MINISTRY OF TRANSPORT VIETNAM

SOUTH EAST ASIA COMMUNITY ACCESS PROGRAMME

MID TERM PAVEMENT CONDITION MONITORING OF THE RURAL ROAD SURFACES RESEARCH

Final Report
The Rural Road Surfacing Research (RRSR) Database

SEACAP 27

June 2009

UNPUBLISHED PROJECT REPORT

UNPUBLISHED PROJECT REPORT

MID TERM PAVEMENT CONDITION MONITORING OF THE RURAL ROAD SURFACES RESEARCH

Final Report

SEACAP 27

Prepared for Project Record:	**SEACAP 27. Mid Term Pavement Condition Monitoring of the Rural Road Surfaces Research**
Client:	**DfID; South East Asian Community Access Programme (SEACAP) for the Ministry of Transport, Vietnam**

	Approvals
Team Leaderr **Dr J R Cook**	
Quality Reviewed **Dr J Rolt**	

CONTENTS

ABBREVIATIONS & ACRONYMS

ADT	Average Daily Traffic
ARRB	Australian Road Research Board
ASEAN	Association of South East Asian Nations
Bmb	Bamboo
BRC	Bamboo Reinforced Concrete
CAFEO	Conference of ASEAN Federation of Engineering Organisations
CBR	California Bearing Ratio
CSIR	Council for Scientific and Industrial Research (South Africa)
DBM	Dry Bound Macadam
DCP	Dynamic Cone Penetrometer
DFID	Department for International Development
DST	Department of Science and Technology, Ministry of Transport
EDCs	Economically emerging and Developing Countries
esa	equivalent standard axles
FHWA	Federal Highways Association (US)
FM	Fines Modulus
FWD	Falling Weight Deflectometer
GMSARN	Greater Mekong Subregion Academic and Research Network
GoV	Government of Vietnam
HDM4	Highway Development and Management Model
HQ	Headquarters
IFG	International Focus Group
ILO	International Labour Organisation
IRI	International Roughness Index
ITST	Institute of Transport Science and Technology
Km	kilometre
LCS	Low Cost Surfacing
MERLIN	**M**achine for **E**valuating **R**oughness using **L**ow-cost **IN**strumentation
MoT	Ministry of Transport
NRC	Non-Reinforced Concrete
OM	Operations Manual
PDoT	Provincial Department of Transport
PIARC	World Road Association
PMU	Project Management Unit

PPC	Provincial Peoples Committee
PPMU	Provincial Project Management Unit
QA	Quality Assurance
RITST	Research Institute of Transportation Science & Technology
RRGAP	Rural Road Gravel Assessment Programme
RRSR	Rural Road Surfacing Research
RRST	Rural Road Surfacing Trials
RTU	Rural Transport Unit
RT2	Rural Transport 2nd Project
SEACAP	South East Asia Community Access Programme
SOE	State Owned Enterprise
SRC	Steel Reinforced Concrete
TBM	Temporary Bench Mark
TEDI	Transport Engineering Design Incorporated
TG	Technical Guidelines
ToR	Terms of Reference
TRL	Transport Research Laboratory
VOCs	Vehicle Operating Costs
VPD	Vehicles per day
WAN	Wide Area Network
WBM	Water Bound Macadam
WLC	Whole Life Costs

The Rural Road Surfacing Research (RRSR) Database

1 Introduction

1.1 Background

In response to the increasing recognition that gravel surfacing was not a universal solution for rural roads in Vietnam, the Ministry of Transport (MoT) in 2002 requested studies of alternative surfaces for rural roads as part of the World Bank-funded Rural Transport Programme 2 (RTP2). These studies became known as the Rural Road Surfacing Research (RRSR) initiative, through which the Rural Road Surfacing Trials (RRST) and the complementary Rural Road Gravel Assessment Programme (RRGAP) were carried out. This research programme and its extensions were subsequently incorporated into the DfID-funded South East Asia Community Access Programme (SEACAP).

The overall objective of these researches is to justify the suitability of the RRST options with their road environment. The deterioration features need to be identified in order to establish the whole life cost as well as to identify the disadvantages of these options. Moreover, information of the required maintenance is needed for whole,life costing and also so that the maintenance interventions can be prioritised.

The RRST studies contained two main phases of trial construction between 2004 and 2006 with a total construction cost of US$4,400,000 which together comprised over 140 km of trial and associated roads from which representative sections have been selected for ongoing performance and whole-life-cost monitoring. Initial phases of this monitoring have been completed by Intech Associates and TRL under previous SEACAP contracts.

1.2 Project Context

The SEACAP 27 project is part of the wider South East Asia Community Access Programme (SEACAP) and is concerned with the essential continuation of the RRST programmes into the vital phases of long term condition monitoring, analysis and research mainstreaming. The sustainable application of all the previous phases of trial road costing, design, construction and short term monitoring is dependant on a successful completion of this project and the continuation of the RRSR programme. The importance of this work was highlighted during the final SEACAP 1 Dissemination Workshop in December 2006, which not only set out the progress and research results to date but emphasised the need to establish the Long Term Monitoring regime to follow through on the initial phases of the RRSR programme.

1.3 Project Aims

The effective mainstreaming and practical application of all the previous phases of RRSR trial road design and construction is dependant on a successful assessment of the performance of the trial roads within their specific road environments. The SEACAP 27 project was therefore a logical and necessary continuation of the RRSR programme and was concerned primarily with the collection and analysis of pavement performance information from RRST I and RRST II trial road sections

constructed from mid 2005 to mid 2006. This mid-term pavement monitoring forms the link between the completed short term monitoring and future longer term monitoring.

A number of key aims were identified as central to the project, as follows:

1. Collection and analysis of pavement and surfacing condition information.

2. Storage of this information in an easily accessible and analysable format within the existing RRSR database

3. Review of existing documentation on maintenance costs, Whole Life cost and pavement option selection in the light of the above data.

4. A successful handover of the RRSR database and associated documents and as much of the institutional "memory" as possible to an identified RRSR home so that further research and mainstreaming is effectively carried forward.

5. Comprehensive final reporting.

1.4 Document Aims

This project completion report describes the project including the contractual arrangements, the relationships with project partners and summarises the main activities and outputs from the project. It also directly addresses the technical issues raised in other project documents and applies them to the central project topics.

This report is closely linked to two other SEACAP 27 documents:

- Technical Report 1, Visual Condition Assessment of RRSR Trial Road Options, by Dr J Rolt and Dr J R Cook for TRL-OtB
- Technical Report 2, The RRSR Database, by Dr J R Cook and Pham Gia Tuan for TRL-OtB

Copies of these reports and other relevant SEACAP documents may be downloaded from www.seacap-info.org

2 Project Description

2.1 Contractual Arrangements

On 2nd July 2007 Crown Agents for Overseas Governments and Administrations Ltd (the "Contracting Agent"), acting for and on behalf of their Principal, the Department for International Development (DFID) invited technical and financial bids for the work under the South East Asia Community Access Programme (SEACAP). The project was designated as SEACAP 27.

TRL submitted Technical and Financial proposals by the revised deadline in early August 2007 and following a period of bid assessment and clarification the contract was awarded to TRL Ltd and signed in November 2007.

The project has been carried out by primarily by TRL Ltd as the Lead Consultants working in association with OtB Engineering (International) Ltd, and TEDI, the local Vietnamese consulting group. In addition, formal sub-contracts were signed with the University of Transport and Communication (Hanoi) and ITST.

2.2 Project Associations

TRL Ltd entered into a number of associations, both formal and informal, for this project either for the straightforward provision of services or with a view to widening the range of local rural road practitioners involved in the RRSR programme in line with overall project aims.

The nature of the associations is outlined below

OtB Engineering (International) Ltd: a formal agreement for the supply of local administrative support and professional services of the Team Leader Dr J R Cook.

ITST; this is a formal agreement for assistance, local administration and liaison with the PDoTs. ITST are also an option for consideration as the institutional home of the database and ongoing research programmes.

TEDI, this is, in the first place, a formal agreement for the supply of local engineering expertise, including that of Local Team Leader Pham Gia Tuan. Secondly, however, this association has the added advantage of introducing a major Vietnamese engineering consultant to the programme as a potential future lead research contractor.

University of Transport and Communications (Hanoi). A formal arrangement has been set up with the Consultancy, Development Technology and Transport Construction and Company (CCTDC) within the University to act as a local counterpart organization on road engineering technical issues with specific responsibilities to

1. Arrange for regular coordination meetings with key road engineering specialists in the University of Transport and Communication.
2. Supply technical advice on an as requested basis for the planning, organisation and analysis of the road monitoring programmes.
3. Arrange for site visits for University Staff and supervision of any agreed technology transfer visits by students from the University
4. Assist in preparing and presentation of technical papers on issues arising out of SEACAP 27

Vietnamese Road Authority (VRA). An informal arrangement was made with the VRA regarding involvement in technical group meetings. VRA have, in the past, been represented on

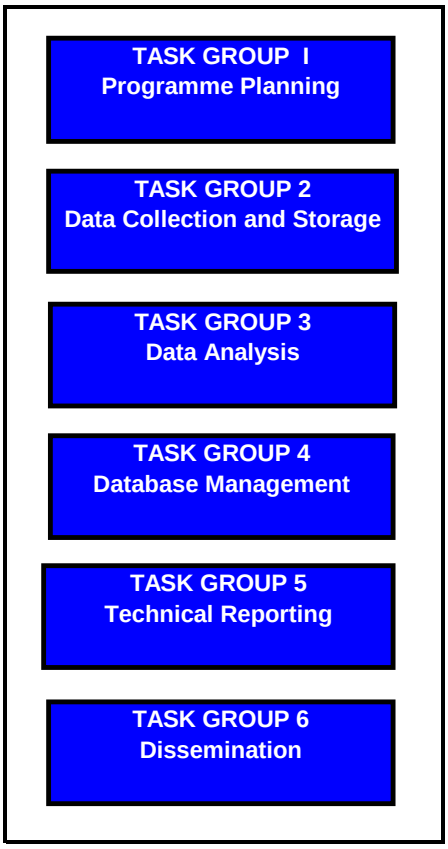
the RRSR Steering Committee and were seen as potential candidates for taking over the RRSR database.

As with all previous research and dissemination activities for the RRSR the SEACAP 27 programme was carried out under the co-ordination of the Ministry of Transport RRSR Steering Committee under the Chairmanship of Dr Nhan as Head of the Department of Science and Technology, within the Mot.. This committee acted very effectively as the coordinating hub for the activities as well as providing strong guidance on the direction of the project in line with the objectives of the Ministry of Transport and GoV.

2.3 Summary of Work Done

The initially proposed SEACAP 27 programme was based on the identification and completion of a number of key tasks grouped together as shown in Figure 2.1

Figure 2.1: Proposed Task Groups



The project programme was based on an inception phase review of the Task Groups which highlighted the key tasks. The subsequent work undertaken was then developed from these key tasks, namely,

1. Undertake three phases of condition surveying and associated traffic counts and update the RRSR database with information from these surveys.
2. Continue development of the database structure and upgrade it from being merely a data storage facility into an analytical and dissemination tool.
3. Develop analytical tools for systematically assessing the performance of the trial options.

4. Review the design approaches developed under SEACAP 1.
5. Review the implication of the performance assessment with respect to maintenance requirements.
6. Review the RRSR Cost Model developed under SEACAP 1.
7. Identify a future institutional home for the RRSR database and make certain that the condition surveying procedures are fully understood by these potential future owners.
8. Undertake key dissemination and technical liaison activities.

Details of the completion of these key is discussed in the following Chapters

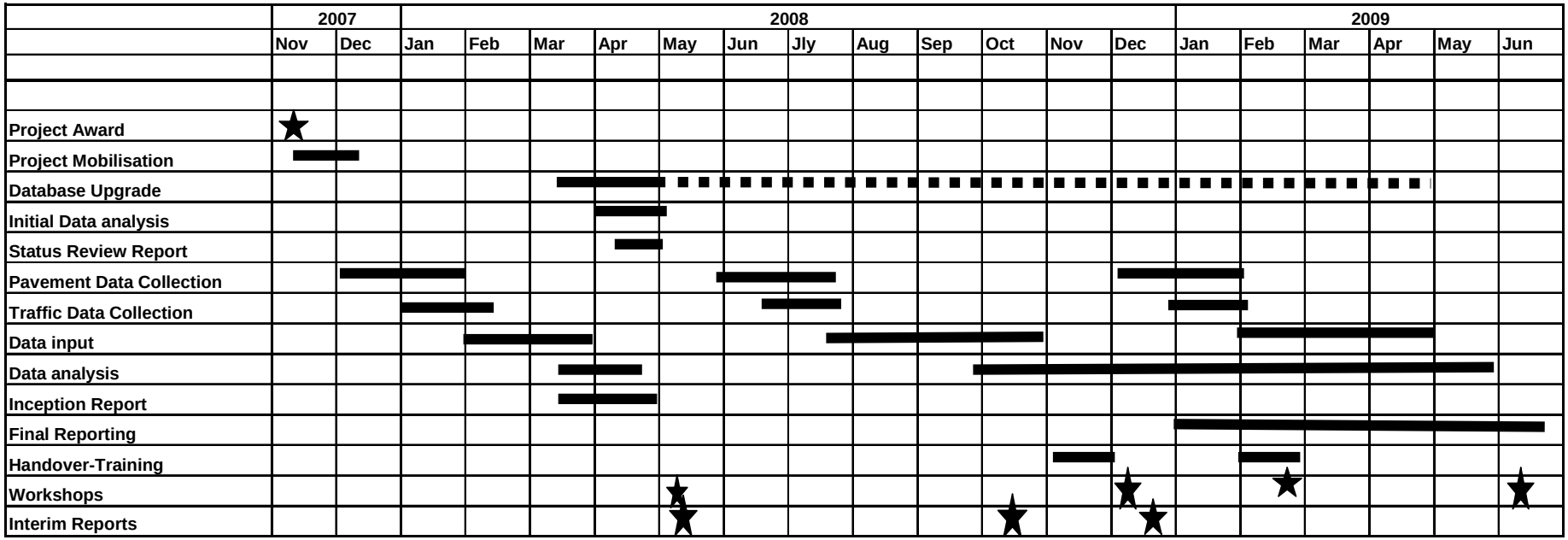
2.4 Programme and Resources

The SEACAP 27 staff resources which were used in the completion of the programme were largely those proposed in the Technical Proposal, although some modifications were necessary in the field staff due largely to the intermittent nature of the fieldwork. The key staff resources are summarised in the Table 2.1 and the outline programme is presented as Figure 2.1

Table 2.1: Key Staff Responsibilities

Key Staff	Designation	Principal Responsibilities
Dr J R Cook	Team Leader	Overall planning and technical responsibility. Establishment of project links. Updating of RRSR database
N Elsworth	Researcher/Road Engineer	Planning of site operations. Quality control on data collection. Technical reporting.
S Done	Researcher/Road Engineer	Quality control on data collection. Technical liaison with local institutions
Dr J Rolt	Analytical Consultant	Specialist advice on condition data analysis
R Petts	Quality Reviewer	Data and report review. Specialist input on Cost Model and Whole Life costs.
T Bradbury	IT Specialist	Software QA and dissemination advice
PG Tuan	Local Team Leader	Detailed planning of site activities
BT Dzung	Local Consultant	Local organisation coordination and liaison. Specialist advice on local technical issues.
N S Ha,	Field Team Manager: Phase I	Field data collection. Data input.
N T Dzung,	Field Team Manager: Phase II	Field data collection. Data input.
D V Dang	Field Team Manager: Phase III	Field data collection. Data input.
Ms N Q Lan	Office Manager	Site team base support.
Ms P T Hang	Technical Translator	Document and report translation.

