In association with
Lao Transport Engineering Consult (**LTEC**)

Lao People's Democratic Republic
Peace Independence Democracy Unity Prosperity
Ministry of Ministry of Public Works and Transport
Department of Roads

Local Resource Solutions to Problematic Rural Road Access in Lao (PDR)

SEACAP 17 Rural Access Roads on Route No.3

End of Project Report

April 2009

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Final Project Report

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Department of Roads
Ministry of Public Works and Transport
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Abbreviations

ABD	Asian Development Bank CRM Community Road Model
CBR	California Bearing Ratio
CRM	Community Road Model
DCP	Dynamic Cone Penetrometer
DCTPC	Department of Communication Transport Post and Construction
DFID	Department for International Development
DOR	Department of Roads
DRR	District and Rural Roads
DWPT	Department of Public Works and Transport, previously DCTPC
EOD	Environmentally Optimised Design
GOL	Government of Laos
gTKP	global Transport Knowledge Partnership
IFG	International Focus Group
IRAP	Integrated Rural Accessibility Planning
IRI	International Roughness Index (m/km)
KfW	Kreditanstalt fur Wiederaufbrau
Lao PDR	Lao People's Democratic Republic
LAK	Lao Kip (The currency of Lao PDR)
LBES	Labour Based Equipment Supported Maintenance
LECS	Lao Expenditure and Consumption Survey
LRD	Local Road Division
LRN	Local Road Network
LSRSP	Lao Swedish Road Sector Project
LTEC	Lao Transport Engineering Consult
LVRR	Low Volume Rural Roads
MCTPC	Ministry of Communication Transport Post and Construction
MDD	Maximum Dry Density
MPWT	Ministry of Public Works and Transport, previously MCTPC
NEC	Northern Economic Corridor
NGL	Natural Ground Level
NGPES	National Growth and Poverty Eradication Strategy
NPV	Net Present Value
NRN	National Road Network
PRC	People's Republic of China
PRoMMS	Provincial Road Maintenance Management System
PRTP	Participatory Rural Transport Planning
QA	Quality Assurance
RIP	Rural Infrastructure Project
RMF	Road Maintenance Fund
RMI	Road Maintenance Initiative under the Sub Saharan Africa Transport Policy Programme
RMP1	Road Maintenance Project 1
RMP2	Road Maintenance Project 2

RMS	Road Management System
RRSR	Rural Road Surfaces Research
SATCC	South Africa Transport and Communications Commission
SEACAP	South East Asia Community Access Programme
SID	Spot Improvement Design
Sida	Swedish International Development Cooperation Agency
SPM	SEACAP Practitioners Meeting
TCTI	Transport and Communication Training Institute
THIP	Third Highway Improvement Project
TKP	Transport Knowledge Partnership
USD	United States Dollar
VMC	Village Maintenance Committees
VOC	Vehicle Operating Costs

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Final Project Report

EXECUTIVE SUMMARY

The Lao People's Democratic Republic in the centre of the Mekong region of South East Asia is an agrarian economy with more than three-quarters of the population living in rural areas, dependent on agriculture. It is estimated that some 90% of the poverty in Lao PDR is rural-based showing a strong correlation with access to basic infrastructure services.

The South East Asia Community Access Programme's (SEACAP) goal is to promote low cost, sustainable solutions for rural access. Improving the sustainability and affordability of rural access will lead to improved access to economic opportunities, and health and education services; thereby creating opportunities for pro-poor growth and poverty alleviation. This project, SEACAP 17, aims at identifying low-cost, locally resource based methods of improving problematic lengths of road to provide sustainable rural access.

The SEACAP 17 research has been implemented in four modules, each of which has previously been reported separately, as follows:

- Module 1: Project Planning and Initiation
- Module 2: The Construction Phase and Base Data Capture
- Module 3: Operational Data Capture and Interpretation
- Module 4: Information Dissemination and Training

This document (Final Project Report) provides a comprehensive report covering the whole project and including all significant data and conclusions from the previous, individual module reports.

The project was implemented in conjunction with the ADB Northern Economic Corridor Project (NEC) to carry out research on a group of rural access roads in Houay Xai district. The approach adopted was to replace the standard NEC gravel pavement with a carefully selected variety of SEACAP trial pavements at specific locations along the access roads. The pavement types selected for the trials were taken from those presented at the Knowledge Exchange Workshop in Vientiane December 2004 and the specifications for each of the trial pavements developed from similar projects in the region and worldwide. The NEC consultant prepared bid documents for the three access road contract packages in Houay Xai, Vieng Poukha and Namtha districts. Amendments were made to the NEC bid documents for the district of Houay Xai for inclusion of the SEACAP trials and the bid documents submitted to the Ministry of Public Works and Transport.

The intention is that the performance of the different pavement types be monitored in service and related to the construction cost and difficulty as well as to the terrain and climate conditions and the maintenance costs and problems ultimately giving a basis for choice between pavement types in any given set of circumstances.

In order to monitor the pavement trials, various base data were collected and stored in a database (developed in Microsoft Access) which is now owned and will be used by Ministry of Public Works and Transport. Data records were collected in a similar method to that of other SEACAP projects so that comparisons with other trial sections in other countries can be made. This report includes a description of the pavement construction and of the base data and the techniques used for collection.

While significant knowledge was gained during the construction phase of this project, little performance data is yet available as only the basic post-construction data has been collected.

Algorithms defining under which conditions particular surface types are best suited have been formulated, however, only after the long term monitoring of the pavements will it be possible to derive relationships between surface performance and key road environment factors.

Environmentally optimised design and spot improvement design are discussed in combination as a road design tool that considers the variation of the different road environments along the length of the road and the need to tailor design to the relevant circumstances of each critical section. Based on knowledge of the key factors of geometry, pavement structure, drainage, slope stability and available materials and labour the optimum road construction can be selected and designed.

During the construction of the trial pavements it became apparent that some pavement structures or surface types are more appropriate in certain circumstances. For example, the sand sealed surfaces are only appropriate for low traffic volumes on flat undemanding terrain – primarily providing a comfortable ride with little dust pollution – whereas the hand packed stone, which results in a rough surface, is more appropriate on very steep sections of road which would otherwise be impassable in the wet season. However, what has become clear is that the environmentally optimised design and spot improvement design philosophy requires that substantial time is taken in the field by experienced Engineers in order that suitable pavement structures are selected for short lengths of problematic road in order to best overcome particular problems at those spots.

It is concluded that all weather access can be provided using techniques which are suitable for local procurement and local supervision but during the design phase it is important that detailed investigations of all successful construction techniques within the project area be investigated and applied or adapted as appropriate to avoid the use of pavement construction methodologies which are not suited to local resources and skills.

The contract documents should encourage, or require, Contractors to use local labour. This has economic benefits for the local community, provides some feeling of ownership and helps create a pool of experienced labour in the area which will be of value in future construction and in maintenance of the existing roads.

Maintenance considerations should be taken into account when selecting pavement types, for example, gravel surfaces and bituminous seals require significantly more routine and periodic maintenance than concrete roads. The designer must consider not only the maintenance requirements of each surface type but also whether maintenance will actually be carried out and the effects of non performance, if this seems likely. Within this project area it must be recognised that maintenance is likely to depend largely on the willingness of the communities to contribute their labour with the Department of Public Works and Transport providing, at best, only technical and minimal budgetary support when necessary.

On the basis of the work to date it is concluded that the advantages and disadvantages for each pavement structure depend on the particular circumstances to which the design is being applied. In order to design rural access roads effectively on a limited budget, it is necessary for experienced engineers to spend time in the field understanding the particular problems and exploring the various solutions. In general it is expected that the preferred design solution will involve a ‘spot improvement’ approach where, for example, substantial and relatively expensive, pavement structures for short, difficult lengths combine with simple and cheap structures in the longer and more forgiving stretches to provide the minimum cost, sustainable, robust solution.

Implementation of the construction phase has highlighted problems which occur when research work is carried out under a more or less conventional construction contract. There is a lack of flexibility which makes changes and adjustments either too expensive or impossible whilst the nature of the contract makes it very difficult to force the contractor to rectify small areas of poor work. These problems are likely to be magnified when, as in this case, the research element is simply a part of a larger, conventional contract which must reflect the realities of the commercial world and an over-riding desire to complete the Contract.

It is necessary that a long term monitoring regime follows through on the base line data capture conducted during this work. This will involve monitoring the performance and deterioration of the trial pavements and the NEC standard gravel, taking into consideration the environments to which they are subjected, the standard of construction, the traffic they carry and the maintenance required and actually carried out.

With the completion of the design and construction of the pavement trials, the baseline data capture and the planning of a future programme of monitoring, the present project has been completed. However, and most importantly, all of this work is in vain unless the awareness of good practice experience resulting from this project is disseminated at the national, sub-regional and international levels.

Throughout this project the transfer of knowledge and the dissemination of the information attained have been taken as one of the key aspects of the SEACAP programme. 'Dissemination' has been achieved by a number of different methods during the course of this project, namely:

- Workshops
- Training
- Guidelines and Specifications
- Mainstreaming

1 INTRODUCTION

The Lao People's Democratic Republic PDR is in the centre of the Mekong region of South East Asia. It has an agrarian economy with more than three-quarters of the population living in rural areas and dependent on agriculture. It is estimated that some 90% of the poverty in Lao PDR is rural-based and there is a strong correlation between access to basic infrastructure services and the incidence of poverty.

1.1 Background to Lao PDR

The Lao PDR is in the centre of the Mekong region of South East Asia, bordered by Thailand, Vietnam, Southern China, Cambodia and Myanmar.

Lao PDR has a population of around 5.5 million, approximately 23 persons/ km, the lowest population density in the region. It has significant natural resources like forestry, minerals and hydroelectric power. Agriculture remains the major sector of the economy, contributing around 51% of GDP and employing over 80% of the labour force; the industrial and service sectors account for the rest

Lao PDR is an agrarian economy with more than three-quarters of the population living in rural areas, dependent on agriculture. 71% of all hours worked concern work on owner operated farms, with very small differences between provinces (except Vientiane)[1]. About 42% of the total area of land is under agriculture of which 82% is used for cultivating rice (2002).

For the preparation of the National Growth and Poverty Eradication Strategy (NGPES) a poverty assessment was carried out using both quantitative and qualitative data. According to the Lao Expenditure and Consumption Survey (LECS 2002/ 2003), 30% of the population are poor and 45% of the total number of poor live in the Northern part of the country. There is a clear pattern showing that those living in rural areas are poorer than people living in urban areas and that access to roads is a main indicator of poverty. This is clearly shown in Table 1 where some socio-economic indicators are presented.

Table 1 NGPES Poverty Assessment showing the Percentage of the Population against the Indicator

Indicator	Lao PDR	Rural with roads	Rural without roads	Average North
Literacy rate (population >15 years old)	74	74	54	66
Completed primary school	15.4	16.7	11.4	15.8
Population with health problems disrupting work	56	58	62	56
Population <10 km to health centre	78	76	56	66
Safe water in the village	50	47	24	37
Population without toilet	49	54	83	47

Source: LECS 2002/3

The Government of Lao PDR has been consistently active to promote economic growth and alleviate poverty through national policies, regional co-operation and bilateral co-operative ties. The development of the road sector has been a cornerstone in this strategy during the past decade and remains so today. There is however still much to be done. It is estimated that some 90% of the poverty in Lao PDR is rural-based with a strong correlation between access to basic

[1] ***Lao Expenditure and Consumption Survey (LECS-III)**, National Statistical Centre Committee for Planning and Investment, Lao, 2002/3*

infrastructure services and the incidence of poverty. The very poor (estimated at some 17% of the population) live in remote areas where infrastructure is especially scarce. Villages in the Northern region are particularly isolated; some have no access to social services even during the dry season. A Poverty Impact Study of rural roads constructed under the Lao Swedish Road Sector Project indicated that all villages provided with road access were now, to a greater or lesser extent, producing more in general, than before. Expenditures had increased more than threefold, transport costs had decreased and there was evidence of positive impacts on education, health, commerce, agriculture, land use and gender; however some concerns regarding wildlife, livestock and the environment have been expressed and inequalities have increased.

1.2 The Road Network

Road is the dominant mode of transportation in the Lao PDR, about 75% of freight and 93% of all passenger traffic is carried by road (river transport carries most of the remaining share of freight). The development and conservation of the road network are critical to national and regional integration and to the socio economic development of the country. In particular, the road network provides connection between the economic centres of the three main regions of Lao PDR: Luang Prabang in the north, Vientiane in the centre, and Savannakhet and Pakse in the South.

1.2.1 Current Situation (2004)

The Lao PDR road network is estimated to have a length of 31,291 km (April, 2004), of which 14.5% is paved as summarised in Table 2. About 40% of the total road network is in excellent to good condition, although for National roads this figure rises to 73%.

Table 2 Road Lengths by Road Class and Pavement Type (Lao PDR)

Road Class	Road Length (km)			
	Paved	Gravel	Earth	Total
National	3,771	2,244	1,126	7,141
Provincial	198	3,038	3,239	6,475
District	31	1,826	2,008	3,865
Urban	429	871	465	1,765
Rural	14	1,815	9,527	11,356
Special Roads	54	304	249	607
Total	**4,497**	**10,097**	**16,615**	**31,209**

Source: MCTPC Planning and Technical Division, April 2004

On some roads, closures are frequent due to poor pavement or bridge condition, as well as landslides. About 10% of all district centres do not have year-round access by road, and almost one third of all villages are without road access at any time. As shown in Table 3, less than 66% of National, and 52% of Provincial roads, are considered to have excellent access with few, mainly short, road closures.

