler radar at DMH Headquarter and MTSAT–1R satellite receiving station began operating.

6.3.2 Summary

The Lao climate is essentially seasonally wet tropical with an annual rainfall of between 1500 and 3000mm occurring principally between May and October. Climatic indices show that Loa falls outside the climatic envelope of recent research in Africa on LVRRs.

On average about 3 Tropical Cyclones per year of various intensities make landfall on Vietnam and then move through to impact upon Lao territory. A summary of rainfall for three typical provinces is shown in Table 8

The climate characteristics may be summarised as follows

- The temperature is lowest in December – January (13^o – 17 ^{o}C) and highest in April (35 ^{o}– 38^{o}C). The annual average temperature is 26^{o}C.
- The dry season (Northeast monsoon) runs from mid – October to mid - May,
- The rainy season (Southwest monsoon) runs from mid - May to mid – October; a, period of heavy and frequent rainfall. The average annual precipitation range from 900 – 3,500 millimetres from, which 80% is concentrated from May to September.
- A short drought of about 2 weeks is normally experienced between the end of June to the beginning of July.

6.4 Hydrology

During the last 37 years (1966–2002), 27 notable floods occurred with an average frequency once in approximate 1.4 years. Of these 27 historic floods only 6 were large floods (1966, 1971,1978,1995,1996 and 2002), giving an average frequency of once in every 6.2 years.

Table 8, Long Term Climatic Data for 3 Provinces

Vientiane		Altitude		m									
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Rainfall	6	20	38	87	241	285	285	329	277	89	10	4	1,673
Evaporation	103	108	133	122	91	74	68	60	62	90	102	105	1,119
Temperature Max	28	31	33	34	33	32	31	31	31	31	30	28	31
Temperature Min	17	19	22	24	25	25	25	25	24	23	20	17	22
Humidity	91	88	86	88	92	94	94	95	95	92	90	91	91
Bokeo		Altitude		m									
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Rainfall	13	31	48	119	243	221	371	418	241	120	43	16	1,883
Evaporation	133	155	206	206	166	144	128	124	129	136	122	125	1,673
Temperature Max	29	31	33	34	32	31	30	30	30	31	29	27	31
Temperatue Min	15	16	19	21	23	24	23	23	23	21	18	15	20
Humidity	91	88	86	88	92	94	94	95	95	92	90	91	91
Attapeu		Altitude		m									
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Rainfall	2	17	45	85	228	334	503	521	439	136	25	5	2,342
Evaporation	140	146	170	128	97	63	51	46	45	71	101	134	1,132
Temperature Max	32	34	36	36	34	32	31	31	31	32	32	31	33
Temperature Min	18	20	23	25	25	24	24	24	24	23	21	20	23
Humidity	39	41	40	45	57	67	73	73	71	61	54	47	56

6.5 Terrain

Geographically setting, the Lao People's Democratic Republic is dominated by two features: The mountains and hills of the North and East and the Mekong River and its east bank tributaries. The topography of Lao People's Democratic Republic is closely related to the geological units with much of the terrain in the northern part of the country being mountainous and along the border with Vietnam, with extensive alluvial plains in the south and west.

A simple three-fold division of terrain has been adopted by the PRoMMS database to describe road alignment topography; Flat, Rolling and Mountainous. Figure 2 summarises this categorisation for rural roads in each of the provinces.