Figure 2.2 Outline SEACAP 27 Programme



3 Data Collection

3.1 Data Collection Phases

Three phases of interim monitoring have been undertaken during SEACAP 27 as follows:

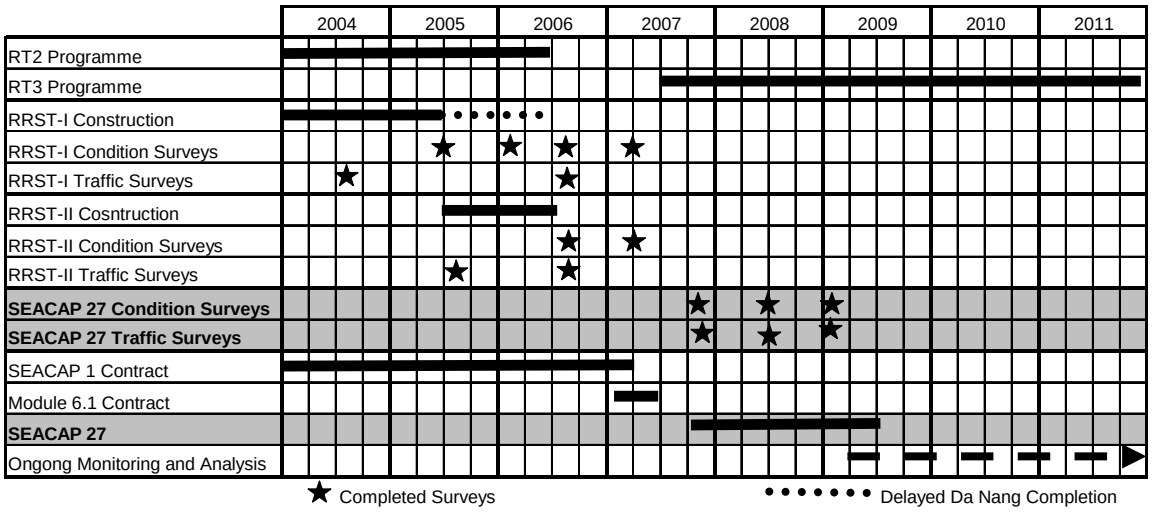
- Phase I: During December 2007 and January 2008
- Phase II: During mid May and July 2008
- Phase III: During December 2008 to mid-January 2009.

These SEACAP 27 monitoring phases were part of a continuing programme that commenced with the construction and as-built assessment of the RRST-I and RRST-II construction trials. Table 3.1 lists all the separate phases of monitoring and Figure 3.1 places them in the context of the research programme as a whole.

Table 3.1: Dates of the Condition Monitoring Phases of the RRST Trials

Province	Monitoring Phases						
	SEACAP 1				SEACAP 27		
Hue	6- 2005	2- 2006	7- 2006	3- 2007	1- 2008	5/6- 2008	1- 2009
Tien Giang	7- 2005	1- 2006	7- 2006	3- 2007	1- 2008	5/6- 2008	1- 2009
Dong Thap	7- 2005	1- 2006	7- 2006	3- 2007	1- 2008	5/6- 2008	1- 2009
Da Nang			7- 2006	3- 2007	1-2008	5/6- 2008	1- 2009
Tuyen Quang			7- 2006	2- 2007	12- 2007	5/6- 2008	1- 2009
Ha Tinh			7- 2006	3- 2007	1- 2008	5/6- 2008	1- 2009
Quang Binh			7- 2006	3- 2007	1- 2008	5/6- 2008	1- 2009
Ninh Binh			7- 2006	3- 2007	12- 2007	5/6- 2008	1- 2009
Hung Yen			7- 2006	3- 2007	12- 2007	5/6- 2008	1- 2009
Gai Lai			7- 2006	3-h 2007	1- 2008	5/6- 2008	1- 2009
Dak Lak			7- 2006	3- 2007	1- 2008	5/6- 2008	1- 2009
Dak Nong			7- 2006	3- 2007	1- 2008	5/6- 2008	1- 2009

Figure 3.1: The Overall RRSR Monitoring Programme



3.2 Collection Procedures

Monitoring procedures were based on internationally accepted procedures and on the guidelines for the monitoring of RRST trial roads which were drafted under the SEACAP 1 project[1].

Deterioration Mechanism or Parameter	Techniques and Equipment	Derived Information	Application to Trial Options
Surface condition	Standard visual condition survey	Type, intensity, width and position of cracking. Potholes and patching	All trial options
Roughness	MERLIN	Derivation of standard measure of road roughness; International Roughness Index (IRI)	All trial options
Deformation	2m straight edge	Load associated deformation, in terms of rutting	All trial options excluding concrete surfacing
Erosion	Engineering Level	Road cross section shape and comparative levels; leading to erosion rates	Unsealed carriageway sections
Layer/ pavement strength	Dynamic cone penetrometer, DCP	Relationships between DCP readings and CBR established	Gravel and sealed stabilised base options. All shoulders
Moisture	Small disturbed samples	Variation in moisture content	Gravel and unsealed options. Unsealed shoulders

Traffic count surveys were also undertaken on the monitored trial roads during each phase of the work. The traffic count form was modified during the programme to accommodate the increasing need to analyse the size and axle loads of heavy trucks that were found to be using some Vietnam rural roads.

[1] Intech-TRL, 2007. Rural Road Pavement Monitoring Guidelines. SEACAP 1 report for the MoT, Vietnam

Some Key points to note with respect to the completion of these surveys are:

- PDoT and PPMU staff were involved in all the condition data collection procedures as part of the handover process. There is now an established capability at provincial level to undertake further monitoring with some necessary technical QA back-up.
- Members of the Steering Committee accompanied the field teams on a number of occasions.
- The field surveying was managed by two TRL-OtB field managers working as separate teams. Specialist TRL-OtB staff also accompanied the field teams to selected province for QA purposes.
- 3-day traffic counts were completed on each of the monitored trial roads in all 12 RRST participating provinces. Start and finish points of all monitored sections were re-established with GPS coordinates. Concrete marker posts were established on all RRST-II start points similar to those on RRST-I.

There was an increased emphasis on technology transfer during the 3rd Phase of data collection as follows:

- VRA staff accompanied TRL-OtB teams to the three provinces in the Central High and to Ha Tinh and Quang Binh.
- UTC lecturing staff accompanied the TRL–OtB team to Tuyen Quang, Hung Yen and Quang Binh provinces.
- A UTC student field trip was made to Ha Tinh as part of the undergraduate project work. Prior to the UTC undergraduate visit a guest lecture was given by Dr J Cook at UTC on the RRSR programme in general and the trials monitoring in particular.
- Additional engineers from all the participating PDoTs were trained in the data collection procedures.

A full listing of the monitored sections is included in Appendix A to this report.

4 The RRST Data and Its Analysis

4.1 The RRSR Database

A database for the RRSR information was assembled under the SEACAP 1 programme and its extensions. This was essentially a working database of files containing data complied from:

1. RRST-I trials - SEACAP 1
2. RRST-II trials – SEACAP 1
3. RRGAP road condition survey – SEACAP 4

The SEACAP 27 project is primarily concerned with the RRST-I and RRST-II data and the structure and content of this part of the database is summarised in Table 4.1. SEACAP Technical Paper 3 contains further detail on the whole of the RRSR database.

Table 4.1: RRST Elements of the RRSR Database

Data Sets	Files	Comment
General location and definition of trials roads and monitoring sections Summary Traffic data Summary IRI roughness data Summary deterioration analyses	ACCESS .mdb tables and associated queries and reports	Separate ACCESS table are linked by unique provincial and road reference codes.
Visual assessments	Visual.xls files held within each provincial folder	Coded field data sheets transcribed onto EXCEL sheets for each monitored section.
MERLIN roughness data	IRI-data.xls files held within each provincial folder.	MERLIN raw data calculated on spreadsheets
Unsealed control sections level data	Level.xls files held within each provincial folder	Tabulated cross section level data referenced to local TBMs. Plots of each cross section updated for each monitoring survey.

4.2 Analytical Objectives

There were two main objectives to the SEACAP 27 analysis programme;

1. A statistical assessment of pavement and surfacing condition and causes of deterioration based primarily on coded visual assessment data
2. An interpretation of the above trials assessments as they impact on option selection, maintenance and cost models

The first completed task is reported in Technical Paper 1 and comprised the following key steps:

1. Collation of trial road condition data within three trial road groups and one control road group (Table 4.2)
2. Statistically organisation and assessment of the data sets within each primary group
3. Ranking of the relative condition of trial sections within each group.
4. Identification of likely key factors influencing the deterioration of the worst performing roads in each group, for example; traffic, axle loading, rainfall/flooding, poor construction, poor materials, or lack of maintenance.

The second main task is reported in this document in the following sections 4.3 and 4.4 and in Chapters 5 and 6.

4.3 The Analytical Methodology

The analytical procedures have been based around the numeric assessment of the deterioration of the trial sections with time. The overall assessment approach is described and reported in Technical Paper 1, whilst further analysis aimed at the practical application of the trials data is included here.

To simplify the assessment of rural roads two indices have been set up; the Road Condition Deterioration Index (RCDI) and the Deterioration Extent Index (DEI). These indices are aimed for use in establishing the level of maintenance requirement and thus providing a starting point for the calculation of the whole life cost. They can also be used to establish relationships between the performance of the trial surfacing options within a series of road environment in Vietnam. These simplified indices can be used at provincial or district level to monitor maintenance requirement.

Table 4.2 lists these key factors for each road group. The Calculation of a Road Condition Deterioration Index (RCDI) for each trial section, based on these factors, allows assessment of the level of deterioration on a percentage basis, whilst the calculation of the Deterioration Extent Index allows assessment of the extent of deterioration for each trial section by summing all 5m blocks of the trial length of road showing any deterioration with respect to the key indicators.

The estimation of the costs required to rehabilitate the trial roads can then be based on the above data.

Table 4.2 Key Performance Indicators

Trial Group	**Indicative Factors**
Concrete	Joint condition Crack extent Surface condition Potholes
Sealed Flexible	Crack extent Ruts Potholes
Blocks	Block condition Joint Condition Ruts Potholes
Control Group	
Unsealed	Erosion Ruts Potholes

The Road Condition Deterioration Index of a trial section is the ratio of Road Condition Deterioration (RCD) and maximum Road Condition Deterioration (RCD_{max}). This index shows the level of deterioration on each trial section for the features mentioned above.

As an example, a maximum deterioration for potholes is code "3" (i.e. >3 potholes in a 5 m block). If every 5m block on a 100m trial section had this maximum deterioration this would be equal to 100% index.

Note that 100% does not indicate a complete disintegration of the road, but rather an extremely serious pot-holed condition. Table 4.3 presents sample worksheet for the calculation of RCDI and DEI.

Table 4.3: Sample Calculation of RCDI and DEI

			Key defects							
			Left carriageway			Right carriageway				
	Chainage	Concrete slab No.	Cracking area	Wheel rut	Pothole	Cracking area	Wheel rut	Pothole	Block damaged on LHS	Block damaged on RHS
			(1)	(2)	(3)	(4)	(5)	(6)		
	0	1	0	0	0	0	0	0	0	0
	5	2	0	0	0	0	0	0	0	0
	15	3	0	0	0	0	0	0	0	0
	20	4	0	0	0	0	0	0	0	0
	25	5	0	0	0	0	0	0	0	0
	30	6	0	1	0	0	0	0	1	0
	35	7	0	1	0	0	0	0	1	0
	40	8	0	0	0	0	0	0	0	0
	45	9	0	0	0	0	0	0	0	0
	50	10	0	0	0	0	0	0	0	0
	55	11	0	0	0	0	0	0	0	0
	60	12	0	1	0	0	0	0	1	0
	65	13	0	1	0	0	1	0	1	1
	70	14	0	1	0	0	1	0	1	1
	75	15	0	1	0	0	1	0	1	1
	80	16	1	2	0	0	1	0	1	1
	85	17	0	1	0	2	1	0	1	1
	90	18	1	2	0	3	1	0	1	1
	95	19	3	2	0	3	2	0	1	1
	100	20	2	1	0	3	1	0	1	1
	Total								11	8
Total road deterioration indices	41		7	14	0	11	9	0		
Standard index showing good condition			0	0	0	0	0	0		
Total road condition deterioration (RCD)	41		7	14	0	11	9	0		
Maximum deterioration index			3	2	3	3	2	3		
Maximum total road deterioration condition (RDC_{max})	440		60	100	60	60	100	60		
Individual defect CDIs			12	14	0	18	9	0		
Total RCDI% = (41/440)%	**9.3**									
Total DEI% = (11+8)/40%	**47.5**									

Individual Condition Deterioration Indices (CDIs) for individual factors can also be established. For example, in the case of the concrete slabs, assessing an individual CDI for slab seals has proved to be a necessary step.

The Road Condition Deterioration Index (RCDI) can be calculated for the series of condition surveys over a number of years and the comparative deterioration of pavements can be plotted versus time or traffic (esa). Individual Condition Deterioration Indices (CDIs) for separate factors can be examined to identify the most significant deterioration modes.

The RCDI gives a measure of defect occurrence within a section but does not indicate whether this is an isolated or extensive problem. The associated Defect Extent Index (DEI) is a simple measure of the percentage of the road affected by any deterioration. This is done by noting how many of the 5m visual assessment blocks have a key defect. The combination of RCDI and DEI allows a rapid assessment for maintenance of deterioration, seriousness, and extent; for example,

- A high RCDI and high DEI indicates a widespread serious defect problem
- High RCDI but low DEI indicates a isolated serious defect
- Low RCDI and high DEI indicates a minor widespread defect

A general assessment of trial conditions can be based on these indices as shown in Table 4.4

Table 4.4: Definition of General Road Condition Based on RDCI and DEI

RDCI	DEI	Road condition
RD<C5%	DEI<10%	Good
	10%≤DEI<100%	Fair
5%≤RDCI<20%	DEI<20%	Fair
	20%≤DEI<100%	Fair
20%≤RDCI<50	20%≤DEI<50%	Poor
	DEI≥50%	Very poor
RDCI≥50%	-	Very poor

4.4 Traffic

The evaluation of the overall damaging effect of traffic on the trial road pavements has followed the normal practice of measuring it in terms of equivalent standard axles, as is described in Technical Report 1.

Since the initial review of traffic for SEACAP 27 was undertaken, an amendment was made to the third phase traffic survey which looked in more detail at the axle configurations of the larger trucks (>5T). This latest survey indicated a significant variation in the pattern of truck use between different regions in Vietnam, Table 4.5.