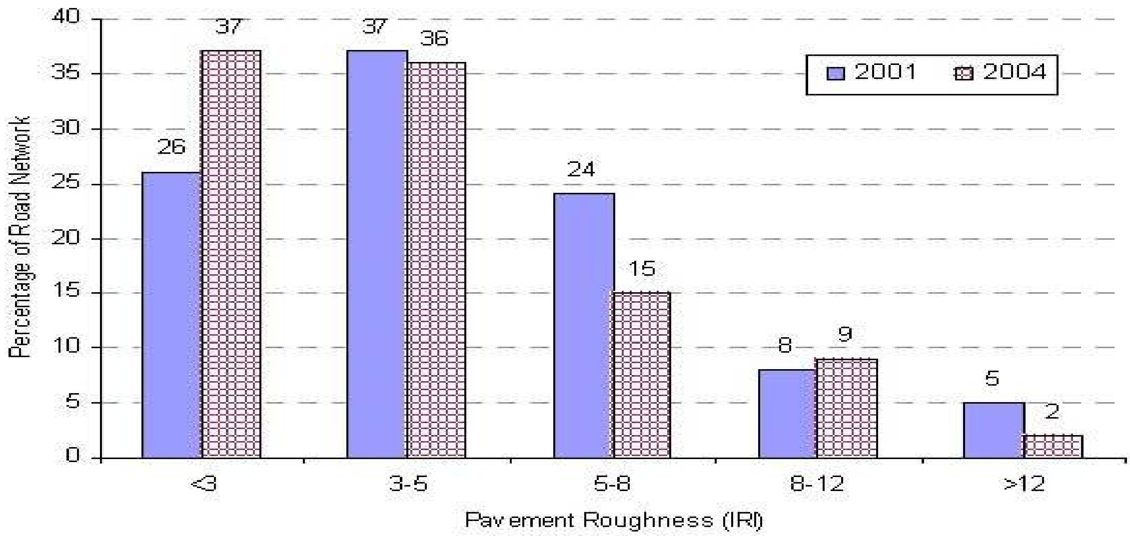
Table 3 Access Constraints on National and Provincial Roads

Road Access	Months Closed per Year	Percentage of Roads by Access Constraint	
		National	Provincial
Excellent	<1	66%	52%
Fair	1 – 3	8%	14%
Bad	3 – 6	6%	19%
Poor	>6	20%	15%

Source: Analysis of data in 'Expenditure Plan 2004-2013' [RMS database, DOR-PTD, April 2004

In spite of the problems with access, there has been a significant improvement in the overall quality of the core national road network in recent years through support from the donor community. This is illustrated in Table 4 which shows the results of roughness surveys on approximately 3,500 km of mainly national roads in 2001 and 2004. It can be seen that there has been a marked increase in the length of excellent roads, primarily through improving the roads that were in the fair category.

Table 4 Pavement Condition Survey Results



Source: Analysis of MCTPC Data, April 2004

1.2.2 Traffic

The road network is lightly travelled; only 12% of National roads carry over 1,000 vehicles/ day as shown in Table 5. Provincial and rural roads generally carry traffic <50 vehicles/ day. The low traffic flows are a reflection of the low levels of vehicle ownership (7 vehicles/ 1,000 people) in 2002 there were 150,000 motorcycles, 30,000 cars and light trucks; and 10,000 heavy trucks and buses registered.

Table 5 National Road Traffic Distribution

Percentage of National Roads by AADT (vehicles/day)					
<100	100- 300	300-1000	1000- 3000	3000-10000	>10000
18.4%	37.8%	32.1%	9.4%	2.0%	0.3%

Source: Analysis of MCTPC Data, April 2004

1.2.3 Rural Infrastructure

Infrastructure is strongly related to the development of off-farm employment opportunities, farmers' integration into the market economy and increased agricultural productivity, which in turn are key to increasing rural incomes and alleviating rural poverty. Table 6 provides an overview of access to rural infrastructure and services by expenditure quintiles; it shows that there is a clear correlation between the availability of rural infrastructure and per capita expenditures. The rural population in the lowest two expenditure quintiles is significantly less well served by rural roads, public transportation, electricity, markets and safe water supply than the population in the top expenditure quintiles. Similarly, the lowest expenditure quintiles have significantly less access to support services, such as visits by extension officers. The table also demonstrates that rural areas in Lao PDR in general face severe infrastructure constraints. About one third of all villages and 22% of the population are in areas which are not accessible by truck, only 11% of the population lives in villages with access to electricity and only 7% live in villages with a permanent market.

Table 6 Rural Accessibility by Population (Lao PDR)

Expenditure Quintiles	% of Population with Access					
	20	40	60	80	100	Avg.
Village can be reached by truck						
Never	36	29	16	14	6	22
Always	30	41	57	63	75	50
Dry season only	33	31	26	22	20	28
<1 km from public transport	25	26	40	48	61	37
>10 km from public transport	36	25	17	14	11	22
School in village	88	91	95	94	96	92
Market in village	3	5	8	12	12	7
Visit in last 12 months by extension worker						
Agriculture	30	38	44	42	38	38
Livestock	21	27	33	35	36	29
Safe water	21	29	41	37	41	33

Source: Social Development Assessment, World Bank Report 13992-LA, 1995

Accessibility is essential to promote agricultural development and rural development in general. Difficult accessibility conditions hinder farmers' adoption of new technologies, use of information and support services and result in higher input and lower output prices or prevent access to input and output markets altogether. Accessibility is also important for the development of off-farm employment because it increases the rural population's mobility, allowing those seeking ‘off-farm’ employment to travel to areas with demand for unskilled labour.

1.3 Road Maintenance

Lessons from the Road Maintenance Initiative (RMI) under the Sub Saharan Africa Transport Policy Programme show that the provision of adequate stable flow funds is critical for successful contract maintenance. To create this flow of funds, many countries have opted for the establishment of a road fund.

1.3.1 Road Maintenance Fund

In accordance with the Prime Minister’s Decree No.09/PM dated 15/01/2001, the Lao Government agreed to set up the Road Maintenance Fund (RMF) in order to ensure an adequate, sufficient, constant and stable source of revenues for road maintenance works. The target was that the RMF would be able to finance the maintenance for all roads in the country by the year 2009.

1.3.2 Maintenance Management

The Provincial Road Maintenance Management System (PRoMMS) was developed under RMP 1. One of its uses is to prepare the 'Annual Routine and Periodic Maintenance Plan' for the District and Rural Roads (DRR) and bridges. The total DRR network is 15,294 km of which 3,848 km is thought to be in a maintainable condition.

The costs used by the PRoMMS for routine maintenance are labour based, equipment based and emergency works (set at 10% of the routine maintenance cost). The periodic maintenance is based on actual cost, calculated and adjusted for regional differences. Routine maintenance and periodic maintenance for culverts and small improvement works such as the installation of culverts are included in the cost estimates. A comparison between the unconstrained budget, assuming that the average road condition will improve over a 10 year period and therefore the number of people without year round access will reduce, shows a large gap between the needs and the actual funding for road maintenance.

Typically, local resources should cover a significant portion of the expense of local road maintenance and, to this end, the GoL has looked to community participation as a means of providing basic access to rural communities.

1.3.3 Community Participation

Community participation in road maintenance was developed under LSRSP II to involve local communities in the process of planning and implementing investment and maintenance works on district and community roads, as well as on other types of access. The reason for involving rural communities is that public funds are insufficient to create and sustain the basic access that is needed in order to help provide basic access to rural people.

A study on community participation in rural road maintenance which was conducted as part of the RMP 1 which covered 201 villages in Luang Namtha and Savannakhet provinces concluded that most villagers are in favour of a system that can incorporate their participation in rural road maintenance on condition that tools and materials, and payment for time spent is provided.

The conclusion was that a subsidised road maintenance system, where training, tools and materials were provided free of charge, would only be successful where a clear sense of ownership could be established, such as a road linking up a village to a core road, and that village labour would expect to be be paid.

1.3.4 The Community Road Model

Thus an approach to integrate Participatory Rural Transport Planning (PRTP) with village-based maintenance and improvement of rural access was formulated called the Community Road Model (CRM). The CRM is designed as a sustainable management model for the further development of basic access in rural areas of Lao PDR. Its in-built cost-sharing principles result in a reduced cost for the government with the aim to make the system financially sustainable. The system is based on the critical assumption and pre-condition that only by involving the villagers in the planning and decision-making process can a cost-sharing system ever be equitable, fair, and most of all sustainable.

1.3.5 Bokeo Province Data

Bokeo is one of the 17 provinces that, together with the prefecture of Vientiane and the special zone of Xaisomboun, constitute the Lao PDR. The province was created in 1983 when it was split from Louang Namtha province and has a total land area of 6,196 km2. The province is bordered by the province of Louang Namtha on the north, the province of Xaignabury to the south and the province of Oudomxai on the east, the western boundary borders on Thailand.

Population

The total population of Bokeo province is 141,000 as detailed in Table 7.

Table 7 Bokeo Population Statistics (2003)

Location	Area (km)	Population ('000)			Population Density
		Total	Female	Male	
Lao PDR	236,800	5,679.0	2,872.3	2,806.7	24.0
Bokeo	6,196	141.0	71.3	69.7	22.8

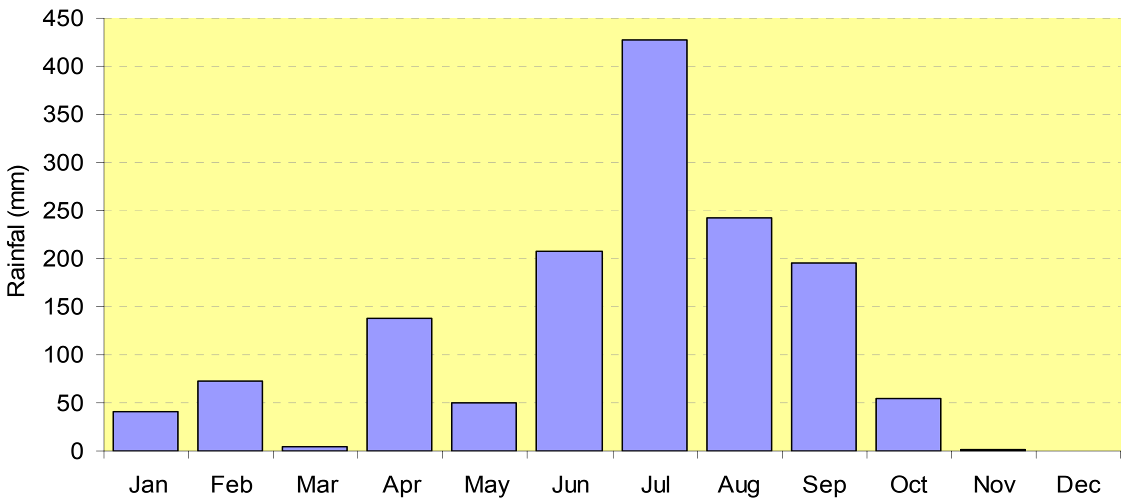
Source: National Statistics Centre

Climate

Lao PDR is in AEZ 3[2] , characterised as warm humid tropics. The climate is tropical, dominated by the monsoons, especially the southwest monsoon from May to October, which brings up to 75% of the annual rainfall. The average annual rainfall for much of the country is between 1,300 and 1,500 mm. Rainfall exceeding 3,000 mm is not uncommon at higher elevations. Temperatures are highest in April and early May. The period October or November to February or March is coolest, depending on location. Frost is sometimes recorded at higher elevations. Generally speaking, the monsoon season produces severe rain that lasts for short periods of time.

Bokeo province has a subtropical type of climate. The temperature ranges fro 21°C in December to 28°C in May. The dry period usually starts in October and the wet period usually starts in June, although heavy rainfall is generally only experienced during July as shown in Figure 1.

Figure 1 Bokeo Province Rainfall Trend



Source – Department of Meteorology and Hydrology

Road Network

Bokeo consists of relatively small communities scattered over a large area. Many villages are isolated and have no road access. The majority of roads in the province are earth roads, comprising 64% of the road network. Gravel roads comprise 29% of the network.

Economy

Bokeo's economy is primarily a subsistence economy. Farming is the most important economic activity and is the main source of income for the majority of the rural population.

2 Agro Ecological Zones (AEZ) as defined by the Technical Advisory Committee of the CGIAR (TAC 1994)

2 THE SEACAP 17 PROJECT RATIONALE

The goal of the South East Asia Community Access Programme (SEACAP) is to support the uptake of low cost, sustainable solutions for rural access. Improving the sustainability and affordability of rural access will lead to improved access to economic opportunities and to health and education services, thereby creating opportunities for pro-poor growth and poverty alleviation. SEACAP 17 aims at identifying cost-effective methods of improving all-year access to the rural poor through low-cost locally resource based improvement of problematic lengths of road resulting in effective and sustainable rural access roads. The SEACAP 17 project area is shown on Figure 1 and the actual roads in Figure 2.

The overall goals of SEACAP 17 are to investigate and to promote suitable methods of sustainable technology for the construction of low volume roads. Essentially, the project has questioned the practicalities of gravel surfacing over the long term and sought to develop options and strategies for alternative, more sustainable pavement structures.