Figure 2, General Terrain Grouping

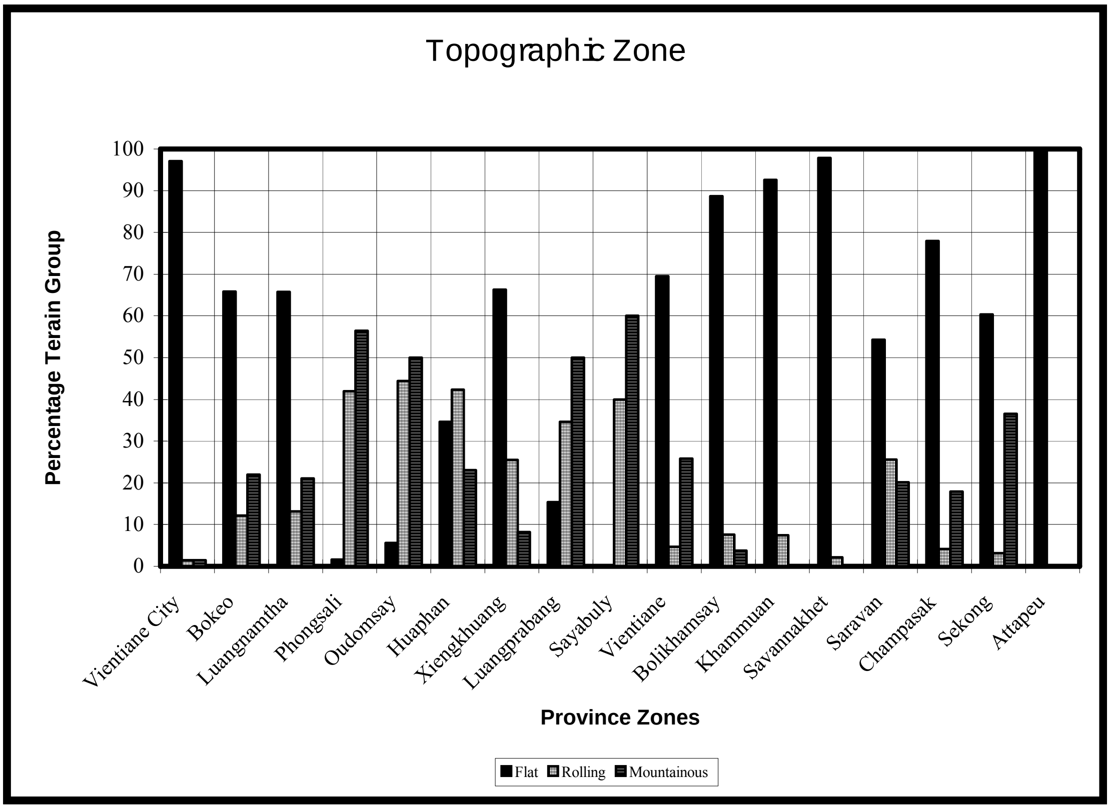


Figure 3 indicates that most of maintainable rural roads in the majority of Provinces are located in flat terrain, and that only in four Provinces are they located in mountainous terrain, namely Phongsali Oudomsay Luangprabang and Sayabuly.

While this categorisation of terrain is useful for general planning and cost purposes a more detail system that models the actual impacts within these units on the road would be more appropriate for the selection of pavement, drainage and structure options.

6.6 Sub-Grade

The climate data shows a high rainfall environment where sub-grade conditions can be expected to be at least seasonally wet. Some drying out is to be expected during the dry season, but road sub-grades are likely to wet for at least 6 months of the year and probably longer, consequently a compacted sub-grade is likely to reach an equilibrium moisture content close to saturation of the material. It follows that the measurements to assess the strength of the sub-grade in the laboratory for use in design charts etc should be undertaken in the soaked condition.

A comparison with similar environments in Vietnam indicates that sub-grade conditions are likely to be highly variable. Highland regions are likely to produce generally good sub-grade conditions (CBR>10%), if allowance is made for local unpredictability and localised flat-lying areas. In contrast, rural roads on flat low-lying terrain on variable quality embankments or on saturated natural ground are unlikely to have general CBR sub-grades values in excess of 5%.

Use of field measurement techniques for assessing strength such as the DCP may yield stronger strength results than will be actually experienced in the road. This is partly because, for practical reasons, field assessments are more likely to be carried out in the dry season than the wet season. Road designers should take a cautious approach to using these data for pavement design. More confidence in the results and their use for design will be gained if tests are undertaken to determine the strength of a nearby road more than say two years old with the same material in the subgrade and with similar cross-sectional dimensions.