Table 4.5: Analysis of Larger Trucks on Trials Roads: January 2009

Region	Trucks >5T			Total Number
	% 2 Axle	% 3 Axle	% 4 Axle	
All Regions	61	30	9	745
N-C Coastal	70	30	0	117
Central Highlands	44	42	14	445
Red River Delta	95	5	0	20
N Highlands	98	2	0	159
Mekong Delta	100	0	0	1

In the light of this significant variation traffic analysis of the larger (>5t) truck fraction has been assessed using the regional weighted average values, as follows:

Mekong delta(Dong Thap; Tien Giang)	esa 1.0
N Central (Da Nag, Hue, Quang Binh, Ha Tinh)	esa 3.9
C Highlands (Gia Lai, Dak Lak, Dak Nong)	esa 4.1
Red River delta (Hung Yen, Ninh Binh)	esa 1.4
N Highlands (Tuyen Quang)	esa 1.1

Large buses and small trucks have been assessed at 1.5 and 0.12 esa respectively. A summary of the revised traffic data for all the sites is shown in Appendix B.

5 Review of Pavement and Surfacing Selection and Construction Guidance

5.1 General

The following sections summarise the key points to arise out of the trials condition monitoring to date as they impact upon the selection and design procedures for rural roads in Vietnam. These comments arise out of the conclusion both of Technical Paper I and the further analyses reported in this document (Tables 5.1 to 5.9).

5.2 Concrete Pavements

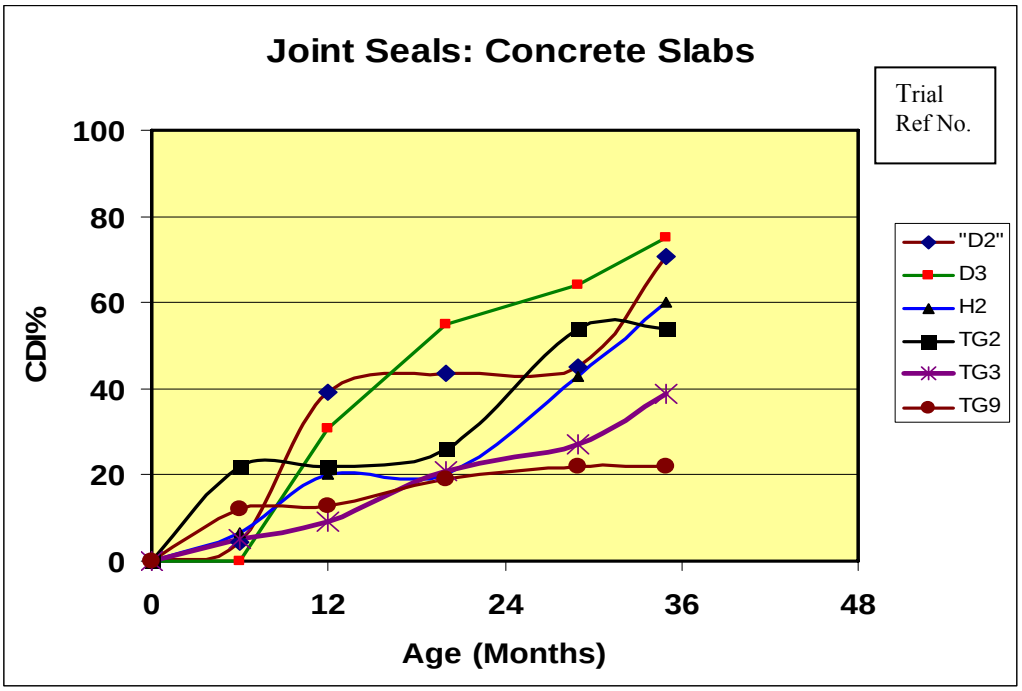
Table 5.1: Deterioration of Concrete Pavements Based on RDCI and DEI

Trial Sections Ref. Code	Type	Performance	Age (Months)	RCDI% Pavement Slab	DCI% Inter-Slab Joint	DEI (%)
GL(1)-2	NRC	Very poor	24	36	21	85
TQ(1)-2	BRC	Very poor	24	28	28	68
T9	BRC	Very poor	36	27	30	70
DL(3)-1	NRC	Very poor	24	25	69	70
T2	BRC	Very poor	36	24	63	53
DN(1)-5	NRC	Poor	24	17	100	53
HT(2)-2	NRC	Poor	24	10	50	23
QB(2)-2	NRC	Poor	24	9	21	20
GL(2)-3	NRC	Poor	24	7	36	23
TQ(1)-5	NRC	Fair	24	6	16	18
HT(2)-3	BRC	Fair	24	4	50	10
DaN2	SRC	Fair	24	3	81	11
HT(1)-1	BRC	Fair	24	3	95	8
HT(1)-2	NRC	Good	24	3	86	5
NB(1)-2	NRC	Good	24	2	89	8
TQ(1)-4	NRC	Good	24	5	4	10
H2	BRC	Good	37	3	63	9
D2	BRC	Good	36	1	73	3
QB(1)-3	BRC	Good	24	0	46	0
HY(1)-1	BRC	Good	24	0	43	0
T3	SRC	Good	36	0	44	0
D3	SRC	Good	36	2	76	9
HY(1)-2	NRC	Good	24	1	65	2.5
HT(3)-2	NRC	Good	24	2	13	5

Table 5.1 summarises the road condition indices and related information for 24 concrete monitoring sections. The principal points to arise out of combination of these data combined and the review undertaken in Technical Paper 1 are:

1. Concrete roads are generally performing well. Even on the sections characterised in the review as "poor performers", the pavement slabs are still performing adequately in a zero-maintenance regime. The reason is that although there may be cracking present on the pavement; its severity (width and depth) is low.
2. The early deterioration in the inter-slab joint seals is a significant feature in the cost-performance review of these options, Figure 5.1.
3. Poor construction technique has been shown to be a major factor whenever the performance of the slabs is poor.
4. Bamboo reinforcement has been shown to have no advantage over properly constructed non-reinforced concrete. It's continued use is not recommended.
5. The use of a sand bedding layer is now not recommended. The advantages appear to be outweighed by the risk of erosion and undercutting, particularly in high rainfall and flood prone areas. Concrete slabs may be constructed directly on a smooth well prepared sub-base.

Figure 5.1: Deterioration Patterns in RRST-I Concrete Joint Seals



5.3 Flexible Sealed Pavements

As noted in Technical Paper 1, the analysis of sealed flexible pavements has to acknowledge and take into account the occurrence of two separate modes of deterioration; surface seal deterioration and structural failure of the base, sub-base or sub-grade.

By comparing the CDI for surface cracking with the CDI for rut development it is possible to get an indication of the relative importance of these two modes in a deteriorating trial section. Table 5.2 presents a summary of this analysis, which has taken a rut CDI of 20% and a crack DCI of 10% as the starting indication of structural and seal problems respectively. Tables 5.3 to 5.5 summarise the condition a data for the flexible sealed options.

Table 5.2: Deterioration Modes Based on DCIs

Site	Base (layer thickness mm)	Sub-base (layer thickness, mm)	DCIs %				Comment
			Crack Right	Crack Left	Rut Right	Rut Left	
Triple BST							
DN(1)-1	WBM (120)	Gravel (200)	**10**	**17**	**8**	**5**	Surface
DN(2)-1	DBM (120)	Gravel (200)	**0**	**0**	**0**	**0**	
DBST							
HT(1)-5	WBM (100)	WBM (100)	**0**	**0**	**4**	**7**	
HY(2)-3	Crushed stone (150)	Cement stab sand (150)	**5**	**25**	**9**	**13**	Surface
HY(2)-4	WBM (100)	WBM (150)	**27**	**12**	**23**	**20**	Structural
HY(3)-2	Crushed stone (120)	Cement stab sand (150)	**45**	**23**	**20**	**20**	Structural
HY(3)-2a	Crushed stone (120)	Cement stab sand (150)	**7**	**12**	**15**	**14**	Surface
NB(1)-1	WBM (100)	WBM (150)	**0**	**0**	**18**	**18**	
NB(2)-1	WBM (100)	WBM (150)	**0**	**0**	**13**	**18**	
NB(2)-3	WBM (100)	WBM (150)	**0**	**0**	**10**	**15**	
NB(3)-2	WBM (100)	WBM (150)	**0**	**0**	**0**	**6**	
QB(3)-2	WBM (100)	WBM (100)	**0**	**0**	**0**	**0**	
TQ(1)-3	WBM (100)	WBM (100)	**55**	**8**	**10**	**5**	Surface-drainage
TQ(2)-1	WBM (100)	WBM (100)	**40**	**35**	**22**	**21**	Structural
TQ(2)-1a	WBM (120)	WBM (120)	**0**	**0**	**0**	**0**	

Table 5.2 (Contd)

Site	Base (layer thickness mm)	Sub-base (layer thickness, mm)	DCIs %				Comment
			Crack Right	Crack Left	Rut Right	Rut Left	
Sand Seal on SBST(e)							
D05	DBM (200)	Crushed fine aggregate(120)	0	0	0	0	
D06	Lime stab soil (150)	Lime stab soil (150)	0	0	0	0	
DaN03	Cement stab sandy soil (150)	Cement stab sandy soil (150)	60	59	8	4	Surface-Reflection
DaN04	Cement stab sandy soil (150)	Emul stab sandy soil (150)	78	78	2	1	Surface-Reflection
DL(2)-2	DBM (100)	DBM (100)	35	52	27	27	Structural
H09	Crushed stone (70)	Gravel (200)	0	0	0	0	
TG05	DBM (200)	Sand (120)	31	26	0	3	Surface
TG06	Lime stab soil (150)	Lime stab soil (150)	56	30	1	7	Surface-Reflection
Pen Mac							
DL(1)-2		WBM (100)	0	0	2	4	
D07	WBM (100)	WBM (100)	0	0	0	0	
DaN05	WBM (100)	WBM (100)	0	0	0	0	
DL(3)-2		WBM (100)	0	0	13	11	
DN(2)-2	WBM (100)	WBM (100)	0	0	0	0	
H04	WBM (100)	WBM (100)	0	0	1	1	
TG07	WBM (100)	WBM (100)	0	0	0	0	
DBST (e)							
DL(1)-1	DBM (100)	DBM (100)	0	0	0	0	
DL(2)-1	DBM (100)	DBM (100)	95	85	58	61	Structural
DL(2)-3	DBM (100)	Gravel (200)	52	42	26	26	Structural
DL(2)-4	DBM (100)	Gravel (200)	0	0	8	11	
DN(1)-2	WBM (120)	Gravel (200)	27	25	9	9	Surface
DN(1)-3	DBM (120)	Gravel (200)	0	0	14	14	
DN(1)-4	DBM (120)	Gravel (200)	25	32	0	0	Surface
DN(2)-3	DBM (120)	Gravel (200)	0	0	0	0	
DN(2)-4	DBM (120)	Gravel (200)	0	0	0	0	
GL(1)-1	DBM (100)	DBM (150)	0	0	0	0	
GL(1)-3	DBM (100)	DBM (150)	52	3	0	0	Surface
GL(2)-1	DBM (100)	DBM (150)	0	0	0	0	
GL(2)-3	DBM (100)	DBM (150)					
HT(1)-3	DBM (100)	DBM (100)	12	0	4	1	Surface
HT(1)-4	WBM (80)	WBM (100)	0	0	4	5	
HT(2)-1	WBM (100)	WBM (150)	0	0	0	0	
HT(3)-1	WBM (100)	River gravel (120)	0	0	0	0	
HY(3)-1	Cement stab sand (150)	Cement stab sand (150)	32	73	0	0	Surface-Reflection
NB(3)-1	WBM (150)	Soil (150)	0	0	0	0	
NB(4)-1	WBM (150)	Soil (150)	0	0	7	4	
QB(1)-1	Crushed stone (100)	Cem St sandy soil (150)	0	0	0	0	
QB(1)-2	DBM (120)	DBM (120)	0	0	0	0	
QB(2)-1	Crushed stn (100)	Crushed stn (150)	5	0	11	13	
QB(2)-3	Crushed stn (100)	Crushed stn (150)	0	0	3	8	
QB(3)-1	DBM (100/120)	DBM (120)	0	0	1	1	
TQ(1)-1	WBM (120)	WBM (120)	0	0	6	8	

Table 5.3: Hot Bitumen Sealed Trial Section Condition Based RCDI and DEI

Trial Sections Ref No.	Performance	Age (months)	RCDI Index (%)	DEI Index (%)	Comment
Pen Mac					
D7	Good	24	0	0	
T7	Good	36	0	0	
H4	Good	37	0	0	
DL(1)-2	Good	24	0	0	
DN(2)-2	Good	24	0	0	
DaN5	Good	24	1	5	
DL(3)-2	Poor	24	5.5	60	Very shallow ruts
Hot Bitumen Seals					
HY(3)-2	Very poor	24	23	95	Structural problem
HT(2)-1	Very poor	24	21	83	
HY(2)-4	Poor	24	18	100	
HY(3)-2	Poor	24	14	93	Structural problem
TQ(1)-3	Poor	24	14	58	
HY(2)-3	Poor	24	10	55	
NB(1)-1	Poor	24	8	88	
NB(2)-3	Poor	24	8	83	
NB(2)-1	Poor	24	5	55	
HT(1)-4	Fair	24	1	10	
TQ(2)-1a	Fair	24	2	18	
HT(1)-5	Fair	24	2	18	
NB(3)-2	Fair	24	3	33	
HT(3)-1	Good	24	1	3	
QB(3)-2	Good	24	1	8	

Table 5.4: Bitumen Emulsion Sand Seal over SBST Emulsion Seal

Trial sections	Performance	Age (months)	RCDI Index (%)	DEI Index (%)	Comment
DL(2)-2	Very poor	24	55	100	Traffic Overloading
DaN4	Very poor	24	31	99	Cement cracking
DaN3	Very poor	24	24	99	Cement cracking
D6	Poor	36	12	59	
T6	Poor	36	10	64	
D5	Poor	36	10	64	
T5	Poor	36	9	53	
DaN8	Good	24	1	3	
H9	Good	37	1	1	

Table 5.5: Bitumen DBST Emulsion Sealed Trial Sections

Trial Sections Ref No	Performance	Age (months)	RCDI Index (%)	DEI Index (%)	Comments
DL(2)-1	Very poor	24	75	100	Traffic overload
DL(2)-3	Very poor	24	39	100	Traffic overload
HY(3)-1	Very poor	24	31	100	Cement cracking
TQ(2)-1	Very poor	24	20	95	Structural problem
GL(1)-3	Poor	24	12	53	
DN(2)-3	Poor	24	11	53	
QB(2)-1	Poor	24	10	75	
QB(3)-1	Poor	24	10	55	
DN(1)-4	Poor	24	9	51	
DN(1)-2	Poor	24	10	33	
HT(1)-3	Fair	24	4	28	
DN(1)-3	Fair	24	4	48	
GL(2)-1a	Fair	24	3	25	
TQ(1)-1	Fair	24	2	25	
QB(2)-3	Fair	24	2	20	
GL(1)-1	Fair	24	2	18	
GL(2)-1	Good	24	2	18	
DL(2)-4	Good	24	2	18	
NB(4)-1	Good	24	1	8	
QB(1)-1	Good	24	1	2	
NB(3)-1	Good	24	0	0	
DN(2)-1	Good	24	0	0	
QB(1)-2	Good	24	0	0	
DN(2)-4	Good	24	0	0	

The following conclusions may be drawn on the deterioration of flexible pavements based on the available data:

1. There is evidence that the DBST (e) seals are performing at least as well as the Vietnamese standard hot bitumen DBST seals. It may be truer to say that the combination of DBST(e) over DBM is performing better than the Vietnamese standard option of DBST over WBM. The former combination is therefore considered preferable.

