Intech Associates
CONSULTING ENGINEERS

IN ASSOCIATION WITH

Transport Development Strategy Institute

SUPPORTED BY

DFID Department for International Development

MINISTRY OF TRANSPORT VIETNAM

Rural Transport Project 2

RURAL ROAD SURFACING RESEARCH

SEACAP 1

Final Report

Volume 1 of 3

Draft, December 2006

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Dear David,

RE: Rural Road Surfacing Research (RRSR)
RRST Trials Final Report, Volume 1, Main Text (Draft)

Please find attached a copy of the RRST Trials Draft Final Report Volume 1 in English language for the Rural Road Surfacing Research for MoT. There will be two Volumes of supporting Appendices issued shortly.

The Vietnamese language version of this document is being issued after the English version to allow for full Quality Assurance checking of the technical translation.

We welcome any comments on this document.

English versions of the Document have been sent to DFID and World Bank representatives as indicated below. Copies will be posted on the RRSR website after approval.

Yours sincerely

Robert Petts
RRST Project Manager

cc Dr Nhan, Chairman RRST Steering Committee
RRST Steering Committee members (with copy of report in Vietnamese)
PDoTs 12 Number Trial Provinces (with copy of report in Vietnamese)
Mme Tran Minh Phuong, World Bank, Hanoi
Dr Simon Lucas, World Bank, Hanoi.
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Ms Pham Tuyet Giang, Assistant Project Manager SEACAP, Vietnam
Dr Doan Minh Tam, ITST, (with copy of report in Vietnamese)
Akram Ahmedi, TRL Ltd, UK.

ACKNOWLEDGEMENTS

The success and achievements of the SEACAP 1 project are due to the contributions and commitment of a large number of persons over an extend period of time. Firstly the vision and belief of Peter O'Neill and Simon Lucas of DFID in the development of the SEACAP concept and support for this particular (the first) SEACAP project is acknowledged. The local support and commitment of the Ministry of Transport and the Steering Committee chaired by Dr Nguyen Van Nhan and secretary Mr Tran Tien Son has been a vital facilitating framework for the research and dissemination work. Hoang Cong Quy (Head of RTU), Tran Quoc Thang (PMU18), Dr Nguyen Manh Hung (ITST South), Dr Vu Duc Chinh (Director, Road Laboratory 1), and the provincial administrations in the twelve RRST provinces provided invaluable cooperation and contributions to the programme. The local contractors and consultants cooperated to develop knowledge and apply and improve the various paving techniques. Strong support was also provided by Mr. Simon Ellis (Task Team Leader) and Ms. Tran Thi Minh Phuong (Operations Officer) of the World Bank. David Salter, the SEACAP Programme Manager, provided invaluable facilitation, guidance and programme support.

The sustained efforts of the Project team of Robert Petts, Dr Jasper Cook, Pham Gia Tuan, Bach The Dzung, Le Duc Tho, Ms Nguyen Quynh Lan, Nick Elsworth, Trevor Bradbury, Dr Doan Minh Tam (ITST), Ta Van Giang (ITST), Ung Viet Trung (ITST), Le Minh Duc (ITST), Dr Doan Thi Phin (TDSI), Ms Pham Kim Hanh (TDSI), Heng Kackada (Intech Cambodia), and the ITST Field Engineers also ensured the delivery of a professional and appropriate series of project outcomes.

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ABBREVIATIONS & ACRONYMS

ACCESS	Microsoft database software
ADT	Average Daily Traffic
AFCAP	Africa Community Access Programme
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
CNCTP	Cambodia National Community of Transport Practitioners
CSA	Crushed Stone Aggregate
CSIR	Council for Scientific and Industrial Research (South Africa)
DBM	Dry Bound Macadam
DBST	Double Bituminous Surface Treatment
DCP	Dynamic Cone Penetrometer
DFID	Department for International Development
DST	Department of Science and Technology, Ministry of Transport
EDCs	Economically emerging and Developing Countries
ENS	Engineered Natural Surface
esa	equivalent standard axles
EXCEL	Microsoft spreadsheet software
FHWA	Federal Highways Association (US)
FM	Fines Modulus
FWD	Falling Weight Deflectometer
GMSARN	Greater Mekong Sub-region Academic and Research Network
gTKP	global Transport Knowledge Partnership
HDM4	Highway Development and Management Model
HQ	Headquarters
IFG	International Focus Group
IFRTD	International Forum for Rural Transport Development
ILO	International Labour Organisation
IRF	International Road Federation
IRI	International Roughness Index
ITC	Institute of Technology, Cambodia
ITS	Indirect Tensile Strength
ITST	Institute of Transport Science and Technology
Km	kilometre
LCS	Low Cost Surfacing
m	metre(s)
mm	Millimetre(s)
MERLIN	**M**achine for **E**valuating **R**oughness using **L**ow-cost **IN**strumentation