The Northern Economic Corridor (NEC) project has upgraded (gravel to bitumen) the Route No.3 (R3) road from Houay Xai on the Thai/ Lao PDR border with Boten on the Chinese border as shown in Figure 1. The primary goal of the NEC project was to accelerate regional development through more efficient infrastructure networks. A direct link between the PRC and Thailand via Lao PDR reduces transport costs in the regional project influence area, and increases the efficiency of vehicle, goods, and passenger traffic.

The road links two remote provinces of Bokeo and Louang Namtha in northern Lao PDR. High dependence on subsistence agriculture is a major reason for poverty in the project area. According to the participatory poverty assessment of December 2001 the problem most cited by villagers as preventing economic growth is lack of all-weather roads by which to market their produce. Accessibility to markets in the wet season is essential since that is when most agricultural goods are mature and ready for sale. Areas that have potential for developing cash crops cannot take advantage of such income enhancing opportunities due to lack of reliable transportation. Table 8 shows the percentage of villages in Bokeo, Louang Namtha and Lao PDR that have access to main roads and thus the rest of the country. Louang Namtha is among the most transport deficient areas in the country.

Table 8 Access of Villages to Main Roads

Province	Percentage of all Villages in the Region (%)		
	Greater than 6 km to a Main Road	Access in the Wet Season	Access in the Dry Season
Louang Namtha	42%	31%	41%
Bokeo	38%	41%	77%
Lao PDR	35%	50%	79%

Source: National Statistics Centre, Vientiane

Restricted access and weather dependent roads also have implications for the cost effectiveness of development programs, on the ability to target health care and educational services to the poor and the sustainability of such programs.

Figure 2 Location of Road No.3 and the NEC Project

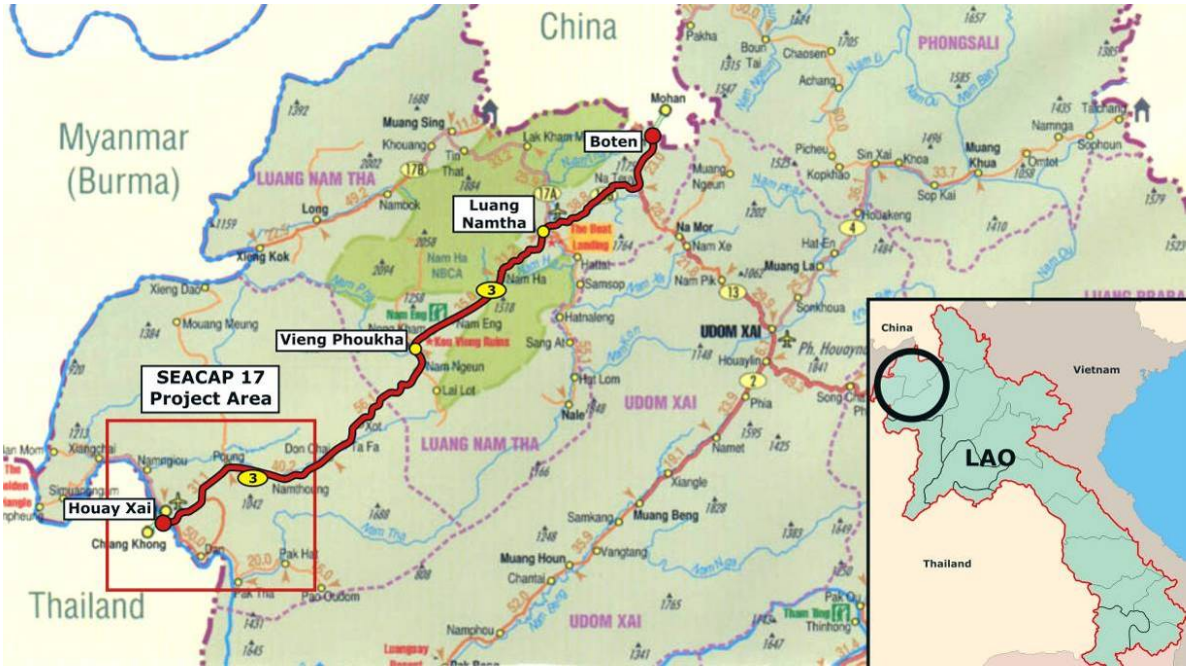
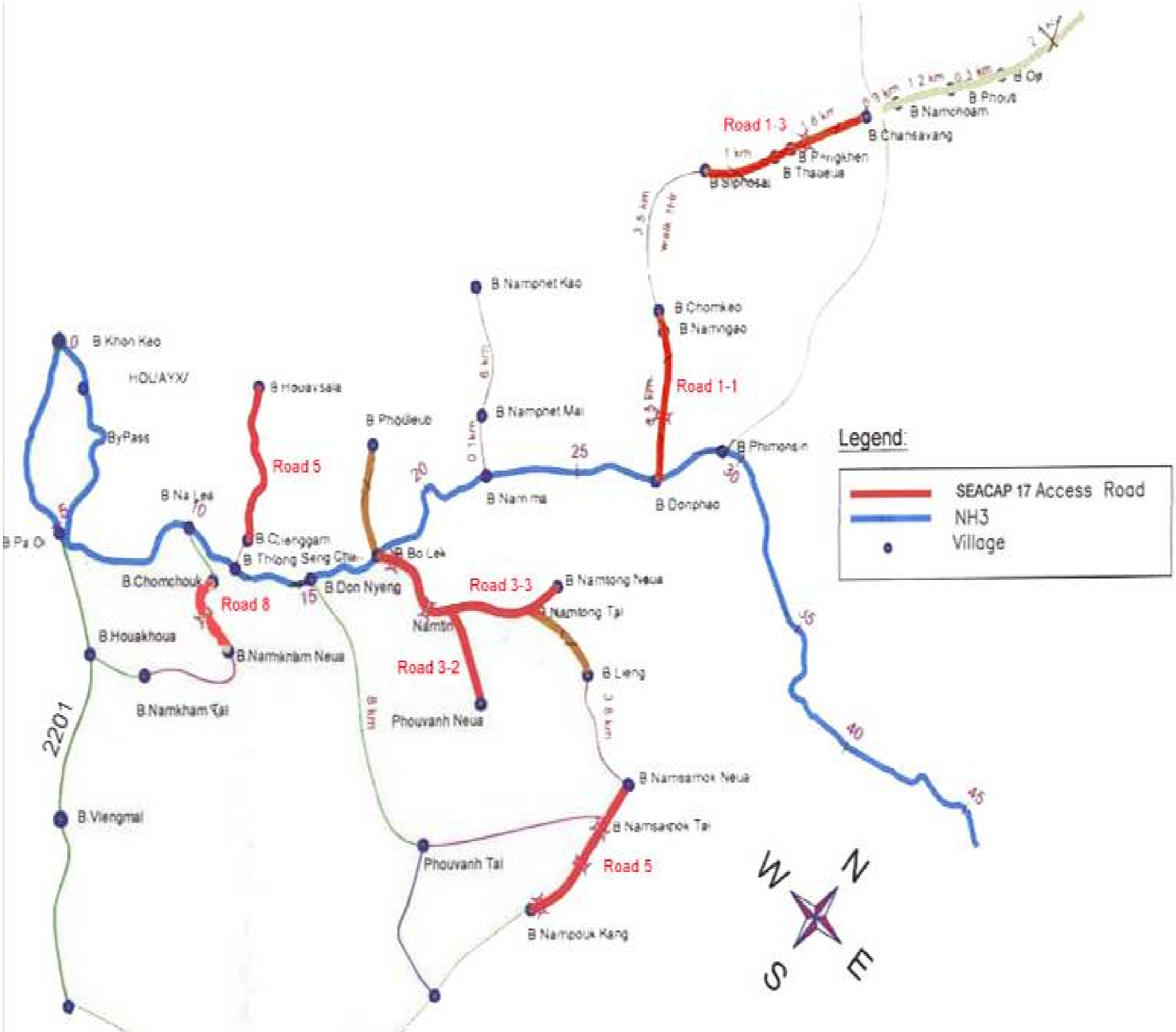


Figure 3 Location of the Selected SEACAP 17 Access Roads



2.1.1 The NEC Gravel Road Design

The NEC rural access road pavement thickness was calculated based on a representative traffic mix, 20 year traffic volume and gravel loss of 8% per year, however recent research in South East Asia suggests that annual gravel loss can be as high as 50 mm. The principal concern about the NEC pavement design was the likelihood of erosion of the pavement and eventual loss of access. Therefore, trial pavements were introduced on a number of the steep gradients, which will maintain access through the problematic areas. In addition to this, the NEC construction contract includes an item for the provision of material stockpiles along the access roads for future routine maintenance. This will allow maintenance and minor repairs to other sections of the access roads where pavement loss becomes problematic. It is therefore considered that the pavement design for the remainder of the Houay Xai access roads will be adequate for the level of service to be provided. The NEC gravel pavements will be used as 'standard' pavement sections during the monitoring phase.

Essentially, three specific wet-season problems were identified, during this project, that cause sections of rural access roads to become impassable, namely:

- Rapid and serious pavement deterioration due to weakened subgrades with inadequate pavement, particularly in flat, flood prone areas;
- Rapid and serious pavement deterioration due to erosion of pavement materials particularly on steep gradients, and;
- Road blockages or collapse through landslips in hilly and mountainous terrain.

2.1.2 Pre-Construction Data:

The data collected prior to making decisions on the types of pavement to be constructed included the following:

- Visual subgrade assessment;
- Horizontal gradient;
- Vertical gradients;
- Ground water;
- Cross drainage;
- Distance from the main road;
- Proximity to construction materials;
- Availability of construction materials;
- Construction cost;
- Traffic, and;
- Population.

For the design of the pavement test results for the road subgrade and local construction materials will also be required

2.1.3 SEACAP Pavements

The maximum use of the NEC access road designs was used for the trial pavements. There have been no alterations to the geometric alignment, drainage or embankment protection works. At specific locations along the access roads the NEC gravel pavement has been replaced with a SEACAP trial pavement. The pavement types selected for the trials were taken from those presented at the Knowledge Exchange Workshop in December 2004 and described above.

The trial pavement designs have different layer thicknesses depending on the subgrade strength however as no subgrade test results were available a minimum subgrade strength was defined according to the NEC Specification. During construction a number of subgrade tests were undertaken to confirm the trial pavement designs.

The approach adopted was to identify key sections at specific locations along the access roads and to replace the standard NEC gravel pavement proposed for these sections with a SEACAP trial pavement. Trial pavement were constructed over a 400-500 m length with a 50-100 m ‘training section’ was included for each pavement type. The training section was used to instruct the contractor on the construction techniques for the trial pavements. This gave reasonable assurance that the trial sections were properly constructed and could therefore be readily evaluated following monitored.

The pavement types selected for the trials were as follows:

- **Standard NEC Gravel**, this construction comprises 200 mm of gravel wearing course with a bearing capacity of CBR≥25% constructed on an in-situ subgrade which, after mechanical modification, should have a bearing capacity of CBR≥8% in fill and CBR≥5% in cut. Alternatively, where the in-situ subgrade does not meet these standards a 300 mm thick selected subgrade layer should be imported having a bearing capacity of CBR≥8%.
- **Bamboo Reinforced Concrete**, a bamboo reinforced surface consists of a layer of concrete, reinforced with strips of bamboo, and laid upon a compacted base.
- **Geocell**, manufactured plastic formwork is used to construct in-situ concrete paving. The plastic formwork is sacrificial and remains embedded in the concrete creating a form of block paving.
- **Mortared Stone**, this surface consists of a layer of large stones, placed closely together to form a tight surface. The voids are filled with mortar to form an impervious layer.
- **Hand Packed Stone**, this surface consists of a layer of large stones into which smaller chips are packed. Remaining voids are filled with sand or gravel to form a strong and semi-impervious matrix.
- **Concrete Paving Blocks**, the blocks are precast in moulds and then laid side by side on a prepared subbase. Gaps between blocks are filled with fine material to form a strong and semi-impervious layer.
- **Sand Seal**, this seal consisting of a machine applied film of bitumen followed by the application of excess sand which is lightly rolled into the bitumen.
- **Otta Seal**, this surface comprises a layer of binder followed by a layer of aggregate that is rolled into the binder using a roller or loaded trucks. It is different to surface dressing in that an 'all in' graded gravel or crushed aggregate is used instead of single sized chippings. The layer is thicker and more bitumen is used.
- **Engineered Natural Surface**, this construction is used where the existing subgrade material comprises natural gravel with the same engineering characteristics as the pavement layer.

2.1.4 Estimated Construction Costs

The cost estimates were prepared from unit rates derived from recent bid prices and from first principles utilising experience of road construction in Lao PDR. The initial intention was to balance the higher cost solutions with low cost solutions to ensure there would be no significant increase in the cost estimates. However due to the lack of subgrade information, it was not possible to identify sections where lower cost pavements could be utilised prior to tests during construction.

The estimated cost during the design phase of SEACAP 17 for the 28.8 km package was USD 881,200, which compared with the original NEC estimate of USD 735,800. The reason for the cost increase was the introduction of the more expensive SEACAP trial pavements.

2.2 The Design of the Access Roads

2.2.1 Road Alignment

Apart from some small changes that were executed during construction, the SEACAP 17 consultant had no input into the design of the alignment of these access roads. The consultant did, however, conduct a detailed topographic survey along the original tracks and then again along the finished access roads.