2. The local contractors had significant experience in constructing Pen Mac pavement and they were generally constructed to a reasonable standard. The data indicates that the penetration macadam option is performing better than either DBST or DBST(e) seals. However some evidence from non-monitored sections on the Ea Sup road in Dak Lak[2] indicates that they are susceptible to shallow potholing or ravelling deterioration under heavy truck traffic and once this occurs the subsequent further deterioration may be rapid.

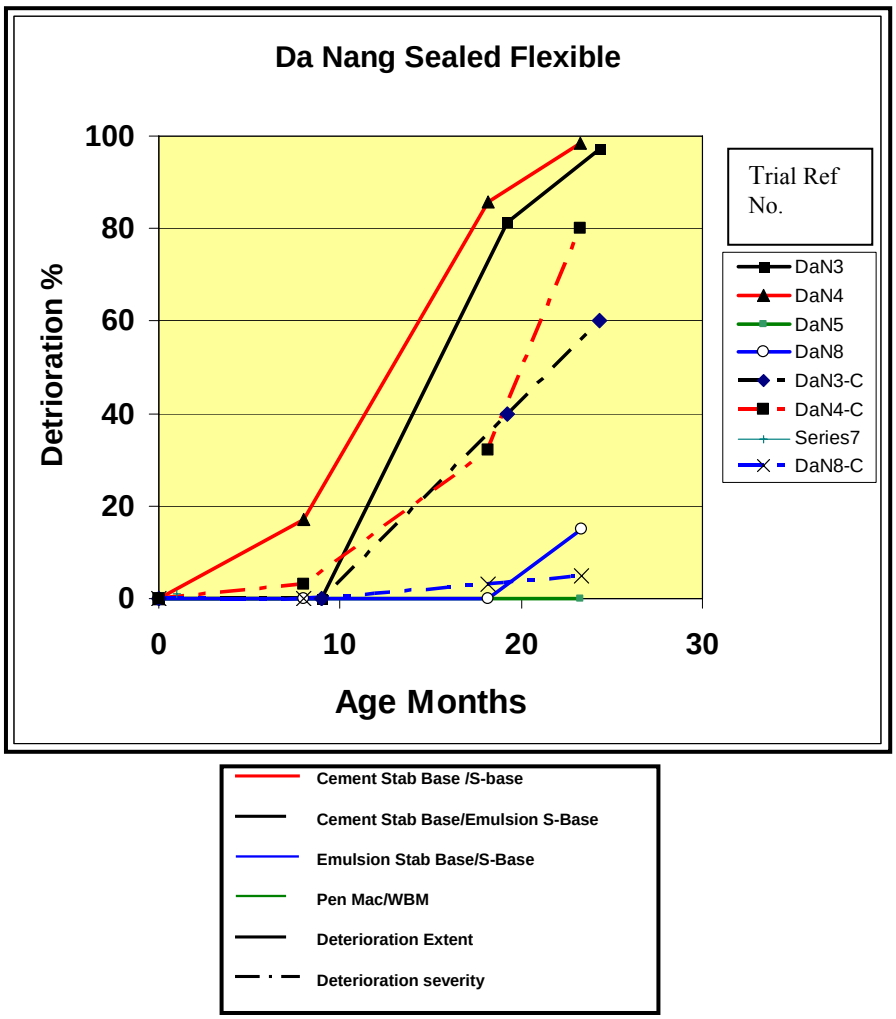
[2] TRL-OtB, 2008 Case Study of Dak Lak RRST Pavement and Surface Deterioration: Ea Sup Road. SEACAP 24 Report to the MoT, Vietnam

3. The single sand emulsion over SBST(e) seals are showing distinct signs of erosion. However it is worth noting that most of these seals are now over 3 years old and that current international advice recommends a second layer of sand seal should be laid within six months of construction.

4. The performance of a significant number of the poorly performing sites is being influenced by base, sub-base or subgrade issues. This is can be demonstrated by comparing DCI % for crack extent with that for rut development (Table 5.3).

5. Particularly noticeable is the reflection cracking associated with lime or cement stabilised bases. Figure 5.2 shows the significance of this cracking compared to other sealed flexible options within one road environment.

Figure 5.2: Cracking in Seals over range of Flexible Sealed Options; Da Nang



6. Poor construction is major issue with the flexible pavement sites, particularly with regard to the seals.

7. The trial flexible sealed options have been shown to be vulnerable to traffic and axle loads over and above the design criteria. Unless specifically designed with this hazard in mind then these options are “at risk” in poorly managed environments.

8. It is apparent the sand-sealing is not a suitable option within the high rainfall - low maintenance road environments in Vietnam.

5.4 Block Paving Options

Table 5.6 summarises the condition data for the block pavement options in all RRST trial sections.

Table 5.6: Performance of Block pavements based on RCDI and DEI

Trial Sections Ref. Codes	Performance	Age month	RDCI (%)	CDI % Seal or Joint Condition	DEI %	Comment
D10	Fair	36	8	15	97	Cement mortar brick
H11	Fair	37	10	11	98	Cement mortar stone setts
HY(2)-2	Very poor	24	44	100	100	Sand emulsion seal
HY(2)-2a	Very poor	24	42	98	100	Sand emulsion seal
D11	Poor	36	18	58	100	Sand emulsion seal
H7	Poor	37	16	64	100	Sand emulsion seal
HY(2)-1	Very poor	24	39	100	100	Sand emulsion seal
D12	Very poor	36	16	59	100	Sand emulsion seal
H6	Poor	37	17	67	100	Sand emulsion seal
HY(4)-1	Poor	24	19	68	100	Sand emulsion seal
NB(2)-2	Very poor	24	33	45	100	Fine chipping jointed stone cobbles

Based on the definitions of road condition and the above results, the performance and causes of defects of block pavements have been assessed as follows:

1. In general, the performance of block pavement is poor. Only 3 out of 11 sections could be considered as having performed well after 24 – 36 months of operation. However, this conclusion should be further considered in terms of the scale and types of defects.
2. The single sand seals on block options have performed very poorly. Recent international advice recommends a second layer of sand seal should be laid within six months of construction. This however, would add to the cost without any guarantee of improvement in high rainfall and flood environments.
3. The use of mortared joints may appear to have some advantages over sealed sand joints in high erosion environments; however, there could be a disadvantage in the loss of inter-block flexibility.
4. It is found that on the 8 poorly performing sections, the overall DEI% is high but the RDCI is less than 20%, i.e. the defects are widespread but not yet significant. Hence the sections classified with a high DEI% in fact are still performing well as their deterioration condition is not serious.
5. Having reviewed the database, it was found that the joint and surface deterioration are the dominant defect. Significant block damage was found only on section HY(2)-2, where there were recorded problems with compliance with brick strength specifications. . The minimum strength requirement of 20-25MPa for manufactured engineering quality bricks is therefore important.

6. Based on the RRSR evidence, these block options cannot be described as low maintenance options. However, if the relatively cheap maintenance is carried out timely and regularly then good performance can be retained for a long time.

5.5 Unsealed Granular Options

Technical Report 1 reviewed all 8 trial sections in terms of gravel loss, although the 4 RRST-I sections have now been rehabilitated. In this section Table 5.7 deals with the remaining 4 RST-II sections in terms of their condition as assessed using the Road Condition Deterioration Index and Deterioration Extent Index up to August 2008.

Table 5.7: Performance of Unsealed Wearing Course Surfaces based on RDCI and DEI

No	Trial Sections Ref. Codes	Performance	Age (Months)	RDCI Index (%)	DEI Index (%)	Comment
1	DN(2)-5	Very poor	24	55	100	Gravel
2	DaN6	Very poor	24	100	100	WBM
3	GL(1)-4	Very poor	24	56	100	Gravel
4	GL(2)-2	Very poor	24	58	100	Gravel

The above results show that all 4 sections are seriously deteriorated. While the deterioration rate of natural gravel sections after 24 months is over 50%, the waterbound macadam sections are totally damaged. This result together with the fact of 4 totally damaged sections in RRST 1 conforms the general poor performance of this option within most of the road environments in Vietnam.

The causes for deterioration of unsealed flexible pavement in general and each trial section in particular are described in more details in the Technical Paper 1.

5.6 Summary

The SEACAP 1 Final Report recommended a 2-stage option selection and pavement design process. Following the mid-term monitoring and review process, this continues to be a key recommendation. However, within that process there are some recommended changes to the detail of the option selection and to the suitability matrix, Figure 5.3. This figure has been amended to reflect the results from the monitoring to date.

In particular the following structural changes have been made to the matrix :

1. The ranking system now runs on a scale of 1(best option) to 4 (poor option or not recommended).
2. Bamboo reinforced concrete and sand-sealed block options are no longer included as options.
3. The following additional Selection Factors have been added:
    - Ease of Quality Control
    - Green Environment - Safety issues

Figure 5.3: RRST Suitability Matrix

Key Trial and Control Pavement Layers	Key Selection Factors														
	Local material Use*	Labour-Based	Ease of Construction	Quality Control	Maintenance	Sustainability	Resitance to Rainfall/Flooding	Load Spreading on Weak Sub-Grades	Small Contractor Suitability	Local Economy Advantages	Resistance to Axle Overloading	Relative Initial Cost	Likely Whole Life Cost Advantages	Green Environment-Safety	User advantages (Roughness)
Emulsion Sand Seals	1	1	1	1	3	4	4	3	1	2	3	1	3	2	2
Emulsion Stone Chip Seals	3	1	2	1	2	2	2	3	1	2	3	2	2	2	2
Lime stabilised Base/Sub-base	1	2	3	2	3	2	3	3	1	2	2	2	2	3	3
Cement Stabilised Base/Sub-base	1	2	3	2	3	2	2	3	1	2	2	2	2	2	3
EmulsionStabilised Sub-Base	1	4	4	3	2	2	2	3	4	3	2	3	2	4	3
Sealed Dry-Bound Macadam	3	3	2	3	1	1	2	2	2	3	2	2	2	3	2
Sealed Water-Bound Macadam	3	3	2	3	1	1	2	3	2	3	2	2	2	3	2
Dressed Stone/Cobbles	1	1	2	1	2	1	1	1	1	1	1	3	2	1	4
Fired Clay Bricks	1	1	2	1	2	2	3	1	1	1	2	2	2	2	3
Concrete Bricks	2	1	2	1	2	2	3	1	1	2	1	3	2	1	2
Sealed Armoured Gravel	2	3	2	2	2	2	2	3	2	3	4	2	2	2	2
Steel Reinforced Concrete	2	2	3	3	1	1	1	1	2	3	1	4	2	3	1
Non-Reinforced Concrete	2	2	2	2	1	1	1	2	1	2	1	4	2	2	1
Hot Bitumen Stone Chip seals	3	2	2	4	2	2	2	3	2	2	3	2	2	3	2
Unsealed Natural Gravel	1	3	1	3	4	4	4	3	1	2	3	1	4	3	3
Penetration Macadam	3	3	2	3	2	2	2	3	2	2	3	2	2	4	2
Unsealed Water-Bound Macadam	2	2	2	2	4	4	4	3	2	3	3	1	4	3	4

* Assuming material locally available

Notes 1 = Significant advantages 2 = Some likely advantages
3 = No clear advantage 4 = Significant disadvantages

6 Review of Maintenance and Cost Model Issues

6.1 The Calculation of Maintenance Costs

The cost for maintenance of low volume rural roads is the function of the nature and extent of road deterioration and the rate at which this occurs and can be estimated with the aid of the RRSR data analytical tools. In SEACAP 27 the required costs to restore the as-built condition of the RRST pavements have been calculated in order to better ascertain the relative maintenance costs within their various road environments and to further highlight performance issues.

The required costs to rehabilitate the RRST options have been calculated using the following information:

1. Existing circulars and decrees of the Government of Vietnam regarding the cost estimation for capital construction.
2. Procedures and norms of maintenance of rural road trials established under SEACAP based on the Vietnamese and international norms on maintenance of rural roads.
3. Assessment of key maintenance factors for each trial group included in the interpretation of trials assessments based on data collected up to August 2008.
4. Unit cost of material, labour and equipment per work shift in the relevant provinces

On the basis of the above, the costs of RRST sections have been calculated and summarised by different groups of pavements together with the Road Deterioration Condition Index and Deterioration Extent Index. Details of the calculations are included as Appendix C to this report.

6.2 Concrete Pavements

The maintenance costs of the cement concrete sections after 2 to 3 years of operation are low but are not insignificant and are mainly associated with the inter-slab joints seals. The cost and condition assessments are summarised in Table 6.1, which indicates the following:

- There are significant costs associated with repairs of cracks.
- Rehabilitation of joint seals is the major requirement and this requirement will be greater in the case of pavements with a central joint.
- Concrete pavement options are not a “zero-maintenance” option; although it is likely that an early maintenance of the joint seals within 12 months of construction would considerably reduce further maintenance requirements. The cost of this earlier preventative maintenance is likely to around $200/km.

Table 6.1: Concrete Trials Rehabilitation Costs

Trial Sections Ref. Codes	Age (Months)	RCDI% Pavement Slab	DCI% Inter-Slab Joint	Rehabilitation Cost/km (US$)	Comment
DL(3)-1	24	25	69	$1211	> 50% slabs with cracks
TQ(1)-2	24	28	28	$624	> 50% slabs with cracks
DN(1)-5	24	17	100	$609	> 25% slabs with cracks
D2	36	1	73	$563	
D3	36	2	76	$537	
DaN2	24	3	81	$530	
GL(1)-2	24	36	21	$516	> 30% slabs with cracks
HT(1)-2	24	3	86	$491	
HT(1)-1	24	3	95	$489	
HT(2)-2	24	10	50	$469	> 30% slabs with cracks
T2	36	24	63	$460	> 30% slabs with cracks
NB(1)-2	24	2	89	$454	
HY(1)-2	24	1	65	$364	
HT(2)-3	24	4	50	$352	
H2	37	3	63	$352	
T9	36	27	30	$329	> 20% slabs with cracks
GL(2)-3	24	7	36	$260	
HY(1)-1	24	0	43	$243	
QB(1)-3	24	0	46	$235	
TQ(1)-5	24	6	16	$199	
QB(2)-2	24	9	21	$195	
T3	36	0	44	$181	
HT(3)-2	24	2	13	$102	
TQ(1)-4	24	5	4	$49	

6.3 Flexible Sealed Pavements

The calculation of rehabilitation costs for the sealed flexible pavement trial sections, summarised in Table 6.2, 6.3 and 6.4, also show that the maintenance costs can be directly related to the pavement performance, apart from some exceptional cases that are explained below.