MoT	Ministry of Transport
MPa	Mega pascals
OM	Operations Manual
ORN	Overseas Road Note
PCU	Passenger Car Unit
PDoT	Provincial Department of Transport
Pen Mac	Penetration Macadam
PI	Plasticity Index
PIARC	World Road Association
PMU	Project Management Unit
PPC	Provincial Peoples Committee
PPMU	Provincial Project Management Unit
QA	Quality Assurance
RED	Roads Economic Decision Model
Ref.	Reference
RRGAP	Rural Road Gravel Assessment Programme
RRSR	Rural Road Surfacing Research
RRST	Rural Road Surfacing Trials
RSRAP	Rural Sealed Road Assessment Programme
RTU	Rural Transport Unit
RT1	Rural Transport 1st Project, Vietnam
RT2	Rural Transport 2nd Project, Vietnam
RT3	Rural Transport 3rd Project, Vietnam
SBST	Single Bituminous Surface Treatment
SDC	Swiss Development Cooperation
SEACAP	South East Asia Community Access Programme
SOE	State Owned Enterprise
TG	Technical Guidelines
TRL	Transport Research Laboratory
UCS	Unconfined Compression Strength
UK	United Kingdom
UNOPS	United Nations Office for Project Services
VN	Vietnam
VOCs	Vehicle Operating Costs
VPD	Vehicles per day
VRA	Vietnam Roads Administration
WAN	Wide Area Network
WBM	Water Bound Macadam
WLC	Whole Life Costs

EXECUTIVE SUMMARY

There is an increasing recognition that gravel surfacing is not always the best solution for rural roads in many circumstances in Vietnam. Therefore, the Government of Vietnam's Ministry of Transport (MoT) in 2002 requested studies of alternative surfaces for Rural (District and Commune) Roads under their Rural Transport Program.

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 South East Asia Community Access Programme (SEACAP).

The research and dissemination activities of the RRSR were carried out under the co-ordination of the Ministry of Transport RRSR Steering Committee. Intech-TRL provided the technical assistance for the various RRSR components, in conjunction with the Institute of Transport Science and Technology (ITST).

The RRST studies comprise two main phases. MoT, World Bank and DFID agreed an allocation of US$600,000 for the works costs of the first trials phase (RRST-I) in the provinces of:-

Mekong Delta:	Tien Giang	US$150,000
	Dong Thap	US$175,000
Central Coastal:	Thua Thien Hue	US$150,000
	Da Nang	US$125,000

Construction of this phase was largely completed in 2005. The second phase (RRST-II) of the trials has also recently been completed (July 2006) with the following works construction budgets:-

Central Highlands:	Gia Lai	US$500,000
	Dak Lak	US$400,000
	Dak Nong	US$400,000
Red River Delta:	Hung Yen	US$400,000
	Ninh Binh	US$700,000
Northern Highlands:	Tuyen Quang	US$500,000
	Ha Tinh	US$500,000
	Quang Binh	US$500,000

The aim of the RRSR programme is to establish a range of sustainable road surfaces that promote better use of local resources; minimise Whole-life-Costs and support the Vietnam Government’s poverty alleviation and road maintenance policies.

These RRST programmes included not only the stabilisation of local soils by lime, cement and bitumen emulsion but also more innovative options for Vietnam such as various surface seals, bamboo reinforced concrete, clay brick (fired using rice husk as fuel), concrete brick dressed stone and cobble stone surfacing.

Complementary investigations were carried out under the SEACAP to investigate gravel road performance of MoT's Rural Transport Program roads. This has led to development of guidelines recommending some restriction of future use of gravel in the range of challenging environments experienced in Vietnam, depending on local influencing factors.

This RRST Final Report summarises and presents the results of nearly 4 years of research into appropriate rural pavement options for Vietnam.

The RRSR has allowed the following conclusions and recommendations to be made regarding rural road surfacing in Vietnam:-

- A substantial and valuable database of rural road surfacing knowledge has been established for the wide range of (challenging) Vietnamese conditions, complementing previous rural road research,
- The Rural Road design approach should be improved to incorporate issues of road task, road environment, local materials available and maintenance regime,
- Gravel is inappropriate for many locations – its use should be restricted,
- A wide range of proven alternatives to gravel is available – with better Whole Life Cost, local resource use & maintenance attributes in many situations,
- Some paving techniques are robust; others carry more risk,
- A range of improvements to practices is required to achieve more cost-effective & sustainable investment in rural roads,
- Improved design of shoulders & earthwork slopes is also desirable,
- A requirement has been identified for more appropriate technical standards,
- Greater emphasis on appropriate surface selection is desirable at PDoT level,
- A Cost Model has been developed to assist decision making on rural road surfacing options. The model is capable of refinement to include the maintenance experiences planned to be gained from the RRST long term monitoring, and incorporation of VOC components.
- Cost Norms and Standard Specifications have been developed for future management and technical application on rural roads in Vietnam.