6.7 Traffic

6.7.1 Volumes

Available average annual daily traffic volumes show that traffic on the National roads are less than 1000, and Provincial roads, less than 100 vehicles per day. However information from the numbers of vehicles registered (including government vehicles) show that the growth rate is high. Annual growth rates are the highest for motorcycles (12%) and those for large buses and trucks are approximately 7%, respectively. These growth rates are quite high especially for heavy vehicles, and in-line with the planned economic growth.

6.7.2 Vehicle loading

From information provided by MPWT it is clear that overloading on the road network has been historically severe, as it is in many developing countries. This problem is being effectively challenged by the establishment of weighbridge stations and penalty systems. By 1999 five weighbridges were operating one in each of the Provinces of Vientiane Capital, Savannakhet, Khammouane Bolikhamxay, and Champassack.

Data show that more than 90% of the vehicles were overloaded at that time, many significantly so. By 2006 a total of 41 weighbridges had been established in the country and data reported from 17 Provinces indicate that overloading has been reduced to usually less than 25%, and frequently less than 5%, however the overloading at the following stations remained very high:

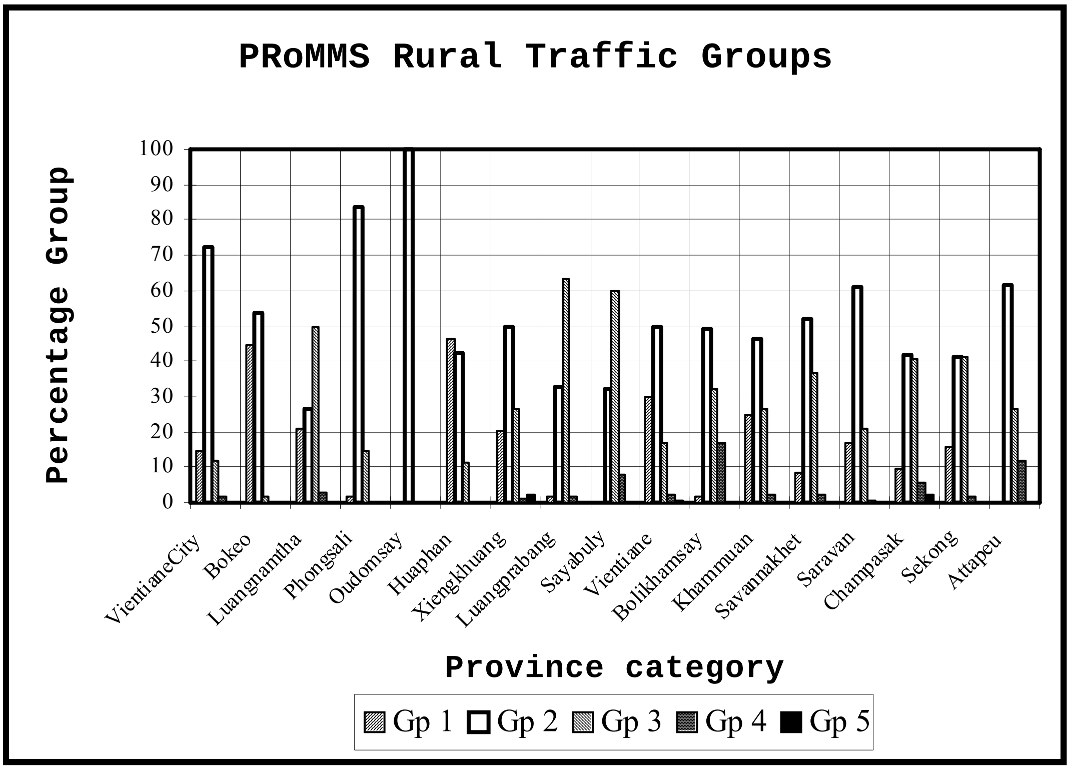
Phongsaly	52%
Bokeo	79%
Houaphan	39%

It is probable that some of these high figures are a reflection of loading on sub-regional national roads and may reflect differences in differing country limits for heavy vehicles in transit between Thailand and China via Lao, for example.