Although design using a computer based, topographic modelling system has probably become the norm and offers considerable advantages over traditional systems, especially in terms of reviewing alternatives and computing quantities, care must be taken that the opportunities offered by such systems do not overwhelm the basic requirement to keep design as simple as possible and make maximum possible use of existing alignments.

2.2.2 Extent of Earthworks

The NEC geometric design had followed the standards set out in the specification without any variation and this has resulted in some large earthworks which may be inappropriate for rural assess roads. It should be noted that steep sections of road, while difficult during the wet season, have been used for many years and using by relaxing the required gradients.

The terrain in which each road was located was initially classified using the customary three grades of Flat, Rolling and Hilly based on road gradients. The earthworks for the seven roads are related to this classification in Table 9 it can be seen that the classification broadly correlates with the earthworks; length of road in cut increases with terrain severity whilst length on fill decreases. It is suggested that the earthworks could have been reduced significantly with the adoption of the more recent standards and with use of a 'spot improvement' philosophy to ensure viability of the resulting steeper gradients.

Table 9 Earthworks Statistics for the Access Roads

Road No.	Terrain Class.	Percentage of the length greater than:	
		Cut -0.3 (m)	Fill 0.3 (m)
Access Road No.: 1-1	Hilly	21%	43%
Access Road No.: 1-3	Rolling	11%	40%
Access Road No.: 2	Flat	3%	74%
Access Road No.: 3-2	Rolling	19%	35%
Access Road No.: 3-3	Rolling	4%	61%
Access Road No.: 5	Hilly	30%	26%
Access Road No.: 8	Rolling	15%	38%

It must be noted, however, that, in the context of this project, excavation is relatively cheap at just over USD 1/m³, embankment relatively expensive at USD 2/m³ using excavated material and USD 3/m³ when borrow must be provided and that a reduction in excavation would not necessarily yield any great saving. More important is the question of whether the small improvements in gradient, achieved at considerable cost to the landscape can result in year round vehicular access without the additional expenditure for improved pavements.

In order that specific engineering solutions can more easily be related to alignment, a more detailed division of terrain types by gradient is proposed as shown in Table 10. It is generally accepted that gradients of greater than 15% are undesirable; however, along short sections, if designed and constructed properly, steep gradients may both be practical and offer significant construction cost savings.

Table 10 Terrain Type as Defined by Gradient

Terrain	From	Up To
Flat	0.0%	3.0%
Slight	3.0%	5.0%
Moderate	5.0%	10.0%
Steep	10.0%	15.0%
Very Steep	15.0%	25.0%

2.2.3 Subgrade Design Bearing Capacity

Since no investigation into the subgrade quality had been conducted during the design stage an investigation of the subgrade quality was undertaken. A number of trail pits were excavated and material samples tested in a laboratory and Dynamic Cone Penetrometer (DCP) survey was undertaken. The DCP data was correlated against the laboratory CBR test data and the design values, that were used to specify the pavement layers, are shown in Table 11.

Table 11 Summary of the Design Subgrade Bearing Capacity

Access Road No.:	Adjusted Bearing Capacity (CBR%)	Laboratory Tests (Trial Pits on Centreline)			
		CBR (%)	MDD (g/cm³)	PI (%)	OMC (%)
1-1	5	6	2	16	18
1-3	10	14	2	16	12
2-2	7	7	2	13	13
3-2	6	14	2	17	17
3-3	6	5	2	16	21
5	7	7	2	17	20
8	10	7	2	17	16

Where CBR Californian Bearing Ratio
MDD Maximum Dry Density
PI Plasticity Index
OMC Optimum Moisture Content

The location and type of each of the trial sections is listed in Table 12 Each access road comprised a variation of conditions which enabled the categorisation of good, standard and problematic lengths and therefore. A summary of the pavement structures applied is shown in Table 13.

2.2.4 Specifications

The construction specifications for each of the trial pavements were developed from similar projects in the region and worldwide. In producing the Specifications every effort was made to minimise the use of unfamiliar construction practices and terminology

Specifications were drafted and the NEC Contract Documents amended to include the construction of the trial sections. The trial pavement specifications, as included in the contract documents, were altered to incorporate a number of issues that were raised by the Contractor and the Consultant.

These specifications helped in the formation of a standard specification for the construction of rural access roads for Lao PDR.

Table 12 List of the SEACAP Trial Sections

Access Road						Trial Section Pavement Type		Lengths		
No.	From	To	Start (km)	End (km)	Length (m)			Start (km)	End (km)	Length (m)
1-1	B.Phimonsine	B.Chomkeo	0.000	2.183	2,183	*Control Section*	*NEC Standard Gravel*	0.500	0.700	200
						Training Section	*None*			
						Pavement Trial	None			
1-3	B.Chansavang	B.Siphosai	0.600	3.487	2,887	*Control Section*	*NEC Standard Gravel*	1.220	1.420	200
						Training Section	*None*			
						Pavement Trial	None			
2	B Namphoukang	B.Namsamokneua	0.000	5.350	5,350	*Control Section*	*NEC Standard Gravel*	0.400	0.600	200
						Pavement Trial	Hand Packed Stone	0.600	1.080	480
						Training Section	Hand Packed Stone	1.080	1.100	20
3-2	B.Bolek	B.Namtong Nuea	0.000	6.880	6,880	*Training Section*	Single Otta Seal	0.020	0.120	100
						Pavement Trial	Single Otta Seal	0.120	0.320	200
						Pavement Trial	Double Otta Seal	0.320	0.520	200
						Training Section	Eng' Nat. Surface	0.520	0.620	100
						Pavement Trial	Eng' Nat. Surface	0.620	0.920	300
						Training Section	Mortared Stone	0.920	1.020	100
						Pavement Trial	Mortared Stone	1.020	1.520	500
						Control Section	*NEC Standard Gravel*	1.520	1.720	200

Access Road						Trial Section Pavement Type		Lengths		
No.	**From**	**To**	**Start (km)**	**End (km)**	**Length (m)**			**Start (km)**	**End (km)**	**Length (m)**
3-3	B.Namtin	B.Phouvanekao	0.000	2.000	2,000	*Control Section*	*NEC Standard Gravel*	1.600	1.800	200
						Training Section	*None*			
						Pavement Trial	None			
5	B Gam Mining	B.Houaysala	0.000	6.093	6,093	*Training Section*	Concrete Paving Blocks	0.900	0.920	20
						Pavement Trial	Concrete Paving Blocks	0.920	1.400	480
						Pavement Trial	Bamboo Concrete	1.950	2.325	375
						Pavement Trial	Bamboo Concrete	2.325	2.500	175
						Training Section	Bamboo Concrete	2.500	2.525	25
						Pavement Trial	Geocells	2.750	2.950	200
						Pavement Trial	Geocells	2.950	3.050	100
						Pavement Trial	Geocells	3.050	3.125	75
						Training Section	Geocells	3.125	3.150	25
						Control Section	*NEC Standard Gravel*	4.500	4.700	200
8	B.Chomchouk	B.Namkhamneua	0.000	2.770	2,770	*Training Section*	Sand Seal	1.500	1.630	130
						Pavement Trial	Sand Seal	1.670	2.200	495
						Causeway	35.400			
						Control Section	*NEC Standard Gravel*	2.200	2.400	200
				Total:	**28,164**				**Total:**	**5,500**

Table 13 Pavement Structures for the SEACAP Trial Sections

Pavement Types		1 Standard NEC Gravel	2 Bamboo Reinforced Concrete	3 Geocell	4 Mortared Stone	5 Hand Packed Stone	6 Concrete Paving Blocks	7 Sand Seal	8 Otta Seal	9 Engineered Natural Surface
Surface Layer	Type	Nat. Gravel CBR ≥ 25%	Concrete	Concrete	Stone	Stone	Blocks	Sand Seal	S.Seal + Otta Seal / Double Otta Seal	Nat.Gravel CBR ≥ 25%
	Thickness	200 mm	125 mm 150 mm	75 mm 100 mm 150 mm	65 mm	100 mm	65 mm	10 mm	20 mm 30 mm	
Sub-surface Cushion	Type		Sand	Sand	Sand	Sand	Sand			
	Thickness		20 mm	20 mm	50 mm	50 mm	20 mm			
Base	Type							C.Rock CBR≥80%	C.Rock CBR≥80%	
	Thickness							150 mm	150 mm	
Subbase	Type		Nat.Gravel CBR≥25%	Nat.Gravel CBR≥25%	Nat.Gravel CBR≥25%	Nat.Gravel CBR≥25%	Nat.Gravel CBR≥25%	Nat.Gravel CBR≥25%	Nat.Gravel CBR≥25%	Nat.Gravel CBR≥25%
	Thickness		125 mm	125 mm	125 mm	125 mm	125 mm	120 mm	120 mm	Levelling only
Selected Subgrade	Type	Nat.Gravel CBR≥8%	Nat.Gravel CBR≥7%					Nat.Gravel CBR≥7%		
	Thickness	300 mm	150 mm					150 mm		
Subgrade	Type	CBR≥5%	CBR≥5%	CBR≥5%	CBR≥5%	CBR≥5%	CBR≥5%	CBR≥5%	CBR≥5%	CBR≥5%
	Thickness	Varies	Varies	Varies	Varies	Varies	Varies	Varies	Varies	Natural ground

2.2.5 Construction Costs

The construction costs for the project roads based on the Contractor's tender offer are shown in Table 14.

Table 14 Tender Price for the Access Roads

Bill	Description	Amount (LAK)	Amount (USD)	Composition
100	General provisions	506,970.24	57,383.98	6.05%
200	Earthworks	2,842,531.07	321,746.19	33.93%
300	Pavement	1,472,111.14	166,628.31	17.57%
400	Drainage	1,645,225.41	186,223.12	19.64%
500	Structures	54,886.40	6,212.59	0.66%
600	Miscellaneous	98,656.16	11,166.89	1.18%
	Subtotal	6,620,380.42	749,361.09	79.02%
900	Trial Pavements			
	Pavement	1,528,577.90	173,019.79	18.24%
	Monitoring (Cost of beacons and equipment)	229,204.00	25,943.61	2.74%
	Subtotal	8,378,162.32	948,324.48	100.00%
	Contingencies	837,816.23	94,832.45	
	Dayworks	61,872.00	7,003.29	
	Total Tender Price	**9,277,850.10**	1,050,160.18	

For comparison purposes, costs in this table, originally tendered in LAKs, are shown in US dollars at the July 2008 exchange rate of USD 1 = LAK 8,835

The construction costs for each of the trial pavement types based on the area constructed and using the Contractor's unit rates are shown in Table 15.

Table 15 Costs of Trial Pavement Types

Pavement Description		Length (m)	Cost (USD)	Cost/m² (USD)
1	Hand Packed stone	500	11,073	6.328
2	Mortared Stone	600	13,288	6.328
3	Sand Seal	625	13,720	6.272
4	Single Otta Seal and Sand Cover	300	8,070	8.070
5	Double Otta Seal	200	6,370	9.100
6	Bamboo Reinforced Concrete			
	125mm	375	19,978	15.222
	150mm	200	12,417	17.739
7	Concrete Paving Block	500	51,793	29.596
8	Geocell Concrete Pavement			
	75mm	200	13,180	18.829
	100mm	100	8,212	23.464
	150mm	100	11,457	32.734
9	Engineered Natural Surface	400		
	Total	**4,100**	**169,560**	
	NEC Standard Gravel Control	1,400	11,891	2.427

July 2008: USD 1 = LAK 8,835

In each case the cost per square metre is the cost of the designated pavement construction above the prepared subgrade. On this basis the cost of Engineered Natural Surface is nil since this is, effectively, the prepared subgrade in an area where the in situ material is of a high enough quality to act as the road pavement/ surface.

Examination of the construction costs for each pavement type indicates two obvious irregularities:

- The cost of a 150 mm Geocell concrete pavement is almost double that of a 150 mm Reinforced Bamboo concrete pavement although the cost of 150 mm Geocell form material is only USD 6/m² against which must be set the cost of providing the bamboo reinforcement and the edge formwork required for the Bamboo Reinforced pavement; and,
- The cost of plain Concrete Block paving is also remarkably high, particularly when compared with the costs of Hand Packed or Mortared Stone pavement (USD 6.328/m²). Even allowing for the cost of concrete it would appear that concrete block paving, which is simpler to lay than the Stone pavements, should have cost no more than USD 14.15/m² (LAK 125,000/m²) at the very most.

Unfortunately, because the project was constructed by a single contractor under a single contract there are no comparative prices available to allow us to refine these rates by reference to other commercially based costing, however, for the purpose of any further analysis the cost of concrete block paving will be considered USD 14.15/m².

The costs of all the proposed trial pavements are substantially higher than for a simple gravel pavement; a 200 mm layer of good quality gravel at this contractor's rates amounts to USD 2.427/m².

Because this trial was superimposed on an existing road project there was no opportunity to investigate, in detail, the possibility of making savings in earthworks costs through the use of more extreme alignments which the greater durability of the improved pavements should make possible. However, the road cutting at the start Road 3-2 as discussed earlier, which was undertaken as a part of the original project design in order to reduce a steep gradient, clearly illustrates the possibility for savings of this nature.