The completion of these construction trials and investigations are a milestone in the development of cost-effective and sustainable surface options for the various regions and environments encountered in Vietnam. Further essential work is required to monitor the performance of the trials, develop important Whole Life Costing guidance, and carry out further specific complementary initiatives. This is required to complete the planned RRSR programme and achieve the effective mainstreaming of the results to deliver the benefits for the Government of Vietnam and the rural communities. These identified further initiatives are also discussed in this report.

The required further important initiatives include:-

- **Implement performance and maintenance monitoring of the trial roads to develop Whole Life Cost guidance (planned since project inception),**
- **Develop realistic VOC relationships for the Vietnamese types of transport and conditions, to assist surface option and road investment decision making,**
- **Develop further the RRST Cost Model to incorporate the range of surface options and road environments,**
- **Develop comprehensive rural road maintenance guidelines and Cost Norms for the range of surface options and environments,**
- **Revise the MoT Rural Design Guide,**
- **Plan National programme of dissemination and mainstreaming of RRSR outputs, and maintenance of the web knowledge portal.**

These initiatives require implementation arrangements, funding and resource allocation to be agreed as a priority.

Further desirable initiatives include:-

- **Repeat surveys of RRGAP,**
- **Rural Sealed Road Assessment Programme (RSRAP),**
- **International Dissemination of RRSR knowledge.**
- **Investigation of the current Axle Loading regime on rural roads in Vietnam.**

1 INTRODUCTION

1.1 Context

DFID and World Bank have been funding the Ministry of Transport (MoT) Second Rural Transport Project (RT2) in Vietnam that has provided basic access roads for communities in 40 provinces of Vietnam (2001 – 2006). Gravel was the surface usually provided for the project roads at the project commencement. Because of increasing recognition that gravel surfacing is not always the best solution for rural roads in all circumstances in Vietnam, the Government of Vietnam MoT requested studies of alternative surfacings for Rural (District and Commune) Roads in Vietnam under the World Bank and DFID RT2 support.

Decision No 2788/QD – BGTVT by the Minister of Transport dated 30 August 2002 authorised the establishment of Rural Road Surfacing Trial (RRST) Technical Steering Committee. The MOT initially decided to trial paving options in 4 regions of Vietnam with different characteristics.

As part of the ongoing Rural Road Surfacing Research (RRSR) initiative undertaken by Intech-TRL, the Rural Road Surfacing Trials Phase 1 (RRST-I) were planned and the 4 trial roads were constructed and performance monitoring has commenced. This programme is being funded by DFID. In addition, DFID agreed to fund a national gravel surface performance study in Vietnam also undertaken by Intech-TRL under the South East Asian Community Access Programme (SEACAP). This study is termed the Rural Road Gravel Assessment Programme (RRGAP) and was implemented as project SEACAP 4.

The technical assistance work of the RRSR has been undertaken by Intech-TRL in conjunction with their local partners ITST, initially under direct DFID appointment, but latterly as project SEACAP 1. The various technical aspects of the RRSR are co-ordinated by a Ministry of Transport Steering Committee under the direction of the Department of Science and Technology.

The aim of the RRSR programme is to establish a range of sustainable road surfaces that better use local resources, minimising Whole-life-Costs and supporting the Vietnam Government's poverty alleviation and road maintenance policies.

1.2 The SEACAP 1 Programme

SEACAP is a research and knowledge dissemination programme supported by DFID in cooperation with local national road authorities, with the support of agencies such as the World Bank and Asian Development Bank. The objectives of the SEACAP programme are 'Livelihoods of poor and vulnerable people in S. E. Asia improved sustainability' and include empowering local ownership of their access. This includes initiatives that allow roads to be constructed and maintained in a sustainable way by the optimum use of local resources.

The original RRST-I trials work was brought under the SEACAP programme in September 2004. During the RT2 review mission in January 2005 it was agreed that the Trials should be extended to the Central Highlands, Northern Highlands and Red River Delta regions utilising some of the remaining funds available under the RT2 programme. DFID agreed to fund the associated consultancy services under the SEACAP initiative. This second phase Rural Road Surfacing Trials has subsequently been termed RRST-II to distinguish it from the initial RRST-I programme. Figure 1.1 shows the location of the trials provinces. Table 1.1 summarises the related provincial construction budgets for the RRST-I and RRST-II programmes, and Figure 1.2 outlines the overall programme.