Key points to arise are:

- The maintenance costs for penetration macadam are likely to be very low because most of the sections do not require maintenance or require only very minor repair.
- There are some very rehabilitation costs associated with repair of structurally failed road sections such as DL(2)-1, DL(2)-2 and DL(2)-3 sections of Buon Ho road, Dak Lak province. These cannot be considered as maintenance costs, but they do serve to highlight the cost penalties associated with poor road management. The causes of these defects were considered separately by the SEACAP 24 project.
- Apart from structural problems, particular issues such as the cracking over stabilised bases, the defects associated with the sealed flexible sections are generally occurring on a wide area (high DEI), but with low severity (low RDCI index).
- The influence of poor seal construction has been highlighted previously in this report and in Technical Report 1.

- Very shallow rutting (<10mm) has not been included as a necessary cost at this time; for example, on sections NB(1)-1; NB(2)-1; NB(2)-3.
- The original RRST-I sand seal over SBST options, following over 36 months with no maintenance, are starting to indicate significant rehabilitation costs.

Table 6.2: Hot Bitumen Sealed Flexible Pavement Rehabilitation Costs

Trial sections Ref. Codes	Age (months)	RCDI Index (%)	Rehabilitation Cost per km (US$)	Comment
DaN5	24	1	$276	Pen Mac
D7	24	0	0	Pen Mac
T7	36	0	0	Pen Mac
H4	37	0	0	Pen Mac
DL(1)-2	24	0	0	Pen Mac
DN(2)-2	24	0	0	Pen Mac
DL(3)-2	24	5	0	Pen Mac Very shallow ruts only
TQ(1)-3	24	14	$3,095	Surface drainage leading to structural problem
HY(2)-4	24	18	$1,967	Structural problem
HY(3)-2	24	23	$1,521	Structural problem
HY(2)-3	24	10	$1,204	
HY(3)-2a	24	14	$108	Structural problem
NB(1)-1	24	8	0	Very shallow ruts only
NB(2)-3	24	8	0	Very shallow ruts only
NB(2)-1	24	5	0	Very shallow ruts only
HT(1)-4	24	1	0	
TQ(2)-1a	24	2	0	
HT(1)-5	24	2	0	
NB(3)-2	24	3	0	
HT(3)-1	24	1	0	
QB(3)-2	24	1	0	

Table 6.3: Bitumen Emulsion Sand Seal over SBST Emulsion Seal

Trial Sections Ref Codes	Age (months)	RCDI Index (%)	Rehabilitation Cost per km (US$)	Comment
DL(2)-2	24	55	$12,746	Traffic Overloading
DaN4	24	31	$5,721	Cement cracking
T6	36	10	$1,796	
D5	36	10	$1,693	
T5	36	9	$1,066	
DaN3	24	24	$902	Cement cracking
D6	36	12	$888	
DaN8	24	1	0	
H9	37	1	0	

Table 6.4: Bitumen DBST Emulsion Sealed Trial Sections

Trial Sections Ref. Codes	Age (months)	RCDI Index (%)	Rehabilitation Cost per km (US$)	Comments
DL(2)-1	24	75	$30,785	Traffic overload
DL(2)-3	24	39	$21,940	Traffic overload
QB(3)-1	24	10	$2,502	
DN(1)-4	24	9	$2,230	
TQ(2)-1	24	20	$2,152	Structural problem
DN(2)-3	24	11	$1,553	
QB(2)-1	24	10	$666	
GL(1)-3	24	12	$602	
HY(3)-1	24	31	$430	Cement cracking
HT(1)-3	24	4	$271	
DN(1)-2	24	10	$52	
NB(3)-1	24	0	$44	
DL(2)-4	24	2	$22	
DN(1)-3	24	4	$10	
GL(2)-1a	24	3	$10	
QB(2)-3	24	2	$10	
TQ(1)-1	24	2	0	
GL(1)-1	24	2	0	
GL(2)-1	24	2	0	
NB(4)-1	24	1	0	
QB(1)-1	24	1	0	
DN(2)-1	24	0	0	
QB(1)-2	24	0	0	
DN(2)-4	24	0	0	

6.4 Block Paving Options

The following conclusions can be drawn from the required maintenance costs for block pavements in Table 6.5:

1. Although the performance is classified as poor, the rehabilitation costs of mortared joints in block pavements are relatively low.
2. Although the costs for block pavements with joints filled with sand/fine chippings (dressed stone pavement) are higher than the cost for block pavements with mortared joints they are still low and are almost exclusively associated with replenishing the fine material, which should be done every 2 years.
3. The maintenance costs for sand emulsion seals on block pavements are high. Almost all of the costs are associated with the restoring of the seals.
4. Indications are that the sand emulsion seals should be reconstructed after 2 years of operation, although the maintenance costs will be increased, to make sure that the road has good performance.
5. Once again, the assessment shows that the use of sand emulsion seals to protect block pavements is not a cost-efficient option.

Table 6.5: Performance of Block Pavements based on RCDI and DEI

Trial Sections Ref. Codes	Age month	RDCI (%)	CDI % Seal or Joint Condition	Rehabilitation Cost per km (US$)	Comment
H6	37	17	67	$10,638	Sand emulsion seal
D12	36	16	59	$9,767	Sand emulsion seal
D11	36	18	58	$9,657	Sand emulsion seal
HY(2)-2	24	44	100	$8,728	Sand emulsion seal
HY(2)-2a	24	42	98	$7,877	Sand emulsion seal
HY(2)-1	24	39	100	$7,803	Sand emulsion seal
HY(4)-1	24	19	68	$7,791	Sand emulsion seal
H7	37	16	64	$6,476	Sand emulsion seal
NB(2)-2	24	33	45	$769	Stone cobbles: Fine chipping joints
D10	36	8	15	$372	Cement mortar brick
H11	37	10	11	$292	Cement mortar stone setts

6.5 Unsealed Granular Options

The calculation of maintenance costs for the 4 unsealed flexible pavement sections included in the analysis have been summarised in Table 6.6 The results show that if the pavements are left unmaintained, the maintenance costs after 24 to 30 months of operation are very high and can be equivalent to approximately 50% of the construction cost.

Reasons for high cost are:

- For gravel: the need for re-gravelling half or full depth of the designed thickness of the pavement,
- For unsealed WBM: compacting placing and compacting fresh coarse aggregate and spreading fine material. The possibility of using the existing coarse aggregate layer depends on the residual aggregate quality

The Table highlights the significant cost requirement for all unsealed surfacing options.

Table 6.6: Performance of Unsealed Wearing Course Surfaces based on RDCI and DEI

Trial Sections Ref. Codes	Age (month)	RDCI Index (%)	Rehabilitation Cost per km (US$)	Comment
DaN6	24	100	14,354	WBM; major reconstruction
GL(1)-4	24	56	1,825	Gravel
GL(2)-2	24	58	1,824	Gravel
DN(2)-5	24	55	1,640	Gravel

6.6 The WLAC Model

The Cost Model for rural roads was developed as part of the SEACAP 1 project in order to analyse the whole life costs. The work only took into account construction and maintenance costs but not vehicle operating costs and its output was therefore termed a Whole Life Asset Cost model. Nevertheless, it has the potential to provide a tool for rural practitioners for the selection of appropriate and cost effective surfacing options. Recommendations were made to further develop the model to include vehicle operating costs.

The construction costs in the model were established based on the detailed design and cost estimates of the RRST options. The routine maintenance costs of the model were calculated in accordance with the current norms and regulations in Vietnam. One additional item of maintenance not included in the Vietnamese norms has been added in the cost model namely grading of gravel road surfaces

It is difficult to identify periodic maintenance cost for the new surfacing options and this can only be done with information from the long-term monitoring of the trials. However, in the first version of the model, the survey results from the Rural Road Gravel Assessment Programme were used to help to assess the required cost for periodic maintenance of gravel/laterite roads.

The periodic maintenance costs for unsealed pavements excluding gravel/laterite was taken to be equivalent to 7% of the construction cost and applied every 6 years.

For gravel/laterite roads, the residual value is assumed to be equal to the residual thickness of gravel divided by the original constructed thickness multiplied by the cost for construction of the original thickness.

For other types of pavements, the residual value is taken as equally percentages of the total cost for constructing the whole pavement structure, i.e. all construction items on the road formation, excluding the shoulder.

6.7 WLAC Updates

The rural road surfacing trial cost model was developed in SEACAP1, based on now outdated decrees and regulations of the Government on the cost estimation of capital construction. There is need to update this model in the light both of current regulations and decrees and the enlarged database of knowledge on the maintenance costs of the RRST trials..

The following factors should be updated and adjusted:

- Method of calculating other costs in the model
- Cost and frequency of periodic maintenance
- Residual value of all surfacing options at the end of the analysis period.

Method of calculating other costs will be adjusted in accordance with the current regulations and circulars of Vietnam such as Circular 05 and Decree 99 and some other instructing documents..

Table 6.6 below indicates some initial adjustments to the cost and frequency of periodic maintenance as well as the residual value of pavement at the end of analysis period. Further details of these adjustments are included in Appendix D to this report.

Table 6.7: Summary of Necessary Adjustments to the Cost Model

Type of Pavement		Periodic maintenance span (year)		Maintenance cost (% of Construction cost)		Residual value after 15 years (% of Construction cost)	
Cement concrete		Previous	Revised	Previous	Revised	Previous	Revised
Block	Mortared joint	10	10	5	4	70	70
	Sand joint/fine chipping	6	4	7	7	60	60
	Sand sealed on sand joint	7	2	15	15-20	60	60
Penetration macadam		10	10	5	5	60	50
Sealed flexible pavement	Hot bitumen	7	7	25	25	40-50	50
	Emulsion sealed	7	7	25	25	40-50	50
Unsealed Water bound macadam		6	2	7	10	50	40
Natural gravel		Continues to be based on SEACAP 4 gravel loss matrix					

7 The Institutional Home for the RRSR

7.1 Review of Options

TRL reviewed key issues in May and June 2008 in relation to possible future arrangements for the RRSR database after the completion of SEACAP 27 and the transfer of the ownership and management of the SEACAP pavement and surfacing trials to Vietnamese institutions.

The following paragraphs summarise both this review and the subsequent discussions held with key stakeholders. A full report on the initial assessment of options was included in Progress Report 2

7.2 Requirements

There are various aspects of the continuity that are required with different activities that must be carried out. The work needs the following capabilities:

1. **Implementation:** to collect road and traffic data from site
2. **Research**: to analyse data and convert it into useful guidance information
3. **Management**: to administer and technically manage the monitoring work within agreed resource budgets
4. **Evaluation**: to technically audit the recovered data and the engineering outputs
5. **Ownership**: to provide an identifiable "home address" for the RRSR database and act as clearing house for incoming and outgoing research and associated ideas and outcomes
6. **Dissemination:** to publicise the outcomes in terms of guidelines, technical notes or similar to an appropriate audience that might in include consultants, contractors, local authorities and other research programmes.

These capabilities do not need to be taken on board by different institutions; some are complimentary and would be best undertaken by the same institution. It is hoped that the current pavement and surfacing trials in Vietnam will lead to longer term research in the rural infrastructure sector. Therefore, to the above list could be added the role of a **'champion'** of rural road research, an institution that will have vision for the future of rural infrastructure and act as a focus both within Vietnam and regionally for the sector.

There are various institutions, or types of institution, that could take on these roles:

- Private sector consultants
- University of Transport and Communications (UTC)
- Institute of Transport Science and Technology (ITST)
- Vietnamese Road Administration (VRA)
- Provincial Departments of Transport (PDoTs)
- Department of Science and Technology (DST) in MoT
- Rural Transport Unit (RTU) within the MoT Department of Planning and Investment (DPI)
- The current SEACAP Steering Committee

7.3 Institutional Assessment

There are a number of criteria which can be used to assess the suitability of an institution for a long term role in work such as this. Most of these criteria are valid for the different roles described above and can be distinguished as 'internal', relating to the institution itself, or 'external', relating to relations between the institution and others.

Internal criteria

- Competence - IT, technical, management
- Experience in project management and the technical subject
- Enthusiasm
- Confident of a long term future - so that work is carried out consistently and that the focus is on ideas in the future as well as the current work
- Reasonable overheads and working costs
- Good leadership
- Attractive to good technical staff - to achieve a long term future
- Have a core of staff rather than relying on a single individual
- Good succession planning
- Experienced at dissemination

External criteria

- Respected
- Seen as impartial
- Incentives to disseminate – rather than a wish to retain information
- Have technical authority within the sector
- Incentives to develop programmes from the project
- Good contacts with PDoTs and other levels of local authority
- Official recognition or mandate

7.4 Recommendations on Handover

Based upon discussions and the assessment it was originally suggested that institutions could take on the roles shown in Table 7.1 However during subsequent discussion it became clear that, because of the “work-in hand” nature of the project, the RRSR database should be handed over to the DST within the MoT rather to the VRA as originally suggested. TRL-OtB fully supported this logical decision and acted accordingly in liaising with the relevant DST engineers.

Table 7.1: Suggested Roles for Continuation of the RRSR

Role	Description of Role	Institution	
		Original Suggestion	As Adopted
Owner	Take the lessons learnt and apply them for the benefit of Vietnam	MoT (DST)	MoT
Manager	Administratively and technically manage the work with a medium term and a short term perspective	VRA	DST
Researcher	Convert data into lessons	ITST	DST
Champion	Have vision for the future of rural road research and act as a technical focus	VRA	MoT
Disseminator	Publicise the lessons and outputs to an appropriate audience, such as tertiary students, consultants and contractors	DST (standards & specs) UTC (academic channels)	DST (standards & specs) UTC (academic channels)
Evaluator	Independent administrative and technical check	Steering Committee, with sub-contracted evaluations by UTC	Steering Committee
Implementer	Collect data from site	ITST/Private Consultants/, PDoTs (on short term, sub-contracted basis)	PDoTs-PPMUs

8 Reporting and Dissemination

8.1 Reports

The following reports have been submitted as part of the SEACAP 1 programme:

- Inception Report and 1st Progress Report
- 2nd Progress Report
- 3rd Progress Report
- Technical Paper 1
- Technical Paper 2
- Final Report

SEACAP 27 also supplied significant source material for other SEACAP initiatives such as SEACAP 19; DF55 and DF 090.02.

8.2 Workshops and Seminars

Three progress and one final workshop were organised during the programme period of SEACAP 27. These are listed below:

- Progress workshop 13th May 2008
- Progress workshop 2nd December 2008
- Progress workshop 24th February 2009
- Final Workshop 9th June 2009

9 Summary and Recommendations

9.1 Delivered Outcomes

The SEACAP 27 project has delivered the following technical outcomes:

1. An updated RRSR database together with guide.
2. An additional 3 phases of condition monitoring information on the RRST- and RRST-II road trials collected and collated.
3. A review and analysis of traffic patterns on the RRST trial roads
4. A comprehensive review of the current condition of the trials roads together with commentaries on reasons for deterioration
5. The development and application of a system of simplified deterioration indices that may be applied at provincial level to monitor road condition and general maintenance requirements.
6. A review of the cost impacts of the deterioration of the RRST trial roads and the implications for maintenance and WLAC models.

9.2 Recommendations

The RRSR monitoring programme is now beginning to produce results that can have a significant impact on the ongoing development of a sustainable Vietnamese rural infrastructure. It is essential that this programme be carried forward not only in terms of continued monitoring but also in the relevant analysis of the recovered data.