The rural roads are shown to be carrying either light to moderate (medium) traffic (Figure 3) where light is up to 50 vehicles per day or up to 4 heavy vehicles, while moderate indicates a traffic volume of up to 150 vehicles per day or up to 10 heavy vehicles per day. No doubt there would usually be a mix of both some light vehicles and some heavy vehicles. It should be noted that some rural roads in some Provinces carry heavy traffic virtually none (4 sections) carry very-heavy traffic. Heavy traffic is recorded in 13 out of 17 Provinces, but only appears to be significant in Bolikhamsay where 9 sections (probably 45 kilometres) have Heavy-Traffic.

If the moderately trafficked roads were to carry 4 heavy vehicles the loading may accumulate to about 150,000esa's over a design life of 12 years and a growth rate of 7%. Heavy traffic class would indicate a very considerable traffic loading, probably inconsistent with both the pavement strengths and the road width.

Figure 3, Typical Rural Road Traffic (PRoMMS)



Group code	Class name	Description	
		Volume **OR**	Heavy vehicles
1	Very light	<20	None
2	Light	21-50	1 to 4
3	Medium	51-150	5 to 10
4	Heavy	151-500	11-100
5	Very Heavy	>500	>100

6.7.3 Traffic Mix

When considering appropriate dimensions for rural roads specifications often declare ADT as the controlling factor. It will clearly be important to also state whether or not the ADT includes any 2 or 3 wheeled vehicles or whether it is solely 4-wheel vehicles (not 4-wheel drive). It will also be important to declare whether or not vehicles have been factored into equivalent ADT for 4 wheel vehicles. For example the road design requirements for ADT of 20 vehicles that each have 4-wheels may be very different for 20 motorcycles compared with 20 cars. Whether or not 100 motorcycles have been factored to be equivalent to 20 cars will also be important.

6.8 Contracting Capacity

According to the register of contractors in the year 2005, 147 contracting firms are registered in Lao PDR, of which 140 are registered for road works. The register shows three classes of capability in terms of the value of a road contract, namely Class 1 US$600,000 and above, Class 2 between US$300,000 and US$600,000 and Class 3 below US$300,000.

The capability is further subdivided to show that, the majority of contractors are experienced with regravelling and carrying out bituminous sealing works, with the number of firms being approximately equal (48 firms) in each of the 3 financial classes. Only six contracting firms are listed as experienced in the construction of asphalt roads. Our understanding of the meaning of being competent in the construction of asphalt roads is that they have the capability experience and machinery to lay asphalt concrete and to construct the whole of the pavement to a satisfactory quality.

Some of the contracting firms have provided information of their construction experience and from the information supplied it would that they are reasonably equipped for routine works to be undertaken but would perhaps not have enough equipment for constructing pavements and alternative surfacings. However, it is understood that hiring of equipment with operators either directly from dealing firms of from other contractors is possible. With the company personnel experience shown, this would seem to be entirely viable so the apparent lack of equipment would not appear to be a constraint. It is noted however that experience in using different materials and techniques may be a constraint, unless training is given or those with experience can be hired.

6.9 Maintenance Regimes

The village based schemes for routine maintenance are in place in some provinces, they do however have some potential problems, namely:

- These schemes rarely if ever include the vital capacity to maintain cross-fall on unsealed gravel roads,
- There remain some doubts as to their long term sustainability without external project support

7 Knowledge Gaps

7.1 General

The cost-effective application of appropriate and sustainable standards and specifications for LVRRs requires that they be based firmly on local conditions, and in particular that they should be compatible with the governing road environment factors, including economic issues. It is also important that as much knowledge as possible is obtained on the performance of existing LVRR roads in order to ascertain deterioration rates and models that can be taken into account in engineering terms and also in assessing Whole Life Costs.

The clear message is that a local resource and task based roads strategy requires local knowledge. The review of existing documents under Module 1 of SEACAP 3, whilst being to access useful sources of local information has also identified significant knowledge gaps, as outlined below.