3 THE CONSTRUCTED TRIAL PAVEMENTS

3.1 Standard NEC Gravel

Gravel surfacing is not always the best solution for rural roads in many circumstances. Work undertaken in neighbouring Vietnam[3] reported that although gravel has been the commonly recommended surfacing in recent rural road rehabilitation programmes, there was little available data on its engineering performance and deterioration and that this knowledge gap required urgent attention.

The subsequent SEACAP 4[4] investigations at a significant number of road sites in Vietnam, found serious shortcomings with the use of gravel due to factors relating to material quality, material availability, climate, terrain, drainage provision and maintenance. Overall gravel loss figures indicate that around 58% of the surveyed sites were suffering unsustainable deterioration, while 28% were losing material at twice the sustainable rate.

Care needs to be exercised when considering these figures as any gravel road is affected by a range of parameters. For example a gravel road in mountainous terrain may have steep gradients, but it is unlikely that the steep gradients extend for the length of the entire road. It is much more likely that the steep gradients comprise, say, just 5% of the length. Therefore, while the gravel surfaced pavement may not be suitable for those steep sections, it may be perfectly suitable for the remaining 95% of the road. It often happens that the design does not provide for additional improvement to the steep sections of the road, the access is broken in the wet season and the entire road is said to be impassable when, in reality, it is only a short section that is impassable. The consultant’s suggested concentration of effort and funds on the problematic lengths is termed the ‘spot improvement design philosophy’ and will be discussed further in this report. This work aims to trial more sustainable, robust pavement structures.

3.2 Bamboo Reinforced Concrete

The construction method is the same as ordinary steel mesh reinforced concrete pavements with the exception that a bamboo mesh replaces the steel mesh. The slab widths were 3.5 m wide (the carriageway width) with a length of 5 m. No dowels were used between the slabs. The specification recommends that the bamboo, which comprises strips cut from large bamboo stems, shall have a minimum thickness of 5 mm and a minimum age of 4 growing years and be dried for a season.

Subsequent to the work under this project, an investigation has been undertaken to establish exactly what contribution to the overall strength of the pavement the bamboo contributes. It was concluded that while this form of construction is quite common in South East Asia, the bamboo does not contribute at all to the structural integrity of the pavement and in fact may have a detrimental effect[5], therefore, bamboo as reinforcement is not recommended for concrete roads.

In consequence, the bamboo reinforced pavement should be treated as a mass concrete pavement without the use of any steel, and should be monitored as such.

Advantages

- Besides the cement, a large amount of the materials needed to construct this pavement can be sourced locally. Aggregates need not be crushed and river gravel and sand can be successfully used.

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3 ***Rural Road Surfacing Research**, SEACAP 1, Final Report, Ministry of Transport Vietnam, December 2006.*

4 ***Rural Road Gravel Assessment Programme**, SEACAP 4, Final Report, Ministry of Transport Vietnam, July 2005.*

5 ***Bamboo Reinforced Concrete Pavements**, J Rolt (TRL Limited), Technical Paper No 1, SEACAP 19. Development of Local Resource Based Standards., South East Asia Community Access Programme Development of Local Resource Based Standards, Royal Government of Cambodia, February 2008.*

- Little sophisticated equipment is required - two smallish concrete mixers can produce a reasonable amount of concrete continually. The construction is well suited to labour based construction and thus to the small scale contractor.
- The resulting pavement is strong and offers long serviceability with little maintenance if constructed properly.

Disadvantages

- Care is needed during the curing period. Loading slabs prematurely may cause failure - ideally the slabs should not be loaded for at least 14 days after concreting.
- Commonly the slabs are 150 mm thick and, even on the 125 mm thick trials conducted here, the cost of the concrete is high.
- While this pavement offers a relatively maintenance free pavement, when repairs are necessary they are difficult to undertake and consequently expensive.

3.3 Geocells

This entails the use of plastic cells as a sacrificial formwork into which concrete is poured and compacted lightly by hand. Rather than a concrete or rigid pavement this construction should be considered more like a flexible block paving surface where the blocks are cast in-situ. The thicknesses trialled varies from the thickness of a paving brick (75 mm) to the thickness of the concrete slabs (150 mm).

Advantages

- This pavement has all of the advantages of the concrete slabs such as the use of locally sourced materials and the fact that little sophisticated equipment is required. Construction is well suited to labour based work.
- The resulting pavement is of a high strength and therefore offers long serviceability with little maintenance. Because it is a flexible pavement it does not crack in the presence of subsurface deficiencies but will deform and, providing the deformation is not too great, should always offer an all weather surface similar to that of block paving.
- It is hoped that thinner pavements will perform as well as thicker pavements and therefore the cost should be lower. Construction time was found to be faster than the concrete slabs as the formwork (cells) were quickly set out and filled with concrete.
- Repairs to this pavement will be much easier and cheaper than that of concrete slabs.

Disadvantages

- Care is needed during the curing period. Loading slabs prematurely may cause failure - ideally the slabs should not be loaded for at least 14 days after concreting.
- It was found that the cost of the Geocell was high as this needed to be imported, however further investigation may source cheaper, local products; especially if a clear requirement is demonstrated.

3.4 Mortared Stone

These pavements are constructed using stone sourced from a quarry. It is necessary to create rectangular dressed blocks of stone which are placed close to one another. The void between the stones is then filled with a cement mortar similar to grouted stone riprap for protection.

Advantages

- The method of construction is almost entirely labour based and needs very little equipment. Only locally sourced natural materials are used except a small quantity of cement for the mortar.
- While skilled labour is required to create the blocks, less skilled labour is required to lay them. Consequently, the pavement can easily be repaired by limited skilled labour.

Disadvantages

- Suitable rock sources must be locally available.
- Requires a high level of expertise and a significant amount of labour and therefore was found not to be suitable for this contractor. It is surmised that unless the contractor has specific masonry expertise, or is able to resource the expertise locally, these highly skilled 'traditional' methods are unsuitable. It is noted, however, that while this contractor proved unable to knap the stone to an acceptable standard there have been major programmes in China, the country of the contractor, using this technology effectively and successfully.
- Slow laborious construction requiring neatness and care.
- The mortar joint is likely to crack under traffic loading, the significance of this is not fully known yet.
- The construction resulted in a very rough surface in this case which is not suited to bicycles.

3.5 Hand Packed Stone

Similar to the mortared stone above except that the voids are filled with sand or crusher dust mixed with smaller chips. The fine material is watered and brushed into the voids while the pavement is compacted with a light roller.

Advantages

- The method of construction is almost entirely labour based and needs very little equipment. Only locally sourced natural materials are used.
- While skilled labour is required to create the blocks, less skilled labour is required to lay them. Consequently, the pavement can easily be repaired by limited skilled labour.

Disadvantages

- Suitable rock sources must be locally available.
- Requires a high level of expertise and a significant amount of labour and therefore was found not to be suitable for a general contractor.
- Slow laborious construction requiring neatness and care.
- The construction resulted in a very rough surface in this case which is not suited to bicycles.

3.6 Concrete Paving Blocks

The contractor cast concrete blocks in his yard, he was able to do this during the earthworks operation on site thus ensuring that the blocks were ready as scheduled. This simple pavement construction results in an attractive flexible pavement.

The joints between the blocks are filled with sand or crusher dust. While it has been suggested that the joints can be sealed with mortar or bitumen this is rarely done worldwide.

Advantages

- Suitable for labour based construction requiring minimal plant and minimal skilled labour.
- Results in a flexibly pavement that will not fail rapidly but will deform in weak areas resulting in a pavement that will remain trafficable under most circumstances.
- The pavement can be easily repaired with minimal skilled labour reusing the displaced blocks.
- Can sustain heavy traffic loads soon after construction.
- Different laying patterns result in an attractive road surface.

- As the blocks remain largely intact during the life of the road there is a high residual value.

Disadvantages

- Requires a significant amount of labour and up front work to construct the blocks.
- Slow laborious construction requiring neatness and care.
- Resulted in a somewhat rough surface.

3.7 Sand Seal

This pavement comprised a crushed rock base of 150 mm primed with MC-70 bitumen at a rate 0.85 l/m². The sand seal was successfully constructed quickly by the contractor using a MC-3000 bitumen applied at a rate 0.80 l/m² followed by a sand cover applied at a rate 0.012 m³/m² and rolled with a 12 t steel wheel roller.

Advantages

- This low cost pavement was easy and rapid to construct.
- Although this pavement as constructed utilises a crushed rock base it might be possible to sand seal a standard gravel road resulting in a more stable non erodible dust free surface.

Disadvantages

- Specialist equipment and plant is required and material (bitumen) needs to be imported, although it should be noted that this equipment is commonly used by contractors.
- Successful construction requires skilled technicians with experience in the construction of bituminous surface dressed pavements. Again, this is fairly common amongst contractors.
- This surface is very susceptible to damage through relatively mild abuse such as dragging of loads, passage of agricultural equipment, vehicle accident damage, etc.
- This is considered a high maintenance option and will need to be resealed every few years, although this activity is fairly easy to perform.

3.8 Single Otta Seal and a Sand Seal

This pavement comprised a crushed rock base of 150 mm primed with MC-70 bitumen at a rate 0.85 l/m². The Otta seal was successfully constructed quickly by the contractor using a MC-3000 bitumen applied at a rate 1.6-1.8 l/m² followed by a sand cover applied at a rate 0.015 m³/m² and rolled with a 12 t steel wheel roller. While it is recommended to use a pneumatic tyred roller in order that the aggregate is kneaded into the surface the steel wheeled roller was allowed due to availability. The overlying sand seal was constructed using a MC-3000 bitumen applied at a rate 0.80 l/m² followed by a sand cover applied at a rate 0.012 m³/m² and rolled with a 12 t steel wheel roller.

Advantages

- This pavement was easy and rapid to construct.
- The pavement structure trialled in this work comprises a crushed rock base, however for low volume rural roads a natural gravel base should be considered. Expanding on this it might be possible to apply an Otta seal to a standard gravel road resulting in a more stable non erodible dust free surface.
- Aggregate specifications are not onerous and natural gravel can be used.
- Results in a thick durable surface with a design life of up to 10 years.

Disadvantages

- Specialist equipment and plant is required and material (bitumen) needs to be imported, although it should be noted that this equipment is commonly used by contractors.

- Successful construction requires skilled technicians with experience in the construction of bituminous surface dressed pavements. Again, this is fairly common amongst contractors.
- This type of surface is a relatively heavy user of bitumen. Whilst this is likely to promote longevity it also increases cost.

3.9 Double Otta Seal

This pavement comprised a crushed rock base of 150 mm primed with MC-70 bitumen at a rate 0.85 l/m². The Otta seal was successfully constructed quickly by the contractor using a MC-3000 bitumen applied at a rate 1.6-1.8 l/m² followed by a sand cover applied at a rate 0.015 m³/m² and rolled with a 12 t steel wheel roller. The second Otta seal was a repeat of the first.

Advantages

- This low cost pavement was easy and rapid to construct.
- The pavement structure trialled in this work comprises a crushed rock base, however for low volume rural roads a natural gravel base should be considered. Expanding on this it might be possible to apply an Otta seal to a standard gravel road resulting in a more stable non erodible dust free surface.
- Aggregate specifications are non-onerous and natural gravel can be used.
- Results in a thick durable surface with a design life of up to 10 years.

Disadvantages

- Specialist equipment and plant is required and material (bitumen) needs to be imported. Although it should be noted that this equipment is commonly used by contractors.
- Successful construction requires skilled technicians with experience in the construction of bituminous surface dressed pavements. Again, this is fairly common amongst contractors.
- Even more so than the single Otta seal, his type of surface is a heavy user of bitumen. Whilst this is likely to promote longevity it also increases cost.

3.10 Engineered Natural Surface

These pavements are gravel surfaces but comprise shaped and compacted existing in-situ soil material to form carriageway with a crossfall of about 5% to disperse rainwater into side drainage in order to ensure that rain water flows away from the road. In general the in-situ soil should have a bearing strength of CBR≥15%.

Advantages

- Very low cost suitable for low and light traffic volumes.
- No imported materials required suitable for labour intensive construction with inexpensive equipment and plant.
- Easy to maintain using labour or simple, low cost, grading equipment.

Disadvantages

- Can only be considered when there are high quality in-situ materials.
- High maintenance requirements.
- May fail in wet weather; however with careful maintenance, specifically of the drainage, this can be avoided in future years.
- Dust pollution in dry weather.

4 MAINTENANCE REQUIREMENTS, CAPACITY AND COST

No road pavement can be expected to perform well in the long term without receiving appropriate maintenance. The road as a whole requires regular maintenance which may vary somewhat depending on climate and terrain but which will consist essentially of cleaning drains and drainage systems, vegetation control, shoulder maintenance and general upkeep and repairs to the road infrastructure, guard rails, signs, etc. These items are independent of pavement type. The maintenance requirements for the road pavement will vary considerably depending on the pavement construction and the traffic to which it is subjected. There is, in general, a trade-off between pavement first cost and subsequent maintenance costs. This trade-off, however, is not constant but will vary with conditions of use. A gravel pavement used on a stretch of straight and level embankment will require very substantially less maintenance than the same pavement employed on a steep gradient with severe curves.

The most cost effective choice of pavement can be assessed on the basis of the estimated whole life cost of the pavement, that is the initial construction cost plus the amortised costs of future pavement maintenance.