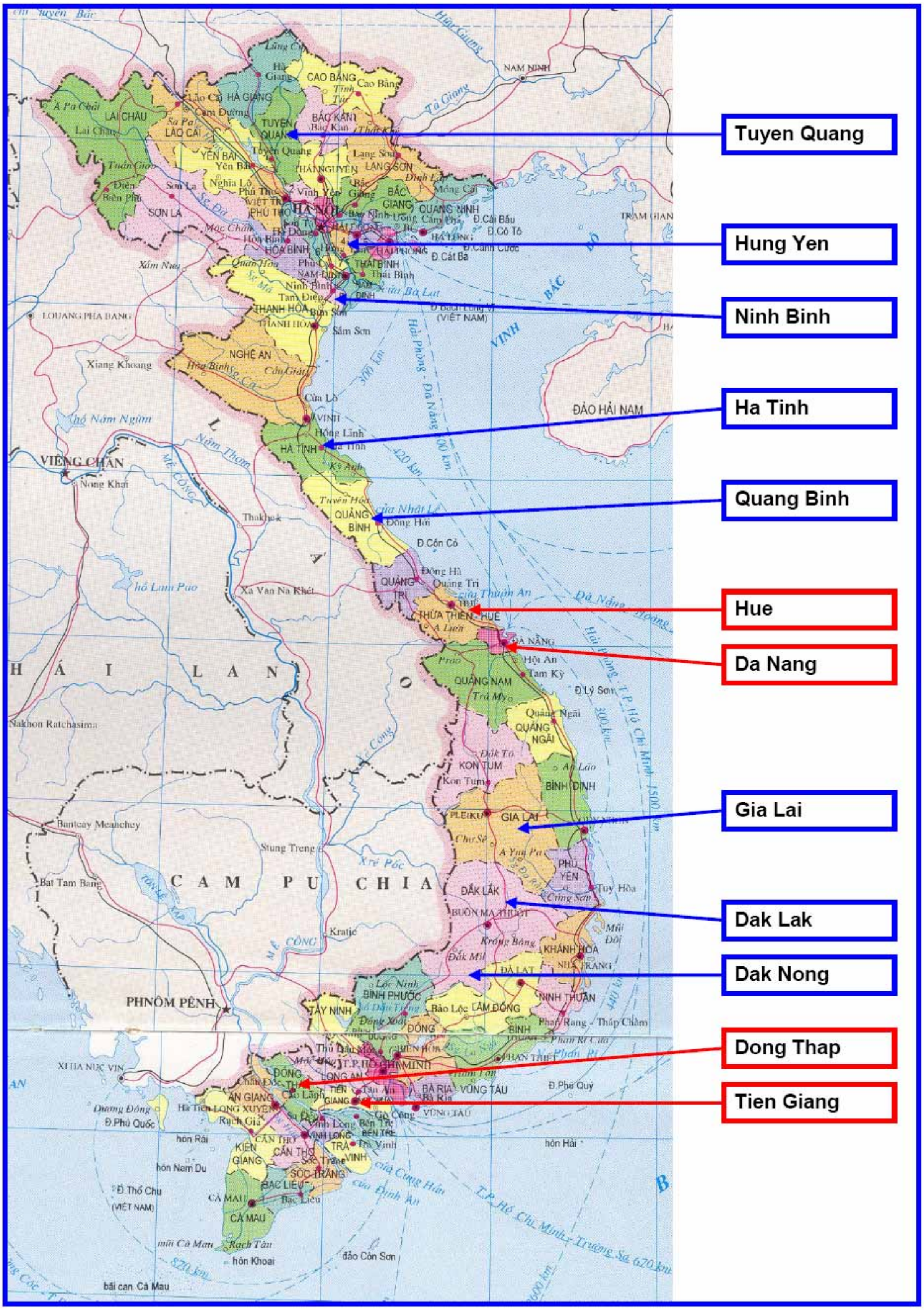


Figure 1.1: RRST-I and RRST-II Provinces

Region	Province	Budget (US$)	Totals (US$)
RRST-I Programme			
Mekong	Dong thap	175,000	US$600,000
	Tien Giang	150,000	
Central Coastal	Thua Thien Hue	150,000	
	Da Nang	125,000	
RRST-II Programme			
Central Highlands	Gia Lai	500,000	US$3,800,000
	Dak Lak	400,000	
	Dak Nong	400,000	
Red River Delta	Ninh Binh	700,000	
	Hung Yen	400,000	
Northern Highlands	Ha Tinh	500,000	
	Quang Binh	500,000	
	Tuyen Quang	400,000	