7.2 LVRR Performance

There is lack of available data on the engineering performance of LVRRs in the range of Lao road environments and due to the delays in the construction of the SEACAP 17 trials, sections it will not be possible to access data on their in service performance for some time. There is therefore a clear knowledge gap in the area of LVRR in service performance

By far the greatest majority of rural roads within Lao PDR are unsealed; there is however little formally collated information on how they are performing in relation to their road environment factors. There is general information on selected LVRR road conditions within the PRoMMS database and whilst this useful and suits its own purpose, it needs to be expanded in order for it to become a guidance tool for road performance.

It is reported that the DoR/LRD has directly overlain a number of gravel roads with thin bituminous seals with the objective of improving their all year round trafficability as well reducing their maintenance burden and extending their effective life without the need for re-gravelling. There are, however, anecdotal reports that these seals show signs of distress after only around 2 years of service. There is clear need, within the context of identifying appropriate LVRR paving options, to examine the effectiveness this gravel sealing and to make recommendation on its use.

SEACAP 4 in Vietnam utilised existing World Bank funded unsealed gravel roads to provide valuable and detailed data on their condition and performance in relation to key impacting factors. This project could stand as`a model for a similar, possibly smaller scale, project in Lao PDR involving both sealed and unsealed gravel roads.

7.3 Local Road Traffic

Although the relative impact of traffic on LVRRs is less than on higher volume roads there is till a design need to both define its level and its make-up in terms of vehicle types. In particular the risk of heavy axle loading has to be assessed. Module 1 and Module 2 studies have indicated that while there is useful general information on traffic levels contained within the PRoMMS database, it is based on informal local evidence, some of it anecdotal. Some traffic data is also available in relation to ADB road programme projects, however this is largely applicable to roads of a higher classification than those covered by the SEACAP 3 programme.

A series of formal traffic counts on a representative selection of LVRRs would be a very valuable source of information for the affective mainstreaming of appropriate LVRR Standards and Specifications.

7.4 Construction Materials Data

One of the basic tenets of the proposed approach to LVRRs is that the specifications and designs should be based on the use of local materials where possible. Some knowledge of the nature and variation of local material is therefore essential in the drafting of these documents. The Module 1 review has accessed information on typical materials but there is still a significant knowledge gap with respect to the detail of available materials throughout Lao.

Based on a review of selected reports it appears that significant amounts of detail exist on the occurrence and geotechnical nature of road construction materials, most related to national and provincial road construction. Much of this information seems to be held in individual project reports or construction records and is not immediately accessible without undertaking a specific desk study focussed on construction materials. It would give added benefit if this study were to collate and store recovered data in electronic format

7.5 Economic Factors

The World Bank Transport Strategy Document (2006) identifies life cycle costing as essential for efficient resource allocation. An approach to LVRR whole life cost modelling has been developed under SEACAP 1 in Vietnam which could be formally modified to suit Lao PDR conditions. This model aims to support decisions on rural road surface options, but it is, as yet, based on construction and anticipated maintenance costs only with no formal account taken either of Vehicle Operating Costs (VOCs) or of other road management costs due to lack of basic information.

Although there is an identified need to develop the SEACAP 1 cost model into a complete Whole Life Cost model for Lao PDR, information reviews under Module 1 have indicated that, as with Vietnam, the existing Lao PDR VoC knowledge base is extremely limited.

8 SEACAP 3.01 Implementation

8.1 Identified Outputs

Clear definitions of achievable project objectives and the components are fundamental to a rational way forward. In order to clarify any potential misunderstandings in the nomenclature of proposed outputs the Inception Report included proposed working definitions which in a slightly modified form are included as Table 8 and discussed in more detail in the following sections.