The following are principal specific points to arise out of this general recommendation:

1. The traffic and condition monitoring surveys should be conducted on a yearly basis for the next 4-5 years.
2. The field work can be adequately undertaken by the PDoT/PPMU staff, but will require some additional QA support.
3. Analysis of the data will require specialist input, although it is likely that a combination of the DST and the UTC could undertake the bulk of this task with some additional QA back-up or review.

On more general issues,the SEACAP 27 project has re-confirmed a number of key points raised in previous SEACAP reports:

1. Poor compliance with construction designs and specification associated with poor construction supervision and a lack of effective as-built Quality Assurance is a major cause of poor rural road pavement performance in Vietnam.
2. With only very minor exceptions, the RRST trial road pavements and surfaces are operating without any effective maintenance. This is an unsustainable situation which will result in a rapidly declining asset value over the coming years. It is worth noting in this context that concrete pavements, which are sometime referred to as “maintenance free” have been shown to require timely maintenance of inter-slab joints, without which they too will deteriorate.
3. The traffic surveys undertaken have indicated a significant mismatch between the existing Vietnamese rural road standards and design approaches and the actual traffic loads in some

regions. An urgent review of Vietnamese rural road standards, specifications and design procedures is strongly recommended.

4. It is essential that the outcomes from SEACAP 27 and associated projects are effectively disseminated at provincial level. Some initial progress has been made in this regard through DF55. Much more remains to be done at this level.
5. The take-up of the RRSR initiative by the UTC would be an important step in ensuring the continuity of the research and keeping the "institutional memory" of the programme alive within an institution capable of further dissemination and development.

MID TERM PAVEMENT CONDITION MONITORING OF THE RURAL ROAD SURFACES RESEARCH

Final Report
SEACAP 27

APPENDIX A

List of Monitored Trial Sections

Province	Road Ref	From	To	Length (m)	Trial ref No.	Pavement Group
Da Nang	DaN02	0.190	0.365	175	DaN02	C
Da Nang	DaN03	0.365	0.540	175	DaN03	SF
Da Nang	DaN04	0.540	0.715	175	DaN04	SF
Da Nang	DaN05	0.715	0.815	100	DaN05	SF
Da Nang	DaN06	0.815	0.915	100	DaN06	U
Dak Lak	Bh3	8.800	8.900	100	DL(2)-1	SF
Dak Lak	Bh4	9.700	9.800	100	DL(2)-2	SF
Dak Lak	Bh5	11.500	11.600	100	DL(2)-3	SF
Dak Lak	Bh6	13.200	13.300	100	DL(2)-4	SF
Dak Lak	Cn1	0.150	0.250	100	DL(1)-1	SF
Dak Lak	Cn2	1.600	1.700	100	DL(1)-2	SF
Dak Lak	Es1	0.220	0.320	100	DL(3)-1	C
Dak Lak	Es2	1.200	1.300	100	DL(3)-2	SF
Dak Lak	Es1	0.150	0.230	80	DL(3)-1a	C
Dak Nong	Kd01	0.045	0.145	100	DN(1)-1	SF
Dak Nong	Kd02	1.600	1.700	100	DN(1)-2	SF
Dak Nong	Kd04	5.850	5.950	100	DN(1)-4	SF
Dak Nong	Kd05	6.900	7.000	100	DN(1)-5	C
Dak Nong	Kd06	0.060	0.160	100	DN(2)-1	SF
Dak Nong	Kd07	0.800	0.900	100	DN(2)-2	SF
Dak Nong	Kd08	1.200	1.300	100	DN(2)-3	SF
Dak Nong	Kd10	2.700	2.800	100	DN(2)-4	SF
Dak Nong	Kd11	3.250	3.450	100	DN(2)-5a	U
Dak Nong	Kd03	4.000	4.100	100	DN(1)-3	SF
Dak Nong	Kd11	3.675	3.775	100	DN(2)-5b	U
Dong Thap	D02	0.133	0.308	175	D02	C
Dong Thap	D03	0.308	0.483	175	D03	C
Dong Thap	D05	0.583	0.758	175	D05	SF
Dong Thap	D06	0.758	0.933	175	D06	SF
Dong Thap	D07	0.933	1.033	100	D07	SF
Dong Thap	D08	1.033	1.123	90	D08	U
Dong Thap	D10	2.065	2.265	200	D10	B
Dong Thap	D11	2.265	2.465	200	D11	B
Dong Thap	D12	2.465	2.665	200	D12	B
Gia Lai	Ip1	0.400	0.500	100	GL(1)-1	SF
Gia Lai	Ip2	1.900	2.000	100	GL(1)-2	C
Gia Lai	Ip3	2.200	2.300	100	GL(1)-3	SF
Gia Lai	Ip4	3.000	3.200	200	GL(1)-4	U
Gia Lai	Xtr1	0.900	1.000	100	GL(2)-1	SF
Gia Lai	Xtr2	1.700	1.800	100	GL(2)-2	U
Gia Lai	Xtr3	0.060	0.160	100	GL(2)-3	SF
Gia Lai	Xtr4	2.200	2.300	100	GL(2)-4	C
Gia Lai	Xtr2	1.500	1.600	100	GL(2)-2a	U

C: Concrete; SF: Sealed Flexible: B: Block : U: Unsealed

Province	Road Ref	From	To	Length (m)	Trial ref No.	Pavement Group
Ha Tinh	CL1	0.100	0.200	100	HT(3)-1	SF
Ha Tinh	CL2	2.600	2.700	100	HT(3)-2	C
Ha Tinh	Hl1	0.050	0.150	100	HT(2)-1	SF
Ha Tinh	Hl2	1.710	1.810	100	HT(2)-2	C
Ha Tinh	Hl3	2.700	2.800	100	HT(2)-3	C
Ha Tinh	Tm1	0.100	0.200	100	HT(1)-1	C
Ha Tinh	Tm2	1.300	1.400	100	HT(1)-2	C
Ha Tinh	Tm3	2.300	2.400	100	HT(1)-3	SF
Ha Tinh	Tm6	4.000	4.100	100	HT(1)-4	SF
Ha Tinh	Tm7	5.700	5.800	100	HT(1)-5	SF
Hue	H02	0.200	0.400	200	H02	C
Hue	H03	1.775	1.875	100	H03	U
Hue	H04	0.600	0.700	100	H04	SF
Hue	H06	0.800	1.000	200	H06	B
Hue	H07	1.000	2.000	200	H07	B
Hue	H09	1.300	1.500	200	H09	SF
Hue	H11	1.600	1.775	175	H11	B
Hung Yen	Hlg2	1.200	1.300	100	HY(3)-1	SF
Hung Yen	Hlg3	1.800	1.900	100	HY(3)-2a	SF
Hung Yen	Nq1	0.650	0.750	100	HY(2)-1	B
Hung Yen	Nq2	1.050	1.150	200	HY(2)-2a	B
Hung Yen	Nq3	2.600	2.700	100	HY(2)-3	SF
Hung Yen	Nq4	4.000	4.100	100	HY(2)-4	SF
Hung Yen	Tl1	0.050	0.150	100	HY(4)-1	SF
Hung Yen	Th1	1.250	1.350	100	HY(1)-1	C
Hung Yen	Th2	1.350	1.450	100	HY(1)-2	C
Hung Yen	Nq2	0.750	0.850	100	HY(2)-2	B
Hung Yen	Hlg3	1.500	1.600	100	HY(3)-2	SF
Ninh Binh	Dh1	1.300	1.400	100	NB(1)-1	SF
Ninh Binh	Dh2	1.500	1.600	100	NB(1)-2	C
Ninh Binh	Nv4	3.600	3.700	100	NB(4)-1	SF
Ninh Binh	Yt2	1.000	1.100	100	NB(2)-1a	SF
Ninh Binh	Yt2	0.600	0.700	100	NB(2)-1	SF
Ninh Binh	Yt3	1.300	1.400	100	NB(2)-2	B
Ninh Binh	Yt4	1.800	1.900	100	NB(2)-3	SF
Ninh Binh	Ynt1	0.200	0.300	100	NB(3)-1	SF
Ninh Binh	Ynt2	1.100	1.200	100	NB(3)-2	SF
Ninh Binh	Dh1	1.400	1.500	100	NB(1)-1a	SF
Ninh Binh	Yt3	1.500	1.600	100	NB(2)-2a	B
Ninh Binh	Yt4	1.600	1.700	100	NB(2)-3a	SF
Ninh Binh	Ynt2	0.500	0.600	100	NB(3)-1a	SF
Quang Binh	CmL2	0.900	1.000	100	QB(2)-1	SF
Quang Binh	CmL3	1.005	1.105	100	QB(2)-2	C
Quang Binh	CmL4	2.000	2.100	100	QB(2)-3	SF
Quang Binh	CmL7	5.900	6.000	100	QB(3)-1	SF
Quang Binh	CmL8	6.000	6.100	100	QB(3)-2	SF
Quang Binh	Nh2	0.600	0.700	100	QB(1)-1	SF
Quang Binh	Nh3	2.200	2.300	100	QB(1)-2	SF
Quang Binh	Nh5	3.910	4.010	100	QB(1)-3	C
Tien Giang	TG02	1.100	1.300	200	TG02	C
Tien Giang	TG03	1.300	1.500	200	TG03	C
Tien Giang	TG05	1.600	1.800	200	TG05	SF
Tien Giang	TG06	1.800	2.000	200	TG06	SF
Tien Giang	TG07	2.000	2.100	100	TG07	SF
Tien Giang	TG08	2.100	2.200	100	TG08	U
Tien Giang	TG09	2.200	2.400	200	TG09	C
Tien Giang	TG10	2.400	2.500	100	TG10	U
Tuyen Quang	Lq1	0.750	0.950	100	TQ(1)-1	SF
Tuyen Quang	Lq2	1.000	1.100	100	TQ(1)-2	C
Tuyen Quang	Lq3	2.100	2.200	100	TQ(1)-3	SF
Tuyen Quang	Lq4	3.000	3.100	100	TQ(1)-4	C
Tuyen Quang	Lq5	3.375	3.475	100	TQ(1)-5	C
Tuyen Quang	Yl2	0.300	0.400	100	TQ(2)-1	SF
Tuyen Quang	Yl2	0.600	0.700	100	TQ(2)-1a	SF

MID TERM PAVEMENT CONDITION MONITORING OF THE RURAL ROAD SURFACES RESEARCH

Final Report
SEACAP 27

APPENDIX B

Traffic Summaries

PROVINCE	ROAD	Date of Survey	VEHICLE			ESAs			esa (12 Hours)	esa (24 Hours)	Average last 2	Age	esa to Aug08	Rounded Figure (x1000)
			Bus	Truck>5t	Truck<5T	Bus esa	Truck>5t esa	Truck<5t esa						
Mekong		**esa factor**				**1.5**	**1.0**	**0.1**						
Dong Thap	Tan Thuan Tay(1)	Nov. 2004	0	0	0	0	0	0	0	0				
	DT	Oct. 2006	0	0	0	0	0	0	0	0				
		Oct. 2006	0	0	0	0	0	0	0	0				
	Tan Thuan Tay	Feb. 2008	0	1	7	0	1	0	1	1				
	DT	Aug. 2008	0	0	3	0	0	0	0	0	0.66	36	713	**1**
Tien Giang	My Phuoc Tay	Nov. 2004	0	0	3	0	0	0	0	0				
	TG	Oct. 2006	0	0	2	0	0	0	0	0				
		Feb. 2008	0	0	0	0	0	0	0	0				
		Aug. 2008	0	0	0	0	0	0	0	0	0.00	36	0	**1**
N-C Coastal		**esa factor**				**1.5**	**3.1**	**0.1**						
Da Nang	Binh Ky	Nov. 2004	0	0	2	0	0	0	0	0				
	DaN	Oct. 2006	0	0	0	0	0	0	0	0				
		Jan. 2008	0	0	2	0	0	0	0	0				
		Aug. 2008	0	0	0	0	0	0	0	0	0.01	24	9	**1**
Hue	Thong Nhat	Nov. 2004	0	0	0	0	0	0	0	0				
	H	Oct. 2006	0	0	0	0	0	0	0	0				
		Jan. 2008	0	0	4	0	0	0	0	0				
		Aug. 2008	0	0	6	0	0	0	0	0	0.06	37	67	**1**
Quang Binh	Cam Lien	July 2005	0	6	5	0	19	0	19	22				
	QB(2)	Jan. 2008	2	41	81	3	127	1	131	157				
		Aug. 2008	3	41	100	4.5	127	1	133	159	158.11	24	113,836	**115**
Quang Binh	Ngu Hoa	July 2005	0	6	25	0	19	0	19	23				
	QB(1)	Sept. 2006	0	43	29	0	133	0	134	160				
		Jan. 2008	2	15	39	3	47	0	50	60				
		Aug. 2008	2	19	43	3	59	0	62	75	67.33	24	48,479	**50**
Ha Tinh	Chu Le - Dia Loi	Sept. 2006	0	33	0	0	102	0	102	123				
	HT(3)	Jan. 2008	0	50	5	0	155	0	155	186				
		Aug. 2008	3	18	13	4.5	56	0	60	73	129.29	24	93,087	**95**
Ha Tinh	Hong Loc - Thu Loc	Sept. 2006	0	164	5	0	508	0	508	610				
	HT(2)	Jan. 2008	0	25	29	0	78	0	78	93				
		Aug. 2008	3	31	56	4.5	96	1	101	121	107.37	24	77,306	**80**
Ha Tinh	Thach Minh - Thach	Aug. 2005	0	14	1	0	43	0	43	52				
	HT(1)	Jan. 2008	0	25	13	0	78	0	78	93				
		Aug. 2008	0	4	21	0	12	0	13	15	54.14	24	38,984	**40**
Central Highlands		**esa factor**				**1.5**	**4.9**	**0.1**						
Gia Lai	Xa Trang	July 2005	0	19	17	0	93	0	93	112				
	GL(2)	Jan. 2008	0	48	60	0	235	1	236	283				
		Aug. 2008	0	48	53	0	235	1	236	283	282.92	24	203,701	**205**
Gia Lai	Ia Pnol	Sept. 2006	0	29	12	0	142	0	142	171				
	GL(1)	Jan. 2008	0	29	32	0	142	0	142	171				
		Aug. 2008	14	29	32	21	142	0	163	196	183.50	24	132,123	**185**
Dak Nong	Kien Duc	July 2005	0	38	27	0	186	0	186	224				
	DN	Feb. 2008	0	41	33	0	201	0	201	241				
		Aug. 2008	45	25	30	67.5	123	0	190	228	234.92	24	169,141	**170**
Dak Lak	Cu Ne	Sept. 2006	0	9	20	0	44	0	44	53				
	DL(1)	Jan. 2008	0	10	11	0	49	0	49	59				
		Aug. 2008	0	53	0	0	260	0	260	312	185.29	24	133,406	**135**
Dak Lak	Buon Ho	July 2005	0	10	8	0	49	0	49	59				
	DL(2)	Jan. 2008	0	51	90	0	250	1	251	301				
		Aug. 2008	0	26	1	0	127	0	127	153	226.93	24	163,387	**165**
Dak Lak	Easoup	Jan. 2008	0	8	12	0	39	0	39	47				
	DL(3)	Aug. 2008	0	51	0	0	250	0	250	300	173.53	24	124,943	**125**
Red River		**esa factor**				**1.5**	**1.4**	**0.1**						
Hung Yen	Hung Long	Sept. 2006	0	2	3	0	3	0	3	3				
	HY(3)	Jan. 2008	0	0	7	0	0	0	0	0				
		Aug. 2008	1	5	15	1.5	7	0	9	10	5.23	24	3,767	**5**
Hung Yen	Nhat Quang	July 2005	0	2	31	0	3	0	3	4				
	HY(2)	Jan. 2008	0	0	37	0	0	0	0	0				
		Aug. 2008	4	0	29	6	0	0	6	8	4.00	24	2,877	**3**
Hung Yen	Thuy Loi	Sept. 2006	0	0	0	0	0	0	0	0				
	HY(4)	Jan. 2008	0	0	15	0	0	0	0	0				
		Aug. 2008	0	0	0	0	0	0	0	0	0.09	24	65	**1**
Hung Yen	Tan Hung	July 2005	0	45	48	0	63	0	63	76				
	HY(1)	Jan. 2008	0	0	11	0	0	0	0	0				
		Aug. 2008	0	0	0	0	0	0	0	0	0.07	24	48	**1**
Ninh Binh	Yen Trach	July 2005	0	0	0	0	0	0	0	0				
	NB(2)	Jan. 2008	0	0	28	0	0	0	0	0				
		Aug. 2008	0	0	23	0	0	0	0	0	0.31	24	220	**1**
Ninh Binh	Yen Tu	Oct. 2006	0	0	3	0	0	0	0	0				
	NB(3)	Jan. 2008	0	0	1	0	0	0	0	0				
		Aug. 2008	0	0	11	0	0	0	0	0	0.07	24	52	**1**
Ninh Binh	Ninh Van	Sept. 2006	0	0	3	0	0	0	0	0				
	NB(4)	Aug. 2008	0	0	39	0	0	0	0	0	0.25	24	181	**1**
Ninh Binh	Dong Huong	July 2005	0	0	0	0	0	0	0	0				
	NB(1)	Jan. 2008	0	0	0	0	0	0	0	0				
		Aug. 2008	0	0	0	0	0	0	0	0	0.00	24	0	**1**
Northern Highlands		**esa factor**				**1.5**	**1.1**	**0.1**						
Tuyen Quang	Lang Quan	July 2005	0	21	23	0	23	0	23	28				
	TQ(1)	Aug. 2008	3	12	14	4.5	13	0	18	21	24.70	24	17,785	**20**
Tuyen Quang	Y La	Sept. 2006	0	92	4	0	101	0	101	121				
	TQ(2)	Jan. 2008	4	14	24	6	15	0	22	26				
		Aug. 2008	0	3	6	0	3	0	3	4	15.00	24	10,800	**10**
Tuyen Quang	Hoang Khai	Jan. 2008	7	17	60	10.5	19	1	30	36				
	TQ(3)	Aug. 2008	0	1	28	0	1	0	1	2	18.71	24	13,470	**15**