In the case of roads carrying substantial traffic this estimation can be complicated by the need to consider the cost implications for that traffic, Vehicle Operating Costs (VOC), of varying road conditions resulting from alternative maintenance scenarios together with variations in the maintenance requirements generated by different traffic levels.

In the case of the project roads, traffic is extremely light and maintenance requirements will be the result more of environmental effects (primarily, if not wholly, rainfall) than of traffic, particularly in the cases of natural and gravel surfaces. Bituminous bound surfaces can be expected to resist environmental effects for some time but they will eventually require repair and renewal. The plain sand seal, in particular, is likely to succumb fairly rapidly as it will be susceptible to damage from even the light traffic on these roads, opening the way to subsequent erosion damage in the wet season. The hard surfaces of the stone, block and concrete pavements can be expected to last much longer.

Routine maintenance must be carried out on the project roads to ensure sustainable access. This concept is well understood in MPWT; however, there are constraints in that the funding available is insufficient to meet the needs of the rural road network. Maintenance works ongoing in Lao PDR are mainly project driven, although some government funding is available for these activities. It is unlikely that an adequate allocation of the scarce maintenance funds will be made available for the access roads in Houay Xai. Sustainable access must therefore rely on the contributions of the local communities with technical support from the DPWT.

All of the general tasks such as vegetation clearance and drain and culvert cleaning are simple to implement and are within the technical capabilities of the local villagers to implement with monitoring from the local DPWT. Pothole patching and some elementary surface regulating on gravel roads is also within the abilities of the community as are repairs and patching to hand packed stone surfaces. Additional maintenance to gravel surfaces will require at least the use of a grader and frequently the use of transport as well to supply additional material. All other surfaces will require additional outside inputs, even though this may only be nominal quantities of cement for patching mortared stone surfaces. Care will be needed in monitoring repair of cement based surfaces to ensure that adequate quantities are supplied and used. Attempts at excessive economy in cement usage are likely to lead to useless repairs.

4.1.1 Execution of maintenance

The Engineered Natural Surface and the NEC Standard Gravel pavements are simple candidates for community maintenance since they are already similar to the bulk of access roads throughout Lao PDR. However, for optimal maintenance a gravel pavement really requires periodic grading and the import of suitable gravel material for patching (except, presumably for the Natural Surface) and these pavements may not, therefore, be the optimal candidates.

With training, the Hand Packed Stone pavement is perhaps the best candidate. The surface should not deteriorate significantly over the medium term and maintenance should be limited to repairs to isolated failed areas. These repairs require no imported materials or equipment and, if they are well executed, the maintenance load may well reduce over time as weak areas are identified, remedied and eliminated.

The same logic applies to the various other block type pavements – Mortared Stone, Block Paving and the Geocell types. They can all be repaired by hand with simple tools and local materials except that they will require the provision of small amounts of cement.

Plain concrete pavements (Bamboo Reinforced in this case) are likely to present more problems, requiring, for proper repairs, the breaking out of substantial sections of concrete and the mixing of larger volumes of replacement material needing more cement and, possibly, mixing equipment.

Bituminous based surfaces are the most problematic. The only way to avoid the use of equipment for heating and spraying the bitumen to give good quality repairs is to use Emulsion. Unless this is in common use it will be difficult to supply in small quantities for local repairs. The alternative is to use crudely heated, hand poured bitumen and accept a (much) lower quality of routine maintenance repair work.

On all roads and pavement types, the execution of routine drainage and shoulder maintenance is important to the life of the pavement itself. Without this routine maintenance, pavement preservation is difficult or impossible. It is good that the Lao authorities acknowledge this and have tried to establish a self perpetuating system of low cost maintenance for their lowest tier of roads.

4.1.2 Whole Life Costs

The use of community labour for routine maintenance confuses the issue of whole life costs, since it adds in a substantial element which is free of charge from the Government's budgetary viewpoint. However, the bulk of routine maintenance (Vegetation control, drainage maintenance, etc.) is common to all roads, regardless of pavement type, and need not be considered in any comparison. Instead, all that is required is to assess the maintenance requirements of the various pavement types including both regular detail surface maintenance and heavy or periodic maintenance.

Without further monitoring of the performance and maintenance costs of the trial pavements, any evaluation of whole life costs is strictly a provisional estimate and it would be unwise to place too much reliance on it.

SEACAP work in Vietnam[6] on the use of various pavement types has provided some insights into possible gravel pavement maintenance requirements within the region but has not yet produced data relevant to other pavement types. The SEACAP data for gravel roads has been used in an approximate form only since it is not clear that conditions between the different areas are wholly comparable and because the SEACAP gravel loss prediction mechanism for Vietnam is still in a preliminary state.

[6] ***Rural Road Surfacing Research**, SEACAP 1, Final Report, (Vol 1 and App A) Ministry of Transport Vietnam, December 2006.*

5 MONITORING OF THE TRIAL SECTION AND INTERPRETATION OF THE DATA

Monitoring will take place in two phases. Initially a complete set of base data must be gathered and subsequently regular monitoring is required to evaluate pavement performance by comparing pavement condition with this base data.

5.1 The Base-Line Data

During the planning and design of an access road it is important to determine a number of characteristics of each road, or part thereof, so that the road can be optimally designed. The three main parameters that should be determined are:

- The alignment (terrain, gradients and horizontal alignment);
- The design strength (bearing capacity) of the subgrade, and;
- The predicted traffic volume over the design life of the pavement.

The first two parameters were measured and analysed and are stored in the database, the third parameter was estimated during the design.

Once the roads were constructed and the trial sections defined a series of base-line measurements were conducted as follows:

- Visual Inspection and surface condition logging;
- Photographic logging;
- Surface deformation recording (dipped levels and rut measurement);
- Surface roughness using a MERLIN apparatus;
- Surface Texture (sand patch test);
- Classified traffic counts, and;
- Structural integrity using a Dynatest 3031 LWD Light Weight Deflectometer.

5.2 SEACAP – Monitoring Programme

A SEACAP programme (No.27) entitled the Pavement Condition Monitoring of the Rural Road Surfaces Research (RRSR) in Vietnam was started in late 2007. This programme is monitoring pavements, similar to those constructed during this project, over the long term. It is therefore envisaged that, in order to allow data to be compared throughout the SEACAP work, these pavements in Lao will be monitored using the same methods as those used in SEACAP 27.

One of the main purposes of this study is to define where particular robust surface types are best suited to be used. In time, with the long term monitoring of the pavements, it will be possible to derive surface performance relationships with key road environment factors, however, at present only indicative recommendations can be made. This section sets out when certain pavement types should be considered.

5.3 Environmentally Optimised Design and Spot Improvement Design

Environmentally Optimised Design (EOD) has been defined as a system of road design that considers the variation of the different road environments along the length of the road. Thus the specific circumstances of different road sections such as climbing steep gradients, crossing wet and marshy areas as well as the converse situation of the passage over easy terrain are considered in the design. At one end of the scale, easy gravel pavement sections may require little more than shaping of the surface to ensure water does not collect on the surface whereas at the other end of the scale robust surfaced pavement solutions may be necessary to allow vehicles to climb otherwise impassable, steep slippery gradients.

Considering the analogy with a chain being only as strong as its weakest link, a road will only remain open to traffic all year round if the worst sections remain passable to traffic at the worst times of the year. The Spot Improvement Design (SID) methodology is applied to the EOD philosophy and concentrates on ensuring that each section of a road is provided with the most suitable pavement type for the specific circumstances, ensuring in particular, that each bad or difficult section, 'Spot', is properly designed and that robust, appropriate solutions (pavement, drainage and slopes) are applied. The worst sections may only comprise a small percentage of the length of the road but can consume much of the cost of the construction of the road pavement.

The main factors likely to render a gravel road impassable are:

- Steep gradients that are made slippery due to water on the road surface or very bumpy due to erosion from rain water flowing down the road;
- Wet areas where the vehicle sinks into the soft material comprising or underlying the pavement structure;
- Severe erosion of the road and embankment due to water flowing across the road path, also relevant to paved roads;
- Debris on the road due to material being washed from side slopes by rain water or in the extreme case due to a landslide, also relevant to paved roads, and;
- Slope failures from poorly designed slopes above and below the road, usually triggered by high rainfall; also relevant to paved roads.

The common factor in all of these failures and problems is water. The answer to the simple question 'when will the road be impassable?' is almost always, 'during the wet season'. It can be concluded, therefore, that the management of the water or 'drainage design' is paramount when designing roads and in particular Low Volume Rural Roads (LVRR) which are particularly susceptible to the influence of water and receive little or no routine maintenance throughout the year.

During the wet season, it is not uncommon for failures to occur to rural roads of all levels. Many of these failures result in the road links becoming impassable and dangerous for users, consequently the various Roads Departments deploy teams to repair these failures. This is appropriately termed 'Emergency Maintenance'. This emergency maintenance work is often undertaken in a hurry, in adverse conditions and with little regard to the science of engineering, following the approach that the road should be repaired and opened temporarily as the problem will be rectified properly later on. This is an expensive and often ineffective method of repairing roads. Little engineering care is taken in the methods, and specifications and future consequences of the work are disregarded in the urgency to keep the road open. Obviously, and understandably, under pressure of an emergency there is very little appreciation of the requirements for a sustainable solution to the problem and only the most obvious and elementary work is undertaken. After the rainy season has passed, due to small maintenance budgets and high demands, many of these temporary works do not get rectified properly and they then reoccur in the following year.

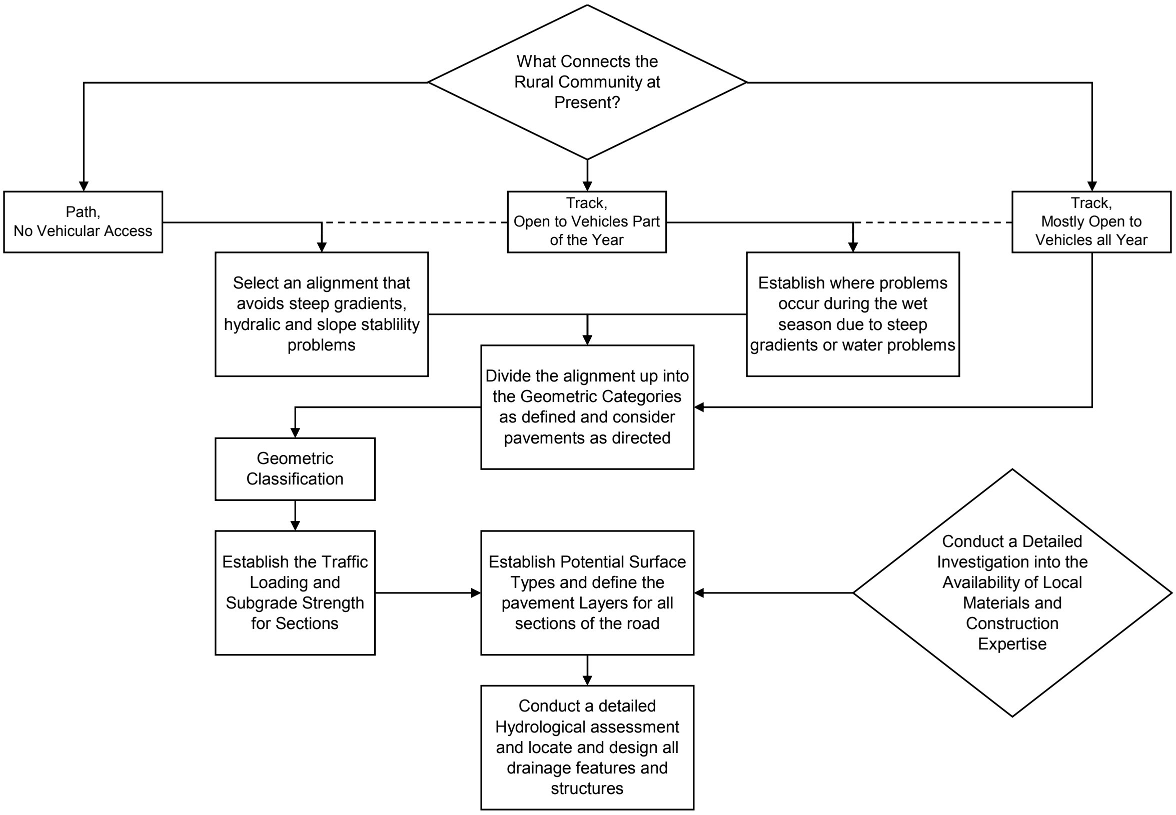
It is in these circumstances that the SID philosophy is likely to be of great value. In order to provide a substantial improvement in the utility of the road it is only necessary to carry out properly engineered 'Spot Improvements' on the sections of the road now known to be most unreliable to achieve the maximum return for a given expenditure. Spot Improvement might, therefore, be considered as 'Improvement through Maintenance conducted in the Dry Season'. Ideally, of course, the works would be conducted prior to any emergency occurring; in reality this is unlikely. The big advantage of Spot Improvement over Emergency Maintenance is that there is time to fully understand the problem and to apply the most appropriate long term solution as identified by experienced engineers in controlled conditions.

The optimum type of road construction can be selected and designed on the basis of four key factors, these are:

- Geometry;
- Pavement Structure;
- Drainage; and
- Slope Stability.