Table 8 Working Definitions for SEACAP 3

ToR and Technical Proposal Terminology	Project Definition	Working Terminology
Local Roads	Low volume rural roads – design classes such as those defined as classes VI-VIII in the MCTPC document "Specification for Local Roads". Definition to be refined as a Task Group 1 output.	Low Volume Rural Roads (LVRRs)
Road Task Standards	A classification of Low Volume Rural Roads and their geometric components based on the function they have to perform in terms of traffic mix and acknowledging the road environment in which they have to operate.	LVRR Classification
Road Design specifications	Technical construction specifications (as drafted for example for SEACAPs 1, 8 and 17)	LVRR Specifications
Design Standards Matrix	A matrix of available pavement and surfacing options related to LVRR Design Classification and appropriate road environment models	LVRR Option Matrix
Local Road Technical Standards.	The combination of the LVRR Classification and LVRR Specifications together with associated commentary documents	LVRR Standards

In line with the ToR, and the time and budget limits to the project, the key outputs from "Standards and Specification" component of the project can be summarised as follows:

5. A proposed LVRR Classification
6. A set of proposed Technical Specifications compatible with (1)
7. A matrix of pavement and surfacing options related to designated function
8. A guideline document associated with (1) and (2) above

It should be clear that the outputs do not include, and were never intended to include, a comprehensive Design Manual for Rural Roads, however, based on the review of available information it is intended that the document (4) will include the following:,

1. Guidance on option selection and general design based on the use of a limited number of standard designs and specifications related to standard Lao rural road environment models.
2. Discussion on key elements of road design relevant to the Lao LVRR sector
3. Comment on a cost model suitable for further development to suit the Lao rural road situation
4. Guidance on general road drainage requirements based on standard Lao rural road environment models
5. Comment on the adoption of a "Low Cost Structure manual" currently being reviewed under SEACAP 19 in Cambodia.

8.2 LVRR Classification

There clearly has to be an upper limit to what roads may be included within the LVRR approach to rural road design and construction.

In terms of current terminology in Lao it is proposed that the upper limit for the LVRR envelope would include Basic Access roads, with the following characteristics:

5. An ADT of <150-200 , all traffic included and factored
6. Low risk of vehicles exceeding the axle load limits (suggested as 4-6 Tonne)
7. A design life involving less then 250-500,000 esa

With respect to current Lao standards this would be the rough equivalent of working within the existing classes VII and VIII. Roads with functions above these requirements, and particularly those with a significant risk of heavier axle loads, would fall outside the LVRR designation and could require a different, more rigorous engineering approach to road design.

As indicated by the review of national and international standards there is a logical requirement for a subdivision within this LVRR definition to take advantage of significant cost savings in the reduction of design standards possible with very low traffic levels or very low axle loads.

The project is, looking closely at this subdivision and some of the issues to be considered are summarised below:

- Any sub-division has to be practical and have positive design benefit
- Each sub-division should take into account the "Standard Vehicle" requirements (discussed more fully in 8.4 below)
- Geometric requirements associated with any sub-divisions must be taken into account the whole road function and not just motorised traffic, in particular, safety factors associated with mixed motor vehicle, bicycle, cart and pedestrian traffic. This has implications for allowable maximum speeds, shoulder widths and the provision of passing places.
- A possible 3-fold sub-division is being considered with the lowest including a 2.5Tonne axle limit
- The additional inclusion of a very low -2-wheeled traffic sub-division (axle limit 0.25Tonne) may also be considered
- The practicality of using an axle load based classification and the possible means to ensure compliance,

8.3 LVRR Standard Specifications

The Lao technical specifications currently only include unsealed natural gravel surfacing as an appropriate option for low volume roads. SEACAP projects in Vietnam, Cambodia and Lao have produced technical specifications, as part of their trial programmes, for a range of pavement and surfacing options as well as for earthworks and sub-grade. The SEACAP 3.01 project intends to evaluate these trial specifications for adoption as LVRR Standard Specifications, although as construction of the SEACAP 17 trials is still ongoing, these will of necessity be of a provisional nature.

Initially it proposed to consider a limited number of pavement types that cover the range of anticipated road classifications and to consider the specification, cost and design options for these in relation to standard Lao environments. The first options to be so considered are:

- Unsealed gravel
- Sealed gravel
- Sealed armoured gravel
- Sealed waterbound or drybound macadam
- Non reinforced concrete

The use of a Spot Improvement approach utilising the above types, possibly together with an Engineered Natural Surface (ENS) option, will also be evaluated. This evaluation will be undertaken in conjunction with knowledge of the Lao road environments and available materials in particular and in the light of the review of relevant international experience. Some key issues that will be taken into account are summarised below.