Table 1.1: RRST Provinces and Construction Budgets

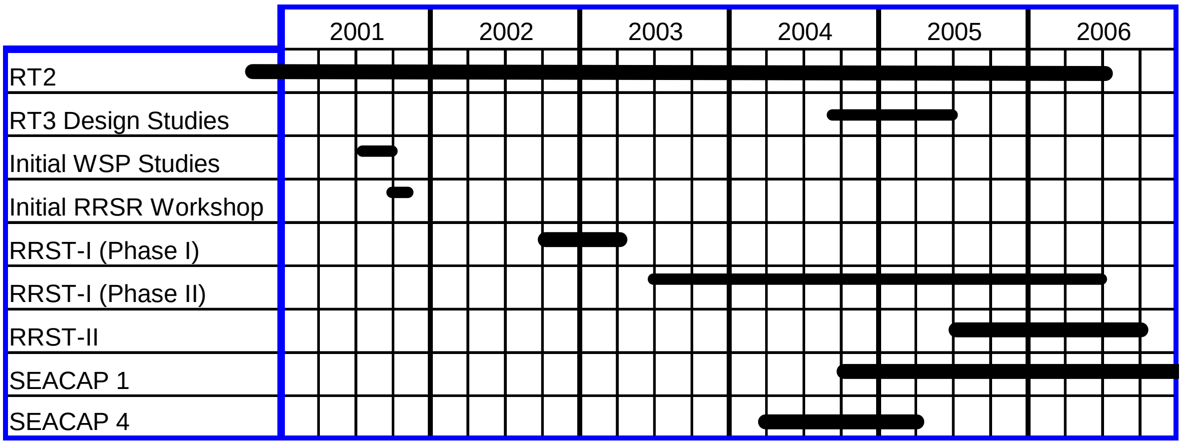


Figure 1.2: Overall RRSR Programme

1.3 SEACAP 1 Contractual Arrangements

The initial contractual arrangement for the RRST-I work was that the planning, advisory and monitoring services were carried out by Intech Associates and TRL, with the support of local organisations ITST and TDSI. From September 2004 the arrangements for managing the RRST-I began to be transferred from DFID directly, to the South East Asia Community Access Programme (SEACAP) on behalf of DFID.

The trials works themselves have been managed by MoT and the respective provincial administrations through the management and funding arrangements of the

RT2 project. The guidance and approval of the work has been carried out by the Steering Committee which has included representatives of interested departments and organisations and chaired by Dr Nguyen Van Nhan, Director of the Department of Science & Technology.

The RRST-II funding arrangements were similar to those of RRT-I in that technical support was funded by DFID. There are, however, some differences in the detail of the arrangements, namely;

1. The DFID support was managed wholly through the South East Asian Community Access Programme (SEACAP).
2. The DFID support through SEACAP was within a phased programme of contracted Modules, rather than through a single consultancy contract. The modules so far contracted being:
   - Module 1 (Intech-TRL) Design and set-up of the trials,
   - Module 2 (Intech-TRL) Quality assurance, technical advice and reporting,
   - Module 3 (ITST) Technical supervision (in conjunction with PPMUs) and collection of construction data.
3. A greater emphasis on the involvement of local consultants in the Technical Assistance support.

There were also significant differences in the technical management of the trial construction programme. Intech-TRL had a direct control on site supervision in RRST-I and was empowered to take the initiative on pavement engineering decisions. In RRST-II direct contract supervision was undertaken by the PPMUs, with support given by a limited number of ITST supervisors and specialist advice being supplied by Intech-TRL. Any changes in pavement design or any technical problems had to be discussed and agreed by the Steering Committee.

1.4 Report Structure

This SEACAP I report is presented in three volumes. The first volume contains the principal text of the report comprising descriptions of the work completed; summaries of relevant data; analysis of the data collected; conclusion and recommendations.

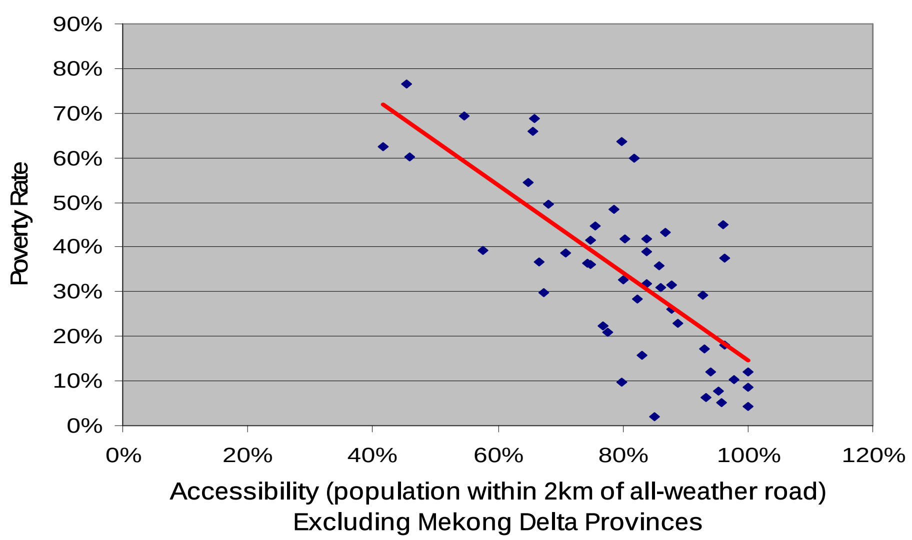
There are two volumes of Appendices Volume 2 and 3); the first containing detailed information, surveys, data and analyses referred to in the Main Report and the Cost Model details. The second volume of Appendices contains the recommended RRST Technical Specifications, Cost Norms, Dissemination workshop details, and information on the Socio-economic surveys.