The EOD/SID Design methodology is set out in Figure 4, which illustrates the interaction of the four key factors. Whilst maintenance is not shown in this figure, it is still an important consideration when selecting a pavement structure or surface type. While no road is entirely maintenance free some surface types will require maintenance less frequently that others. A concrete surface will not require overlays while a thin bituminous surface will need reseals every five to seven years.

Figure 4 Flow Chart describing the SID Methodology



5.4 Ranking of Specific Materials and Pavement Structures

During the construction of the trial pavements it became apparent that some pavement structures or surface types are more appropriate in certain circumstances. For example, the sand sealed surfaces are only appropriate for low traffic volumes on flat undemanding terrain – primarily providing a comfortable ride with little dust pollution. By contrast, the hand packed stone, which results in a rough, but readily maintainable, surface is likely to be more appropriate on very steep sections of road which would otherwise be impassable in the wet season. However, what has become clear is that the EOD/SID design philosophy requires that substantial time is taken in the field by experienced Engineers in order that a suitable pavement structure is selected for each short length of problematic road in order to overcome the particular problems at that spot in the most appropriate and economic way.

The SEACAP 1 project compiled a table (Table 7.1 in the SEACAP 1 report) which defines a representative matrix of rural paving options appropriate to differing (Vietnamese) road environments. From the point of view of selecting the pavement structures in order to undertake a spot improvement design on rural access roads using small scale contractors, it can be seen that just about all of the options set out in this table are suitable. In fact, no matter how this table is considered, apart from the few definite disadvantages no real conclusions can be drawn apart from the fact that all of the pavement structures trialled will be useful in some situation or conditions. It can be noted that the dressed stone surface favourable in Vietnam was difficult to construct and very rough in Lao PDR under SEACAP 17 and that while the bamboo reinforced concrete was successfully constructed in both projects it has been found that the bamboo reinforcement offers no benefit over non-reinforced concrete.

This demonstrates to some degree the subjective nature of producing such tables of comparison and in particular, the possible problems of trying to apply the results reported in this table to another area and country. It could be argued that, if another contractor were used, the subjective ranking of the pavement structures for the same area would probably be different. However, in order to allow some comparison with other work a similar, but more simplistic, table has been completed for the nine pavement structures trialled in SEACAP 17 as shown in Table 16.

Table 16 Trial Pavements Assessed Against some Key Markers

Pavement Type	Key Markers									
	Local Materials	Flat Terrain	Steep Terrain	Populated Areas	Marshy Areas	Weak Subgrades	Small Contractor Suitability	Labour Based	Likely Cost Advantages	Maintenance Reduction
Standard NEC Gravel Pavement	✓	✓	✗	✗	✗	✗	✓	✓	✗	✗
Bamboo Reinforced Concrete	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓
Geocell	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓
Mortared Stone	✓	✗	✓	✗	✓	✓	✓	✓	✓	✗
Hand Packed Stone	✓	✗	✓	✗	✓	✓	✓	✓	✓	✗
Concrete Paving Blocks	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓
Sand Seal	✗	✓	✗	✓	✗	✗	✓	✓	✓	✗
Otta Seal	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
Engineered Natural Surface	✓	✓	✗	✗	✗	✗	✓	✓	✓	✗

Note: ✓ Positive advantage

✗ Probable disadvantage

Based on this table it can be concluded that for this contractor in this region of Lao PDR the pavement types selected were well suited to small labour based contractors. The robust pavement types are suitable for difficult terrain while the less expensive surfaces are suitable for flat and populated areas. The more expensive, robust pavements will require less maintenance than the cheaper options. The robust concrete pavements are advantageous in all situations, but may be found to be so expensive that they are never applied. The real conclusion, based on this work and the work in Vietnam, is that all practical construction options should be investigated and considered during the design and the most suitable for the particular area selected. In Vietnam this may be dressed stone surfaces, in Houay Xai, however, the dressed stone option was extremely difficult to implement, although, it must be noted that was probably a failing of the particular contractor rather than of the pavement type.

5.5 Surface Performance

During this project a number of different surfaces (pavement structures) were applied and trials constructed, at present, these trial sections have only been monitored once, at the completion of the construction. Therefore we have no historic data on how they are performing against time and it is not possible to rank them against one another at this stage. It is planned that long term monitoring will be conducted in the future.

Maintenance will be an important factor in the long term performance of the surfaces as all pavement structures require maintenance of some sort or another. Surface dressed pavements require reseals to be conducted a regular intervals in order to keep the surface malleable and waterproof so as to prevent cracking and the ingress of water into the pavement structure. Realistically, as described earlier, no maintenance can be expected to be conducted on these roads except perhaps, some elements of routine maintenance executed under a system of voluntary labour.

6 INFORMATION DISSEMINATION

Having completed the design and construction of the pavement trials, conducted the baseline data capture and planned a future programme of monitoring all engineering aspects of this project were completed. However, importantly, almost all of this effort is in vain unless the awareness of good practice experience from this project is disseminated at the national, sub-regional and international levels.

This project is part of the wider South East Asia Community Access Programme (SEACAP) which is investigating and improving sustainable and affordable rural access in order to encourage expanding social and economic opportunities for rural people, thereby enhancing pro-poor growth and poverty alleviation efforts. SEACAP is a poverty-targeted transport initiative within the global Transport Knowledge Partnership[7] (gTKP) framework. It is aimed at improving the sustainable access of poor people in rural communities to health, education, employment and trade opportunities.

SEACAP 17 has contributed to this overall objective through the development of the engineering goals set out in this report\and through the mainstreaming of the achievements and results. Local ownership of the techniques and practices investigated and described during this project is very important for sustainability and this theme has been pursued throughout this work.

Throughout this project the transfer of knowledge and the dissemination of the information attained have been taken as one of the key aspects of the SEACAP programme. 'Dissemination' has been achieved by a number of different methods during the course of this project, namely:

- Workshops — In order to develop an understanding of the engineering mechanisms being introduced to Lao PDR and to promote the benefits of long term solutions workshops were organised that specifically targeted groups such as MCPC/DCPC staff; LTEC supervision staff; university lecturers and trainers, the contractor and local village groups.
- Training — Training sessions were conducted in the province of Bokeo in order to ensure transfer of knowledge at all levels. The training was in the form of discussion groups and on-the-job training which covered all aspects of the research together with management issues relating to the project implementation.
- Guidelines and Specifications — Throughout the project various guidelines and specifications have been explored and brought to the attention of participants in SEACAP 17. During the project a number of specifications were development and trialled during the construction.
- Mainstreaming — In order to disseminate the project information via national, international and regional agencies the information must available to a wide audience which has been and is being achieved by:
    - The attendance and presentation of the project findings at International Conferences;
    - The compilation, and presentation, of a proper scientific paper describing the work done and the results, and;
    - The publication of the project details and findings on Websites.

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7 ***global Transport Knowledge Partnership*** *framework http://www.gtkp.com*

7 CONCLUSIONS AND RECOMMENDATIONS

Owing to the long term nature of this project there are only limited conclusions to be drawn at this intermediate stage.

The design process has shown the need for experienced engineers to spend some time in the field understanding the particular problems of the route(s) and exploring the various possible solutions. Solutions adopted should take account of both local materials and any available local skills.

The construction process has provided data regarding the cost of constructing various types of alternative pavement and the problems which may be found in their construction. It has also highlighted the problems which can be encountered when trying to implement a research operation on the back of a regular commercial construction contract. The collection of baseline data has illustrated some problems likely to affect long term data collection systems.

Cost data shows, unsurprisingly, that improved pavements cost more. Accordingly it is recommended that a Spot Improvement philosophy be considered as the normal approach to basic access road provision whereby the simplest pavement structures be used for undemanding sections of road and the higher cost, improved structures be used on sections prone to failure, typically steep gradients. This same philosophy applied during alignment design may be used to limit construction costs by permitting the use of more extreme alignments and thus reducing earthworks and, sometimes, acquisition costs.

A review of the maintenance organisation and funding shows that local participation is essential to the maintenance of access roads in Lao PDR. Measures already exist to provide for such local participation, however, it is highly desirable that construction contracts should be structured to require the maximum possible local employment. Apart from the immediate benefits of employment, this will give the local community a sense of ownership of the road and help equip them with the necessary skills and understanding required for its future maintenance.

At this stage, the advantages and disadvantages for each pavement structure, other than the construction costs, cannot be clearly defined and it would be difficult to compile a table, or indeed a design methodology, that made a definitive recommendation for a particular pavement structure in particular circumstances. This emphasises that in order to draw conclusions in respect of specific pavement types, the medium and long term monitoring of the trial sections is of critical importance.

7.1 Conclusions

During the course of this project it has become apparent that it is important to embrace local materials and expertise. It is considered that substantially more effort should be concentrated during the design phase to ensure that poor and good sections of the road to be identified and the correct pavement solutions applied.

In order to keep a road open throughout the year in is necessary to manage the water during the wet season, this can be done by:

- Ensuring that the geometry is optimised to reduce both steep gradients and sharp curves even if this means increasing the length of the rural access road;
- Optimal pavement structures should be selected which use local materials and expertise as much as is practicable.
- Robust pavement structures should be applied to poor spots while more simple pavements are applied to the easy lengths;
- Depending on the materials and labour available it may be found beneficial to use more than one pavement design for different ‘spots’;
- The hydrology of the project area should be studied properly to allow a detailed drainage design to be conducted. The proper management of water will prevent weakening of the pavement structure due to ingress of water and erosion of the surface due to poor side and cross drainage;

- Detailed assessments of slopes where they cannot be avoided will allow proper engineered solutions to be implemented reducing the chances of slope failures during the wet season.

The following points are the general conclusions regarding the pavement trials highlighting the advantages and disadvantages of each:

- Standard NEC Gravel Pavement, Engineered Natural Surface and Sand Seal should not be used on problematic areas as these surfaces will not withstand heavy traffic, steep gradient or high erosive conditions i.e., rainfall.
- Sand Seals and Single Otta Seals are ideally suited to urban conditions with low traffic where dust from gravel roads is unacceptable. However, both of these surfaces will require periodic maintenance which could, ideally, be undertaken by the communities through which they pass.
- Concrete block paving, concrete pavements and bituminous bound pavements can be undertaken successfully by small scale contractors using imported and local materials. These initially expensive pavements result in sustainable pavements with reduced maintenance needs.
- Hand Packed or Mortared Stone Surfaces appear likely to offer the best value for money and are suitable for community based maintenance. However, unless very experienced artisans are used for the block preparation, extremely rough surfaces will result. Rough surfaces will in general be unacceptable to road users except in cases where the road was extremely bad and mostly impassable previously. Improvement of these areas to year round accessibility, using roughly hewn stone blocks, will be a huge improvement despite resulting in a rough surface. The standard of surface will improve as the community gains experience and will be better with mortared rather than hand packed stone.
- All of the pavements, but in particular the Engineered Natural Surface will perform much better during the wet season if the drainage is functional. A detailed drainage investigation should be conducted at the design stage resulting in drainage designed to function 'with nature' ensuring that water is not routed incorrectly. Routine drainage maintenance before the wet season will be of great help in ensuring that the road remains open throughout the wet season.
- Double Otta seals can be constructed using natural gravel which is well out of specification for normal surface dressed pavements, resulting in a durable surface which can be applied to all but the most severe areas. This construction is ideal for small contractors as it requires little plant and expertise, providing a bitumen distributor is available, but does require labour intensive care during construction.
- Geocells and Non-Reinforced Concrete pavements are suited to small contractors as suitable concrete can be mixed in small mixers using local materials. The specified thickness of the Geocell pavement can be less than that of concrete slabs however, the cost of the plastic Geocell form may negate some of this saving.
- Double Otta Seals, Concrete Blocks and Concrete pavements are suited to high traffic volumes. Also these pavements can be applied to steep gradients and sharp corners where traffic action on the surface is most severe.
- Hand Packed or Mortared Stone Surfaces, Paving Block surfaces are easily repaired reusing much of the materials by unskilled labour.

Some of the chosen pavement methodologies were not as well suited to resources (human and/or material) available in Houay Xai as others. An example was the knapped stone based pavements. Since there seems to be no history of knapped stone in the area (although the stone is available) it was very difficult to find experienced artisans to construct roads using this technique, which has proven successful elsewhere. Detailed investigations of the project area should highlight potential successful construction techniques.

The construction cost of the all-weather surface types exceeds the construction cost of the standard gravel road significantly. It is concluded that these all-weather surface types should be applied at the problematic spots on a rural access road where they are needed to maintain all weather access or, possibly, for social reasons rather than along the entire length. This ‘Spot Improvement’ pavement design philosophy should be applied as widely as possible given a lack of funds to provide improved pavements throughout the road length.

The existing database of rural road surfacing knowledge has been expanded significantly by the work undertaken by SEACAP 17 in Lao PDR.

The DPWT and Governor’s office as well as the communities have a good understanding of the need for maintenance of the access roads in order to provide continued sustainable access.

Maintenance of the roads will depend largely on the willingness of the communities to contribute their labour and on the DPWT providing technical support and budget support when necessary.

Maintenance considerations should be taken into account when selecting pavement types, for example gravel surfaces and bituminous seals require significantly more routine and periodic maintenance that concrete roads. Stone surfaces are potentially most suited for long term community maintenance without significant outside assistance or funding.

7.2 Recommendations

The SEACAP 17 contractor’s staff were almost entirely Chinese. It is recommended that future contracts clearly require local labourers, artisans and technicians to be employed. Not only does this have economic bearing on the local community, but also provides some feeling of ownership and ensures that the expertise created through training is not lost from the area. In the future these trained labourers will be able to construct other roads and to maintain existing roads.