Low volume roads present a particular problem to road engineering in that low traffic levels implies that it is necessary to reduce costs, and this is often done by trying, to use locally available materials which may of lower quality than is normally specified in standard documents. Often the particle size distribution is far from ideal and even more often they contain too much clay especially or silt in the fines in their matrix. These factors contribute to causing the materials to be less stable and more susceptible to wetting, making them weaker than standard quality materials. Nevertheless, they have been used with success different parts of the world. The savings play an important role in developing the road network for alleviating poverty and preserving material resources.

Significant work on appropriate pavement specifications is included within the SADC guidelines and the general concepts for the pavement design of roads and their specifications in the SADC region may be transferred to roads in Lao. The associated detail, such as the pavement design charts cannot be so readily transferred because of the radically different road environment, and in particular the climatic conditions. Much of the SADC work was carried out where N values exceeded 5 and although designs are presented for N-values of less than 4, the climate in Lao indicates an N-value close to 1. This is near the extreme wet limit of the index and the scope of the work in the SADC region. Clearly the material specifications relaxations of wider gradings and higher plasticities permitted for N greater than 4 cannot be directly imported without careful consideration. Usually a drier climate is more likely to permit the use of lower quality compared with the specifications for their use.

A recent TRL-led research project into the use of marginal materials is of significant relevance to the assessment of specifications using locally available materials[7]. The concepts and suggestion with respect to options for using lower grade materials in LVRRs will be assessed for use in Lao. Bangladesh, for example, with a significantly wet climate has developed a specification that allows mixtures of crushed rock or brick with sand to be utilised in the construction of the roadbase for low

[7] Cook J R et al, 2001, Promoting the use of marginal materials, TRL Report no PR/INT/ 205/2001 for DfID Project R6887

volume sealed roads in conjunction with a pavement design chart specifically designed for use with these materials having a soaked CBR strength of 60% (98% Mod. AASHTO)

8.4 LVRR Pavement Selection and Design

8.4.1 General Approach

The proposed approach with respect to guidance on pavement design is currently being considered as two-phased. The first phase would be to identify pavement or surfacing options in relation to a number of standard Lao road environments as defined by the factors discussed in Section 5, including the four identified-terrain-materials systems. This concept is likely to take into account, for example, a high rainfall environment in steep terrain would be far less appropriate for an unsealed gravel solution than a level terrain model close to alluvial/colluvial gravel resources. This concept of appropriate pavement/surfacing types, which may varying along a road link, which has been developed for Vietnam under SEACAP 1, will be assessed for use in the Lao LVRR environment.

The second phase involves the detailed design (thickness etc) and although the SEACAP 3.01 project will not develop a Comprehensive Road design manual it is nevertheless intended to produce some broad guidelines on this issue. The approach will be to identify standard designs using appropriate existing procedures applicable to one or more Lao road design models.. Key inputs at this stage of detailing pavement types identified under Stage 1 would be; “Standard” Vehicles; Road classification/traffic and sub-grade

8.4.2 Standard Vehicles

It is important that rural roads are designed to accept the most common type of 4 wheel vehicle and to accept the largest vehicle that might use the road. The light truck type appears to be very common on Lao roads and is most likely to serve rural areas and access roads to villages. An example is the Kolao Porter model from Hyundai (axle loading around 2.5T). The largest vehicle is likely to be the “Rice truck” which performs an extremely important function for rural communities because it provides them with a means of milling the rice ready for bagging for consumption or market. It is a modified GAZ 66 flat bed medium truck with a rice milling machine located on the rear (axle loading around 4.5T).

8.4.3 Road Widths

An overall road width of between four and five metres providing a single traffic lane is likely to be most suitable for the majority of low volume rural roads.

Special attention will be needed to address the effects on the pavement of vehicles entering and leaving the traffic lane if the construction of the shoulder is not the same construction. The transition between a bituminously sealed traffic lane and an unsealed shoulder will lead to the commonly seen erosion of the sealed width.