2 TECHNICAL BACKGROUND

2.1 Background and Rationale for the Trials

The rural poor do not have motor cars. However they need reliable access for affordable transport or services (both motorised and non-motorised) such as bicycles, motorcycles, animal carts, minibuses, buses, whether owned or hired. Even if a vehicle ride is too expensive for them, they will still depend on the transporters that bring the construction materials, goods, medicine and teachers etc. to the village, or carry crops. The essential challenge for engineers and road managers is therefore how to provide and maintain this rural access for the types of traffic currently in use, on a sustainable basis with the limited resources available. Many communities are currently denied suitable road access for their economic and social needs. There is an established link between poor access and poverty incidence (e.g. Figure 2.1).

Figure 2.1: Poverty & Accessibility, Vietnam 2002



Source: Vietnam 2002 Living Standards Survey

Unsealed rural roads with earth and gravel/laterite surfaces comprise the greater proportion of the length of public roads in rural areas in Vietnam, as in many developing regions.

Engineers have traditionally relied on the use of natural gravel/laterite as a rural road surface, due to its initial low costs and simplicity of use. However recent research[1] confirms the serious problems relating to maintenance and sustainability of such surfaces in many situations common in South East Asia. There are also health and environmental concerns regarding the widespread use of gravel as a road surface.

2.2 RT2 Surfacing Options

The Vietnam Rural Transport Strategy Study (RTSS)[2] had been used as a guiding document for the design of the RT2 project. Some of the assumptions in the study

[1] DFID funded KaR and SEACAP research by Intech Associates and TRL.
[2] Vietnam Rural Transport Strategy Study, IT Transport, 2000

regarding justification of rural road surfacing selection had been questioned in the light of emerging research evidence and concerns of some local stakeholders; specifically regarding the suitability of gravel in some circumstances. For example, the RTSS correctly stated that:

> "*Roads deteriorate and are damaged under the action of traffic, particularly heavy traffic, and climate. Flows of heavy traffic on these roads will be low, but the climatic and terrain conditions are severe – heavy and often intense rainfall resulting in high seasonal water flows. If rural roads are to be durable and maintainable, the crucial requirement is that they are designed and built to withstand seasonal rainfall and water flows, irrespective of the type of improved surfacing provided*"

However, there was increasing unease at the recommendation that gravel should be the general minimum-cost surfacing standard, based on the RTSS conclusions that:

> "*…gravel has a lower whole-life cost than either stone paving or bitumen penetration macadam surfacing*"
>
> and .
>
> "*Even if very low costs are assumed for the maintenance of a bitumen-sealed road, its whole-life cost is still higher than a gravel road when the levels of heavy, road-damaging traffic are low*".

With further evidence of rapid deterioration of some of the early RT2 gravel roads, there was therefore strong support from MoT, World Bank and DFID for the research of gravel road performance and alternative surfacing options for rural roads.

2.3 The RRST Phase I Study

The principal aim of the RRST-I Phase I study was to design and set-up up the framework for a proposed series of rural road trials in contrasting road environments in Vietnam, Figure 2.2