MID TERM PAVEMENT CONDITION MONITORING OF THE RURAL ROAD SURFACES RESEARCH

Final Report
SEACAP 27

APPENDIX C

Rehabilitation Cost Calculations

Bill of quantity and maintenance cost etimation of trial options

Province: Dong Thap

Road: Tan Thuan Tay 1USD = 17000 VND

Trial section	No	Maintenance Iteems	Ref.	Unit	Amount	Unit cost	Maintenance cost (USD)	Maintenance cost/km (USD)
D2	A	Pavement						
	1	Expansion joints repair	C1	m	122.5	13037.22	93.94	
	2	Concrete slab cracks repair	C3b	m	3.5	22432.13	4.62	
						Total	**98.56**	**563.2**
D3	A	Pavement						
	1	Expansion joints repair	C1	m	122.5	13037.22	93.94	
						Total	**93.94**	**536.8**
D5	A	Pavement						
	1	Repair sand seal erosion	S1	m^2	61.25	39256.65	141.44	
	2	Repair chip seal erosion	S2	m^2	61.25	42703.84	153.86	
	3	Filling pothole	DBM1	m^2	0.04	396157.67	0.93	
						Total	**296.23**	**1693**
D6	A	Pavement						
	1	Repair sand seal erosion	S1	m^2	30.63	39256.65	70.73	
	2	Repair chip seal erosion	S2	m^2	30.63	42703.84	76.94	
	3	Repair individual cracks	S3	m	15	8793.42	7.76	
						Total	**155.43**	**888**
D10	A	Pavement						
	1	Repair cracked or missing mortar in joints	BB1	m^2	56	22562.26	74.32	
						Total	**74.32**	**372**
D11	A	Pavement						
	1	Repair sand seal erosion	S1	m^2	700	39256.65	1616.45	
	2	Replace damaged or broken bricks	BB3	m^2	2.5	3083.14	0.45	
	3	Replace or top up missing sand infill to joints	BB2b	m^2	67	79791.12	314.47	
						Total	**1931.37**	**9657**
D12	A	Pavement						
	1	Repair sand seal erosion	S1	m^2	700	39256.65	1616.45	
	2	Replace damaged or broken bricks	BB3	m^2	1.5	3083.14	0.27	
	3	Replace or top up missing sand infill to joints	BB2b	m^2	71.75	79791.12	336.77	
						Total	**1953.49**	**9767**

Bill of quantity and maintenance cost etimation of trial options

Province: Tien Giang

Road:My Phuoc Tay 1USD = 17000 VND

Trial section	No	Maintenance I teems	Ref.	Unit	Amount	Unit cost	Maintenance cost (USD)	Maintenance cost/km (USD)
T2	A	Pavement						
	1	Expansion joints repair	C1	m	91	10975.52	58.75	
	2	Concrete slab cracks repair	C3a	m	72	7860.10	33.29	
						Total	**92.04**	**460**
T3	A	Pavement						
	1	Expansion joints repair	C1	m	56	10975.52	36.15	
	2	Concrete slab cracks repair	C3a	m	0		0	
						Total	**36.15**	**181**
T5	A	Pavement						
	1	Repair sand seal erosion	S1	m^2	0		0	
	2	Repair chip seal erosion	S2	m^2	0		0	
	3	Repair individual cracks	S3	m	28.0	8067.99	13.29	
	4	Repair crocodile cracks	S4	m2	50.3	67574.82	199.94	
						Total	**213.23**	**1066**
T6	A	Pavement						
	1	Repair sand seal erosion	S1	m^2	75.3	32500.67	143.96	
	2	Repair chip seal erosion	S2	m^2	5	35074.82	10.32	
	3	Repair individual cracks	S3	m	118	8067.99	56.00	
	4	Filling pothole	LSS	m^2	5	507352.37	149.22	
						Total	**359.50**	**1797**
T9	A	Pavement						
	1	Expansion joints repair	C1	m	56	10975.52	36.15	
	2	Concrete slab cracks repair	C3a	m	64	7860.10	29.59	
						Total	**65.75**	**329**

Bill of quantity and maintenance cost etimation of trial options

Province: Hue

Road: Thong Nhat, Phu Loc Distric 1USD = 17000 VND

Trial section	No	Maintenance Iteems	Ref.	Unit	Amount	Unit cost	Maintenance cost (USD)	Maintenance cost/km (USD)
H2	A	Pavement						
	1	Expansion joints repair	C1	m	105	10789.92	66.64	
	2	Concrete slab cracks repair	C3b	m	3.5	18062.28	3.72	
						Total	**70.36**	**352**
H4	A	Pavement						
	1	Filling pothole	PM1	m^2	0		0	0
						Total	**0**	**0**
H6	A	Pavement						
	1	Repair sand seal erosion	S1	m^2	700	31143.17	1282.37	
	2	Replace damaged or broken concrete bricks	CB2	m^2	105	136294.7	841.82	
	3	Replace or top up missing sand infill to joints	CB3	m^2	25.25	2310.91	3.43	
						Total	**2127.62**	**10638**
H7	A	Pavement						
	1	Repair sand seal erosion	S1	m^2	700	31143.17	1282.37	
	2	Replace damaged or broken concrete bricks	CB2	m^2	0			
	3	Replace or top up missing sand infill to joints	CB3	m^2	6	2310.91	0.82	
	4	Repair depressed areas	CB4	m^2	5.25	38992.18	12.04	
						Total	**1295.22**	**6476**
H9	A	Pavement						
	1	Repair sand seal erosion	S1	m^2	0		0	
	2	Repair chip seal erosion	S2	m^2	0		0	
	3	Repair individual cracks	S3	m	0		0	
						Total	**0**	**0**
H11	A	Pavement						
	1	Repair cracked or missing mortar in joints	DS1	m^2	13.5	23703.58	18.82	
	2	Repair depressed areas	DS3	m^2	7.5	73066.16	32.24	
						Total	**51.06**	**292**

Bill of quantity and maintenance cost etimation of trial options

Province: Da Nang

Road: Binh Ky-Khue Dong 1USD = 17000 VND

Trial section	No	Maintenance Iteems	Ref.	Unit	Amount	Unit cost	Maintenance cost (USD)	Maintenance cost/km (USD)
DaN2	A	Pavement						
	1	Expansion joints repair	C1	m	122.5	11807.83	85.09	
	2	Concrete slab cracks repair	C3a	m	4	8578.6	2.02	
	3	Concrete slab cracks repair	C3b	m	3.5	27435.1	5.65	
						Total	**92.75**	**530**
DaN3	A	Pavement						
	1	Repair sand seal erosion	S1	m^2	0	36271.24	0	
	2	Repair chip seal erosion	S2	m^2	0	37008.37	0	
	3	Repair individual cracks	S3	m	140	8466.06	69.72	
	4	Repair crocodile cracks	S4	m2	33	45393	88.12	
	4	Filling pothole	CSS	m^2	0		0	
						Total	**157.84**	**902**
DaN4	A	Pavement						
	1	Repair sand seal erosion	S1	m^2	210	36271.24	448.06	
	2	Repair chip seal erosion	S2	m^2	210	37008.37	457.16	
	3	Repair individual cracks	S3	m	0	8466.06	0.00	
	4	Repair crocodile cracks	S4	m2	0	45393	0.00	
	5	Filling pothole	CSS	m^2	5	326537.00	96.04	
						Total	**1001.26**	**5721**
DaN5	A	Pavement						
	1	Filling pothole		m^2	3.5	133849.2	27.56	
							27.56	**276**
DaN6	A	Pavement						
	1	Re-construct a pavement	WBM1	m^2	350	381373.88	7851.82	
	2	Re-construct a pavement	WBM2	m^2	350	315828.53	6502.35	
						Total	**14354.17**	**143542**
DaN8	A	Pavement						
	1	Repair sand seal erosion	S1	m^2	0	36271.24	0	
	2	Repair chip seal erosion	S2	m^2	0	37008.37	0	
	3	Repair individual cracks	S3	m	0	8466.06	0	
						Total	**0**	**0**

Bill of quantity and maintenance cost etimation of trial options

Province: Tuyen Quang

Roads: Lang Quan, Y La

1USD = 17000 VND

Trial section	No	Maintenance Iteems	Ref.	Unit	Amount	Unit cost	Maintenance cost (USD)	Maintenance cost/km (USD)
TQ(1)-1	A	Pavement						
	1	Repair chip seal erosion	S2	m	0		0	
	2	Repair individual cracks	S3	m	0	6164.02	0	
						Total	**0.00**	**0**
TQ(1)-2	A	Pavement						
	1	Expansion joints repair	C1	m	31.5	11889.66	22.03	
	2	Concrete slab cracks repair	C3a	m	67	8633.19	34.02	
	3	Concrete slab cracks repair	C3b	m	7	15381.87	6.33	
						Total	**62.39**	**624**
TQ(1)-3	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	23	6164.02	8.34	
	3	Repair crocodile cracks	S4	m^2	46	112516.7	301.15	
						Total	**309.49**	**3095**
TQ(1)-4	A	Pavement						
	1	Expansion joints repair	C1	m	7	11889.66	4.90	
	2	Concrete slab cracks repair	C3a	m	0		0	
	3	Concrete slab cracks repair	C3b	m	0		0	
						Total	**4.90**	**49**
TQ(1)-5	A	Pavement						
	1	Expansion joints repair	C1	m	17.5	11889.66	12.24	
	2	Concrete slab cracks repair	C3a	m	0		0	
	3	Concrete slab cracks repair	C3b	m	8.5	15381.87	7.69	
						Total	**19.93**	**199**
TQ(2)-1a	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
						Total	**0.00**	**0**
TQ(2)-1	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	46	6164.02	16.68	
	3	Repair crocodile cracks	S4	m^2	30	112516.7	198.56	
						Total	**215.24**	**2152**

Bill of quantity and maintenance cost etimation of trial options

Province: Hung Yen
Roads: NhËt Quang, T©n H- ng, Thuþ L«i vµ H- ng Long

1USD = 17000 VND

Trial section	No	Maintenance Iteems	Ref.	Unit	Amount	Unit cost	Maintenance cost (USD)	Maintenance cost/km (USD)
HY(1)-1	A	Pavement						
	1	Expansion joints repair	C1	m	35	11808.69	24.31	
	2	Concrete slab cracks repair	C3a	m	0		0	
	3	Concrete slab cracks repair	C3b	m	0		0	
						Total	**24.31**	**243**
HY(1)-2	A	Pavement						
	1	Expansion joints repair	C1	m	49	11808.69	34.04	
	2	Concrete slab cracks repair	C3a	m	0		0	
	3	Concrete slab cracks repair	C3b	m	2	20043.86	2.36	
						Total	**36.39**	**364**
HY(2)-1	A	Pavement						
	1	Repair sand emulsion seal erosion	S1	m^2	350	36343.75	748.25	
	2	Replace damaged or broken concrete bricks	CB2	m^2	1	125159.7	7.36	
	3	Replace or top up missing sand infill to joints	CB3	m^2	175	2394.67	24.65	
						Total	**780.27**	**7803**
HY(2)-2	A	Pavement						
	1	Repair sand emulsion seal erosion	S1	m^2	350	36343.75	748.25	
	2	Replace damaged or broken bricks	BB2	m^2	17.8	85894.18	89.94	
	3	Replace or top up missing sand infill to joints	BB3	m^2	175	3365.71	34.65	
						Total	**872.84**	**8728**
HY(2)-2a	A	Pavement						
	1	Repair sand emulsion seal erosion	S1	m^2	350	36343.75	748.25	
	2	Replace damaged or broken bricks	BB2	m^2	2.8	85894.18	14.15	
	3	Replace or top up missing sand infill to joints	BB3	m^2	105	3365.71	20.79	
	4	Repair depressed areas	BB4	m^2	2	38320.74	4.51	
						Total	**787.70**	**7877**
HY(2)-3	A	Pavement						
	1	Repair individual cracks	S3	m	4	6134.74	1.44	
	2	Repair crocodile cracks	S4b	m^2	28.0	72260.08	119.02	
						Total	**120.46**	**1205**
HY(2)-4	A	Pavement						
	1	Repair individual cracks	S3	m	15	6134.74	5.41	
	2	Repair crocodile cracks	S4	m^2	45.4	72260.08	192.98	
	3	Filling potholes	WBM1	m^3	0.018	327076.8	0.35	
						Total	**198.74**	**1987**
HY(3)-1	A	Pavement						
	1	Repair chip emulsion seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	119	6135.16	42.95	
	3	Repair crocodile cracks	S4	m^2	0		0	
						Total	**42.95**	**429**
HY(3)-2	A	Pavement						
	1	Intersecting crack repair (cracks width <3mm)	S4a	m^2	52	42782.41	130.86	
	2	Repair individual cracks	S3	m	59	6135.16	21.29	
						Total	**152.16**	**1522**
HY(3)-2a	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	30	6135.16	10.83	
						Total	**10.83**	**108**
HY(4)-1	A	Pavement						
	1	Repair sand emulsion seal erosion	S1	m^2	350	36307.5	747.51	
	2	Replace damaged or broken bricks	BB2	m^2	6.25	85837.4	31.56	
						Total	**779.07**	**7791**