When using contractors to undertake small scale but accurate work in which they have little or no expertise, it is vital that considerable training is provided in order that the non-standard or unfamiliar construction techniques are conducted properly. It is recommended that small scale local contractors are trained and given a tender advantage over large international contractors. This will empower local communities, provide a sense of ownership within communities and ensure that expertise and economic benefit remains in communities.

Problems were found when applying a research project to a commercial contractor, the contractor had little interest in the research and was primarily concerned with his costs and missed deadlines. An understanding must be shaped early in the project between client, funding agencies, consultant and the contractor such that research related contractual variations and requirements are defined, anticipated, allowable and enforceable. Care should be taken when compiling contract documents to ensure that they are adapted appropriately to the research aims; suitably weighted prequalification would be a significant advantage for research projects.

7.3 Future Work

Clearly, further monitoring work is required to assess the long-term performance of the SEACAP 17 trial pavements against time in order that a detailed cost against longevity/deterioration model can be defined. Only when their success over the long term has been clearly demonstrated, will these techniques be accepted by general practitioners and the recommendations of this work become acceptable practice and mainstreamed.

Both soft and hard actions are required to make an impact of this work with practitioners. Soft action (Dissemination) will increase awareness and knowledge and will win hearts and minds leading to ownership by practitioners who will apply the concepts in their districts. Hard action (Mainstreaming) will result in the production of design guides, specifications and contract documents that allocate appropriate resources to the use of these techniques in the design and construction of rural access roads. This will again lead to the ownership by practitioners who will become confident in the success of these methods.

Long Term Monitoring

It has been agreed that in order for this work to be of value beyond that discussed in this report it is necessary for a long term monitoring regime to follow through on the base line data capture.

This will involve the monitoring of the performance and deterioration of the trial pavements and the NEC standard gravel control sections, taking into consideration the traffic environments to which they are subjected and the maintenance requirements, costs and arrangements.

This assignment is not part of the current SEACAP 17 scope. It is, however, essential that the monitoring work be planned and carried out in a systematic manner and conducted to acceptable standards.

Maintenance Considerations

During Phase 2 of SEACAP 17, the condition of the trial pavements on the access roads will be monitored on a regular basis. During these monitoring exercises, the deterioration and defects on the gravel sections will be highlighted as a comparison with the trial pavements. The consultant must also monitor and comment on the implementation and effectiveness of maintenance on the project roads. Where noticeable deterioration is occurring, this must be brought to the attention of the DPWT and MPWT.

7.4 Follow-On Project

It is recommended that a suitable network of roads is identified and a spectrum of rural road design solutions incorporating EOD and SID using pavements varying from engineered natural material to gravel to durable paving be implemented and constructed. A rural road project would form an ideal testing ground in order to:

- Trial and formalise a detailed EOD taking into consideration the following main design aspects:
  - Alignment (Vertical and horizontal) selection;
  - The investigation into local materials and their construction suitability;
  - Appropriate pavement structure (Surface) selection that will vary along the length of the road depending on need;
  - Detailed hydrological design and the selection of suitable drainage structures, and;
  - Areas requiring specific slope stability solutions.
- Compilation of a Detailed Construction Methodology (considering different construction options) and the compilation of a Standard Construction Contract with the construction options which can be used on similar future projects.
- It is well known that the maintenance budgets for rural access roads are severely limited and therefore such a project should provide a maintenance approach will help practitioners to define the correct pavement structure and corresponding maintenance scenario during the design stage. A much better understanding of the true cost of the rural roads in whole life terms will result which will enable more accurate maintenance budget allocation by central funding or donor-related sources.

It is concluded that the successes and failures from this project, and other similar projects, cannot simply be applied elsewhere. While note should be take of the materials and methods of construction reported here, a detailed investigation must be conducted in the particular region where work is proposed.

Appendix A

Terms of Reference (ToR),

Module 5: Performance Monitoring NEC/ADB project, gravel roads, including the SEACAP 17 trials. Inspection of defects on the NEC/ADB rural access roads within the contract liability period.

(Lao PDR)

SEACAP 017/002

TERMS OF REFERENCE (ToR)

SEACAP 017 – EXTENSION

Module 5: Performance Monitoring NEC/ADB project, gravel roads, including the SEACAP 17 trials. Inspection of defects on the NEC/ADB rural access roads within the contract liability period. (Lao PDR)

1 BACKGROUND

SEACAP 017/001 is completed. It trialled cost effective surfacing and paving technologies on selected sections of Northern Economic Corridor/Asian Development Bank Project (NEC/ADB) Access Road Package #1. It also supervised the construction of standard gravel roads included in Package #1. SEACAP 17 outputs of relevance to these ToR include the following:

a) A database of rural road surfacing and paving established as a source for further analysis and practical application to Laos road environments.

b) An initial analysis of the database including the derivation of surface performance relationships with key road environment factors.

c) Recommendations ranking specific material usage within differing Lao PDR road environments utilising an appropriate performance model.

d) Recommendations for long-term monitoring.

e) Guidelines, design manuals and specifications for each surfacing/paving technology option.

f) Scientific Paper summarizing the research work carried out.

SEACAP is working with the Vietnamese Ministry of Transport (MoT) through the RRSR on similar research to that done in SEACAP 017/001, but on a much larger scale. RRSR outputs of relevance to these ToR include the following:

a) New Cost Norms and Standard Technical Specifications for use by upcoming rural road programs and for inclusion within MoT standards;

b) A general Rural Road design approach which takes into account key road environment issues such as availability of local materials, maintenance regime, climate, and terrain;

c) A Cost Model to assist decision making on rural road surfacing options;

d) A database of rural road surfacing knowledge;

e) Guidelines for Rural Road Pavement and Surface Condition Monitoring.

2 EXTENSION OF SEACAP 017

Pavement deterioration is a complex phenomenon which can manifest itself as distress of various inter-related kinds; hence the requirement to collect data for a range of variables during the performance monitoring stage. A monitoring programme needs to recover a collection of time series data, the analysis of which can then be used to provide robust evidence to explain the observed performance and provide confidence in the findings and derived recommendations.

Pavement condition is normally monitored in terms of surface condition, material strength, riding quality (by surface roughness), deformation (by rutting), in situ moisture condition and deflection (relating to pavement strength).

The Ministry of Public Works and Transport (MPWT) has requested that performance of the various surfacing technologies on the SEACAP 17 access roads is monitored, evaluated and the corresponding performance and cost models, guidelines and documents are developed and updated accordingly.

A minimum of eight years of continuous monitoring of the SEACAP 17 trials is required to fully develop the associated cost and performance models.

This will enhance the following:

a) **Research**. The development of new pavement or surfacing options requires that their performance be proven to be suitable, or otherwise, within the road environment constraints within which they are designed to operate. Their deterioration characteristics need to be identified in order to establish their Whole Life Costs and also to define the limits of their appropriate usage. The regular monitoring of appropriately selected road sections in conjunction with assessments of the governing road environments is an essential part of this process.

b) **Maintenance**. Effective management of rural road assets requires that relevant information on maintenance needs is available in order to prioritise appropriate interventions. This is particularly important in the typical case where maintenance budgets are severely limited and also where maintenance budget allocation requires factual justification to either central funding or donor-related sources. The road monitoring programme will be an invaluable tool in this context.

c) **Specific problems**. It is not uncommon within the sub-tropical and tropical regions for roads to suffer from accelerated deterioration, or even failure, in response to one or more of the following factors of; harsh climatic conditions, poor initial construction control, high axle loads or inadequate maintenance funding. In such cases it may be necessary to assess specific failures to identify the exact nature of problems and hence appropriate solutions.

d) **Transfer knowledge and skills**. It is a priority to transfer the knowledge and skills for monitoring, analyzing and evaluating road technologies to local institutions so that future research related activities can be carried out with minimal support from international experts.

Monitoring the Defects Liability Period. The ADB has requested the assistance of SEACAP to monitor the roads during the Defects Liability Period leading to an issuance (or not) of the Defects Liability Certificate.

3 OBJECTIVES

The overall objective of this module is to achieve a better understanding of the performance of various surfacing/paving options in the northern Laos environment. This will be done by gathering and analyzing data and updating the performance and cost models developed for the SEACAP 17 trial sections and on gravel access roads constructed through the ADB/NEC.

4 OUTPUTS

The main outputs shall be:

i) Recommendations for (or not) issuance of a Defect Liability Certificate.

ii) Updated performance and cost models for the trials and for gravel surfaced LVRR.

iii) A local capacity to continue the performance monitoring and analysis.

5 SCOPE OF WORK

This module will commence in early 2008 and MUST be completed in February 2009. The project will progressively transfer the necessary capacity to a local institution so that the monitoring can continue into the future through that institution. The consultant team will undertake tasks within the following general groups:

i) Program planning;

ii) Data gathering;

iii) Data input;

iv) Inspection of works during the defects liability period and issuance of Defects Liability Certificate;

v) Data analysis and updating the performance and cost models;

vi) Database management;

vii) Module 5 report.

Skill transfer and capacity building shall be an integral component of all of the tasks. The following is an overview of the activities associated with each task:

i. Program Planning:

a) Establish working links with the SEACAP Steering Committee, the relevant Provincial Departments, and other relevant programs and consultants;

b) In cooperation with the relevant authorities, identify an institutional home where the SEACAP 17 database can be stored and managed;

c) Review technical, economic, road user, environmental and social issues relating to LVRR surfaces and pavements in SE Asia including the outputs of the RRSR in Vietnam;

d) Visit relevant roads and materials sources to make an initial assessment of the materials and engineering performance;

e) Select a minimum of 100 sites in addition to the SEACAP 17 trial roads on the NEC/ADB Access Road (All) Packages with contrasting materials and road environments;

f) Investigate the local road maintenance arrangements and inputs;

g) Arrange for appropriate training in the required data collection and data storage procedures for all relevant engineers and operatives;

h) Arrange for the mobilization of all appropriate test equipment;

i) Finalize with the MPWT and ADB the protocol for inspecting the NEC/ADB Access Road Package #1 for defects during the liability period, instructing the contractor to rectify any defects or damages, and for the issuance of the Defects Liability Certificate.

j) Produce a workplan that includes:

- All activities against time.
- Identifies the monitoring and inspecting activities based on the location requirements of the defined road sections;
- A plan for the progressive and responsible transfer of the management and implementation of the Module activities to the local institution.

ii. Data gathering:

a) Before and after each rainy season within the project timeframe, collect information on the condition of the designated trial roads and representative control sections, including traffic counts.

iii. Data input:

a) Quality review and assure the collected data;

b) In-put the relevant data into the existing SEACAP 17 database.

Inspection of works during the defects liability period and issuance of Defects Liability Certificate:

a) Inspect roads for defects and damage as per plan;

b) Record defects and damages and issue instructions for rectification;

c) Approve as appropriate rectification measures;

d) Recommend the issuance of the Defects Liability Certificate as appropriate.

Data analysis and updating the performance and cost models: Upon completion of data entry, analyze the data in order to:

a) Update the performance and cost models;

b) Draft recommendations for long-term monitoring;

c) Update the relevant guidelines, design manuals and specifications for each surfacing/paving technology option.

iv. Database Management:

a) Ensure safe guarding for the safety and the integrity of the database;

b) Backup and handover the database to the appropriate authorities upon completion of the project.

A final Module 5 report that will include:

a) Updated database;

b) Analysis of the database leading to refined performance and cost models;

c) Recommendations for long-term monitoring;

d) Updated guidelines, design manuals and specifications for each surfacing/paving technology option;

e) A paper on Modules 5 in a recognizable scientific format for local and international dissemination;

f) A power point presentation to accompany the scientific paper.

6 PROJECT REPORTING (ALL IN - LAO AND ENGLISH):

g) An inception report will be prepared within one month of mobilization;

h) Quarterly progress reports;

i) Ad hoc reports to address any extra-ordinary findings or concerns;

j) A program and workplan for the transfer of skills to the local institution;

k) A terminal report summarizing the outcomes of the project.

7 DISSEMINATION

a) The consultant shall arrange regular workshops and meetings to update the SEACAP Steering Committee and the Local Roads Department (LRD) and other key stakeholders on the progress of the project. The project shall carry out as a minimum the following workshops:

  - Inception
  - Mid-term
  - Terminal

b) Participate in relevant international meetings in order to present the experiences gained.

8 EXPERTISE REQUIRED

The project will be carried out be a consulting team with the following characteristics:

a) An ability to ensure that internationally accepted scientific/engineering quality standards are maintained;

b) The team shall be composed of a high level of local and minimal level of international experts.

The consulting team shall have extensive experience and expertise carrying out directly related rural road engineering research, including:

a) Designing and trialling LVRR research;

b) Cost and performance modelling of LVRR surfaces and pavements;

c) Monitoring the performance of LVRR;

d) Knowledge and skill transfer.

9 REPORTING LINE

The consultant shall be under the overall coordination of the SEACAP Steering Committee. The consultant shall report on project progress in an agreed upon format on a regular basis to the Steering Committee.

The consultant shall maintain direct contact with the SEACAP program management for all contractual related issues.

The consultant shall be responsible for identifying and notifying SEACAP management of any delays or problems in the process as early as possible and for recommending solutions.

10 TIMEFRAME