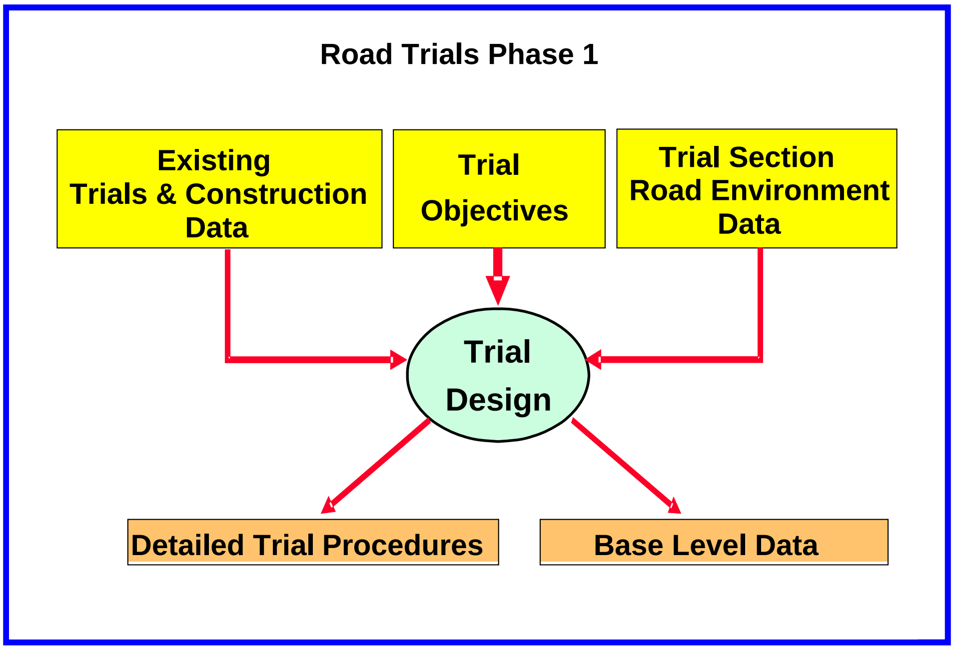


Figure 2.2: Principal Phase 1 Objectives

The proposed pavement trials programme was seen as being only part of a wider objective to provide appropriate design guidance for rural roads in Vietnam within the overall goals of improving rural access and poverty alleviation. This design guidance was seen as necessary to provide an 'appropriate design' approach to rural roads in Vietnam based on road environments and whole life costing. It was acknowledged that neither a blanket approach to road design nor direct import of designs established for other environments was appropriate to the Vietnam rural network. Vietnamese road engineers needed to be able to draw on road pavement options that are appropriate for the Vietnam conditions.

It was apparent however, that there was a significant lack of relevant data on which to develop appropriate designs, in the context of environmentally optimised design. Hence the requirement for soundly based road construction and performance monitoring programmes that can lead directly to improved decision making in upcoming rural road programmes.

Rural road pavement trials were therefore seen as being essential to develop and test the alternative technologies, whilst longer term data collection would be necessary to prove the performance and durability of the surfacings; to make the whole life cost comparisons used to provide the cost-benefit analysis of the technologies. In the longer term the trials were also necessary, to provide the information needed to calibrate relevant deterioration models.

Following discussions with PDoTs and with MoT and a review of site conditions the following road sections were selected as surfacing trial sites:

- Tan Thuan Tay road Dong Thap province.
- My Phuoc Tay road Tien Giang province.
- Thong Nhat road road, Thua Thien Hue province;

In addition the Hoa Hai-An Nong road in Ngu Hanh So'n district, Da Nang province was provisionally selected as a trial road and trial surfacing options discussed and agreed by the PDoT. In fact, during the Phase I work this road was moved under the administration of the Da Nang municipality and the new trial road (Binh Ky) was selected, although the original paving option selections were largely adhered to. .

Proposals for the layout designs for the trials took into consideration a number of essential factors:

- The need for short (approximately 200m) sections of pavement option for detailed monitoring.
- The requirement for 100m lead-in or training/demonstration sections to resolve any issues with new techniques.
- The essential requirement that the trialled pavement options would be compared with "standard" designs, in this case gravel/crushed stone macadam and penetration macadam; these sections to be 100m in length.
- The need to select road sections with consistent road environment characteristics.
- Trial pavement designs to be compatible with the road environments and to be in line with general pavement design principles for low volume roads.

2.4 The Rural Road Gravel Assessment Programme (SEACAP 4)

An initial Rural Road Gravel Assessment Programme (RRGAP)[3] Scoping Study revealed that although gravel has been the commonly recommended surfacing in recent rural road rehabilitation programmes, there was little available data on its engineering performance and deterioration and that this knowledge gap required urgent attention.

The subsequent RRGAP (SEACAP 4) investigations, carried out by Intech-TRL at 766 road sites, found serious constraints to the use of gravel in most of the studied 16 programme provinces due to factors relating to material quality, material availability, climate, terrain, drainage provision and maintenance. Overall gravel loss figures indicate that around **58%** of the surveyed sites were suffering unsustainable deterioration, while **28%** were losing material at twice the sustainable rate; refer to Figure 2.3.