The transverse transition from a gravel road to a sealed surface and vice versa, must also be addressed to prevent excessive erosion of either or both of them. Consideration should be given to the longitudinal gradient of the road where the transition takes place, which ideally should not be on a steep gradient.

Special consideration must be given when concrete pavements are used. Experience from the Philippines, where jointed plain concrete pavements are used extensively shows that older pavements which are 3.0m wide are more prone to longitudinal cracking. Recently the width has been increased to 3.2m. Concrete pavements have a low tensile strength and the stresses imposed by traffic are travelling close to the edge are twice those imposed near the middle of the slab. Vehicles actually entering or leaving the concrete slab are likely to crack the slab. It is recommended that the outer 0.6m of the slab should not be routinely loaded. Thus the acceptable road width would be the track of the widest vehicle plus 1.2 metres. The track is the distance from the centres of the tyres of the widest axle for single rear wheeled vehicles and between the rear tyres for dual wheeled vehicles.

8.4.4 Water Table

The presence of the water-table, or more particularly the crown height of the road above water-table and its variability are key factors known to influence the moisture conditions and hence the engineering performance of the road. A minimum height from the invert level of the ditch to the crown of the road must be established. Typical values lie between 0.65 and 0.75metres.

It is a relatively simple addition to field programmes to establish general water-table and this should be undertaken especially where the use of marginal or poor quality materials is contemplated for the sub-grade or pavement.

Raising the road on a low embankment will help to reduce the risk of low subgrade strengths caused by poor drainage and inundation of the ground surrounding the road.

8.4.5 Earthworks

The use of capping layers or improved sub-grades on low strength sub-grades is to be encouraged if locally available materials are in the vicinity. This is because better pavement performance will be achieved for pavements of the same thickness and materials, and it may be possible to reduce the upper pavement thickness if a sufficiently thick capping layer can be placed.

8.5 LVRR Structures

It is proposed that the issue of LVRR structures be dealt with by considering the suitability of the DfID-funded draft Low Cost Structure Manual that is currently being reviewed as part of SEACAAP 19 in Cambodia.

8.6 LVRR Drainage

Adequate road drainage is commonly acknowledged as being of fundamental importance to satisfactory road performance. This holds true no less for LVRRs, particularly with respect to unsealed gravel or earth roads. In practice however the construction of even the simplest of side drains is commonly omitted and, if constructed, it is left unlined in crucial areas leading to rapid deterioration. A recent survey of rural roads in Vietnam[8] showed that barely 50% of the required side drainage was either constructed or effective

SEACAP3 will highlight the essential role of drainage and associated pavement crossfall in the Guideline Document. Standard detail from exiting specifications will be recommended

[8] Cook J R & Petts R, 2005. Rural Road Gravel Assessment Programme; Final Report. SEACAP 4, for Vietnam Ministry of Transport.

8.7 Construction and unit costs

Historical information on the unit costs for road construction have been provided by MPWT These originate from the past ten ADB projects in Lao. It should be noted that gravel wearing courses are those listed as sub-base. The average cost has not increased in line with inflation in recent years. It is understood from discussions that this was because more foreign contractors were entering the Lao construction market which has tended to keep costs down. In further discussions it has been noted that for local contracts using as-dug local gravels the unit cost may be as low as $3 per cubic metre.

A straightforward spreadsheet-based cost model was set up under SEACAP 1 in Vietnam and some initial work has been undertaken by using Lao materials costs. Some further work will undertaken on then standard LVRR designs within the option matrix Table 9 presents some typical preliminary costs per kilometre of a 3.5m carriageway; sub-grade CBR 5% and traffic of 50 ADT.

Table 9 Preliminary Cost Comparisons

Pavement Option	Cost/km: Construction (US$)	Cost/km: Construction +10 yrs Maintenance
Non Reinforced concrete over gravel sub-base	$46,788	$52,682
Sealed armoured gravel	$12,173	$20,992
Unsealed gravel	$5,395	$19,712 (2% gradient) $22, 135 (6% gradient)

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