Bill of quantity and maintenance cost etimation of trial options

Province: Ninh Binh
Roads: Yª n Tr¹ ch, § ăng H- í ng, Yª n Tõ, Ninh V©n

1USD = 17000 VND

Trial section	No	Maintenance I teems	Ref.	Unit	Amount	Unit cost	Maintenance cost (USD)	Maintenance cost/km (USD)
NB(1)-1	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
	3	Repair crocodile cracks	S4	m^2	0		0	
						Total	**0**	**0**
NB(1)-2	A	Pavement						
	1	Expansion joints repair	C1	m	63	12023.88	44.56	
	2	Concrete slab cracks repair	C3a	m	0		0	
	3	Concrete slab cracks repair	C3b	m	1	15001.20	0.88	
	4	Repair pavement small defected	C2	m^3	0.00	**Total**	**45.44**	**454**
NB(2)-1	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
	3	Repair crocodile cracks	S4	m^2	0		0	
						Total	**0**	**0**
NB(2)-2	A	Pavement						
	1	Replace damaged or broken block	CBS2	m^2	3.2	63737.81	12.00	
	2	Top up missing fine stone infill to joints	CBS3	m^2	350	3152.1	64.90	
	3	Repair depressed areas	CBS4	m^2	0			
	4					**Total**	**76.89**	**769**
NB(2)-3	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
	3	Repair crocodile cracks	S4	m^2	0		0	
						Total	**0**	**0**
NB(3)-1	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	12	6206.24	4.38	
	3	Repair crocodile cracks	S4	m^2	0		0	
	4	Filling potholes	WBM1	m^2	0	**Total**	**4.38**	**44**
NB(3)-2	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
	3	Repair crocodile cracks	S4	m^2	0		0	
						Total	**0**	**0**
NB(4)-1	A	Pavement						
	1	Repair chip emulsion seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
	3	Repair crocodile cracks	S4	m^2	0		0	
						Total	**0**	**0**

Bill of quantity and maintenance cost etimation of trial options

Province: Gia Lai
Roads: X· Trang, Ia Pnol

1USD = 17000 VND

Trial section	No	Maintenance Iteems	Ref.	Unit	Amount	Unit cost	Maintenance cost (USD)	Maintenance cost/km (USD)
GL(1)-1	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0	42119.27	0	
	2	Repair individual cracks	S3	m	0	5884.11	0	
	3	Repair crocodile cracks	S4	m^2	0		0	
						Total	**0**	**0**
GL(1)-2	A	Pavement						
	1	Expansion joints repair	C1	m	21	10811.32	13.36	
	2	Concrete slab cracks repair	C3a	m	80	8125.85	38.24	
						Total	**51.59**	**516**
GL(1)-3	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	19.55	42119.27	48.44	
	2	Repair individual cracks	S3	m	34	5884.11	11.77	
						Total	**60.21**	**602**
GL(1)-4	A	Pavement						
	1	Grading and reshaping of pavement	NG1	m^2	700	312.14	12.85	
	2	Re-graveling (thickness is10cm)	NG2	m^3	56	91685.04	302.02	
	3	Repair soft spot	NG3	m^3	3.6	240000	50.82	
							365.70	**1828**
GL(2)-1	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
	3	Repair crocodile cracks	S4	m^2	0		0	
						Total	**0**	**0**
GL(2)-1a	A	Pavement						
	1	Repair sand emulsion seal erosion	S1	m^2	0.18	34510.33	0.37	
	2	Repair chip emulsion seal erosion	S2	m^2	0.18	41043.45	0.43	
						Total	**0.80**	**8**
GL(2)-2	A	Pavement						
	1	Grading and reshaping of pavement		m^2	350	312.14	6.43	
	2	Re-graveling (thickness is10cm)		m^3	35	85477.32	175.98	
						Total	**182.41**	**1824**
GL(2)-3	A	Pavement						
	1	Repair chip seal erosion	C1	m	31.5	10759.3	19.94	
	2	Repair individual cracks	C3a	m	10	7698.09	4.53	
	3	Repair crocodile cracks	C3b	m	2	13315.08	1.57	
						Total	**26.03**	**260**

Bill of quantity and maintenance cost etimation of trial options

Province: Dak Lak
Roads: C- NĐ, Easup, Bu«n Hå

1USD = 17000 VND

Trial section	No	Maintenance I teems	Ref.	Unit	Amount	Unit cost	Maintenance cost (USD)	Maintenance cost/km (USD)
DL(1)-1	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	140	41635.62	342.88	
	2	Repair chip emulsion seal layer 2	S2b	m^2	350	41635.62	857.20	
						Total	**1200.09**	**12001**
DL(1)-2	A	Pavement						
	1	Filling potholes	WBM1	m^2	0		0	
						Total	**0**	**0**
DL(2)-1	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	350	41521.26	854.85	
	2	Repair chip emulsion seal layer 2	S2b	m^2	350	41521.26	854.85	
	3	Removal existing pavement	RP	m^3	42	71186.39	175.87	
	4	Re-construct layer 1 of DBM	DBM1	m^3	21	482854.13	596.47	
	5	Re-construct layer 2 of DBM	DBM2	m^3	21	482854.13	596.47	
						Total	**3078.50**	**30785**
DL(2)-2	A	Pavement						
	1	Repair sand emulsion seal erosion	S1	m^2	350	34298.8	706.15	
	2	Repair chip emulsion seal erosion	S2	m^2	210	41521.26	512.91	
	3	Filling potholes	DBM	m^2	2	472218.8	55.56	
						Total	**1274.62**	**12746**
DL(2)-3	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	262.5	41521.26	641.14	
	2	Repair chip emulsion seal layer 2	S2b	m^2	262.2	41521.26	640.40	
	3	Removal existing pavement	RP	m^3	28	71186.39	117.25	
	4	Re-construct layer 1 of DBM	DBM1	m^3	14	482854.13	397.64	
	5	Re-construct layer 2 of DBM	DBM2	m^3	14	482854.13	397.64	
						Total	**2194.08**	**21941**
DL(2)-4	A	Pavement						
	1	Repair sand emulsion seal erosion	S1	m^2	0.5	34298.8	1.01	
	2	Repair chip emulsion seal erosion	S2	m^2	0.5	41521.26	1.22	
						Total	**2.23**	**22**
DL(3)-1	A	Pavement						
	1	Expansion joints repair	C1	m	153	10989.71	98.91	
	2	Concrete slab cracks repair	C3a	m	46	8218.54	22.24	
						Total	**121.15**	**1211**
DL(3)-2	A	Pavement						
	1	Filling potholes	WBM1	m^2	0		0	
						Total	**0**	**0**

Bill of quantity and maintenance cost etimation of trial options

Province: Đắk Nông
Road: Kien Duc - Cai Chanh

1USD = 17000 VND

Trial section	No	Maintenance Items	Ref.	Unit	Amount	Unit cost	Maintenance cost (USD)	Maintenance cost/km (USD)
DN(1)-1	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
	3	Repair crocodile cracks	S4	m^2	30	66553.1	117.45	
						Total	**117.45**	**1174**
Đ N(1)-2	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	1.17	34848.59	2.40	
	2	Repair chip emulsion seal layer 2	S2b	m^2	1.17	40598.69	2.79	
						Total	**5.19**	**52**
DN(1)-3	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	0.18	34848.59	0.37	
	2	Repair chip emulsion seal layer 2	S2b	m^2	0.18	40598.69	0.43	
						Total	**0.80**	**8**
Đ N(1)-4	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	2.4	34848.59	4.92	
	2	Repair chip emulsion seal layer 2	S2b	m^2	2.4	40598.69	5.73	
	3	Repair individual cracks	S3	m	6	5814.14	2.05	
	4	Repair crocodile cracks	S4	m^2	49.1	66553.1	192.22	
	5	Filling potholes	DBM1	m^2	0.6	511657.8	18.06	
						Total	**222.98**	**2230**
DN(1)-5	A	Pavement						
	1	Expansion joints repair	C1	m	70	10845.85	44.66	
	2	Concrete slab cracks repair	C3a	m	11	8001.37	5.18	
	3	Concrete slab cracks repair	C3b	m	6	13983.08	4.94	
	4	Repair pavement small defected	C2	m^3	0.1	1034168.3	6.08	
						Total	**60.86**	**609**
DN(2)-1	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
						Total	**0**	**0**
DN(2)-2	A	Pavement						
	1	Filling potholes		m^2	0		0	
						Total	**0**	**0**
DN(2)-3	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	35	34848.59	71.75	
	2	Repair chip emulsion seal layer 2	S2b	m^2	35	40598.69	83.59	
						Total	**155.33**	**1553**
DN(2)-4	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	0			
	2	Repair chip emulsion seal layer 2	S2b	m^2	0			
						Total	**0**	**0**
DN(2)-5	A	Pavement						
	1	Grading and reshaping of pavement	NG1	m^2	350	312.14	6.43	
	2	Re-graveling (thickness is 10cm)	NG2	m^3	35	76463.32	157.42	
						Total	**163.85**	**1639**

Bill of quantity and maintenance cost etimation of trial options

Province: Quang Binh

Roads: Cam Lien-Ng- Thñy Trung, Ng- Ho¸ 1USD = 17000 VND

Trial section	No	Maintenance I teems	Ref.	Unit	Amount	Unit cost	Maintenance cost (USD)	Maintenance cost/km (USD)
QB(1)-1	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	0		0	
	2	Repair chip emulsion seal layer 2	S2b	m^2	0		0	
	3	Repair individual cracks	S3	m	0		0	
	4	Repair crocodile cracks	S4	m^2	0		0	
						Total	**0**	**0**
QB(1)-2	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	0		0	
	2	Repair chip emulsion seal layer 2	S2b	m^2	0		0	
	3	Repair individual cracks	S3	m	0		0	
	4	Repair crocodile cracks	S4	m^2	0		0	
						Total	**0**	**0**
QB(1)-3	A	Pavement						
	1	Expansion joints repair	C1	m	35	11403.12	23.48	
	2	Concrete slab cracks repair	C3a	m	0		0	
	3	Concrete slab cracks repair	C3b	m	0		0	
						Total	**23.48**	**235**
QB(2)-1	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	0.54	29387.34	0.93	
	2	Repair chip emulsion seal layer 2	S2b	m^2	0.54	34106.96	1.08	
	3	Repair individual cracks	S3	m	0		0.00	
	4	Repair crocodile cracks	S4	m^2	19.5	56275.38	64.55	
						Total	**66.57**	**666**
QB(2)-2	A	Pavement						
	1	Expansion joints repair	C1	m	7	11403.12	4.70	
	2	Concrete slab cracks repair	C3a	m	0		0.00	
	3	Concrete slab cracks repair	C3b	m	20	12193.6	14.35	
	4	Repair pavement small defected	C2	m^3	0.01	839884.8	0.49	
						Total	**19.53**	**195**
QB(2)-3	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	0.27	29387.34	0.47	
	2	Repair chip emulsion seal layer 2	S2b	m^2	0.27	34106.96	0.54	
						Total	**1.01**	**10**
QB(3)-1	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	10	29387.34	17.29	
	2	Repair chip emulsion seal layer 2	S2b	m^2	10	34106.96	20.06	
	3	Re-construct the pavement	DBM	m^3	0.75	356646.2	15.73	
	4	Soil filling	E	m^3	10.5	124235.7	76.73	
	5	Soft spot treatment	SS	m^3	8.75	233826.9	120.35	
						Total	**250.17**	**2502**
QB(3)-2	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
						Total	**0**	**0**

Bill of quantity and maintenance cost etimation of trial options

TØnh:Hµ Tünh

§-êng: Th¹ch Minh-Th¹ch Ngäc; Chu LÔ-§¹a Lî i; H«ng Léc-Thô Léc 1USD = 17000 VND

Trial section	No	Maintenance Iteems	Ref.	Unit	Amount	Unit cost	Maintenance cost (USD)	Maintenance cost/km (USD)
HT(1)-1	A	Pavement						
	1	Expansion joints repair	C1	m	70	11509.34	47.39	
	2	Concrete slab cracks repair	C3a	m	3	8350.08	1.47	
	3	Concrete slab cracks repair	C3b	m	0		0	
						Total	**48.86**	**489**
HT(1)-2	A	Pavement						
	1	Expansion joints repair	C1	m	70	11509.34	47.39	
	2	Concrete slab cracks repair	C3a	m	3.5	8350.08	1.72	
	3	Concrete slab cracks repair	C3b	m	0		0	
						Total	**49.11**	**491**
HT(1)-3	A	Pavement						
	1	Repair chip emulsion seal layer 1	S2a	m^2	8.5	41924.92	20.96	
	2	Repair chip emulsion seal layer 2	S2b	m^2	8.5	41924.92	20.96	
	3	Repair individual cracks	S3	m	4	6007.66	1.41	
	4	Repair crocodile cracks	S4	m^2	8.5	69755.51	34.88	
						Total	**78.22**	**782**
HT(1)-4	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
						Total	**0**	**0**
HT(1)-5	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
						Total	**0**	**0**
HT(2)-1	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	4	6009.86	1.41	
	3	Repair crocodile cracks	S4	m^2	61.1	69784.72	250.81	
						Total	**252.23**	**2522**
HT(2)-2	A	Pavement						
	1	Expansion joints repair	C1	m	49	11515.95	33.19	
	2	Concrete slab cracks repair	C3a	m	5	8354.05	2.46	
	3	Concrete slab cracks repair	C3b	m	13	14766.47	11.29	
						Total	**46.94**	**469**
HT(2)-3	A	Pavement						
	1	Expansion joints repair	C1	m	35	11515.95	23.71	
	2	Concrete slab cracks repair	C3a	m	13	8354.05	6.39	
	3	Concrete slab cracks repair	C3b	m	8.75	14766.47	7.60	
						Total	**37.70**	**377**
HT(3)-1	A	Pavement						
	1	Repair chip seal erosion	S2	m^2	0		0	
	2	Repair individual cracks	S3	m	0		0	
	3	Repair crocodile cracks	S4	m^2	0		0	
						Total	**0**	**0**
HT(3)-2	A	Pavement						
	1	Expansion joints repair	C1	m	10.5	11513.21	7.11	
	2	Concrete slab cracks repair	C3a	m	0		0.00	
	3	Concrete slab cracks repair	C3b	m	3.5	14763.92	3.04	
						Total	**10.15**	**102**