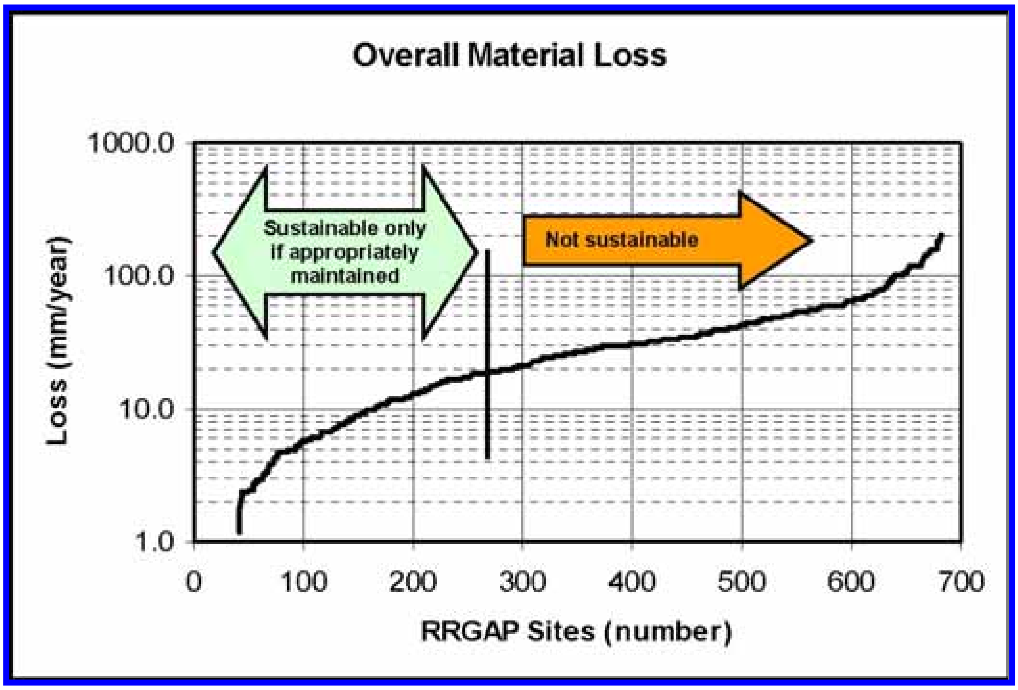


Figure 2.3: RRGAP Material Loss Diagram

From the RRGAP investigations, and consideration of other complementary research and knowledge of the performance of gravel roads elsewhere, the following guidelines have been proposed for the restriction and use of gravel as a rural road surfacing in the range of conditions experienced in Vietnam:-

It was recommended that the use of gravel as an unsealed rural road surface in Vietnam should take into account defined limits on the following road environment factors:-

1. Rainfall
2. Longitudinal gradient
3. Materials Haulage
4. Traffic
5. Flooding

[3] Cook J R and Petts RC. Rural Road Gravel Assessment Programme, Module 4: Final Report. DFID funded South East Asian Community Access Programme (SEACAP 4), Intech-TRL. 2005.

6. Quality Control
7. Drainage
8. Maintenance

The recommendations in the final RRGAP report were summarised into an unsealed gravel assessment diagram, which in turn has been incorporated into the RRSR Pavement Selection Process (Appendix H). See also Section 8.6 of this report.

2.5 ITST (South) Pavement Trials

Prior to the initiation of the RRST programme ITST (South) had been undertaking a number of low-cost construction trials in the Mekong region using lime stabilised local clay/silt soil as a road-base (Figure 2.4). Useful discussions were held with ITST (South) and with their co-operation, three of the lime stabilisation trials were visually inspected and their existing foundation strengths examined using a DCP apparatus,

Key points to arise from the site visits were:

1. A nominal 8% of lime stabilisation achieved in situ CBR of up to 50% (locally 70%), although the results were variable between 30 and 50%.
2. A nominal 6% of lime stabilisation achieved in situ CBRs in the range 12-35%.
3. Unstabilised soil had CBRs generally in the range 3-6%, although some were locally higher.
4. Lower CBRs were recorded under a patched area on one road (Binh Minh).
5. There was marked decease in CBR value with depth within the stabilised layers, particularly evident below a depth of 100mm. This may be due a combination of poor mixing of lime and/or layers being too thick for adequate compaction with the available light plant.
6. Thin, recent, longitudinal cracks were evident in some sections of the Binh Minh road surface. This appeared to correlate with open shrinkage cracks on the adjacent embankment edges.

Binh Minh District; Dong Thanh Commune . Carriage way: 3.5m Surface: 20mm emulsion and chip seal Base: 120mm lime (8%) stabilised soil Sub-base: 120mm lime (6%) stabilised soil	20mm **8%** 120mm **6%** 120mm
Long Ho District: Hoa Phu Commune Carriageway: 3.0m (Table 2.1) Surface: 20mm emulsion and chip seal Base/Sub-base:150mm lime (6%) stabilised soil	20mm **6%** 150mm
Cao Lanh District, Bin Hang Tay Commune Carriageway: 2.0m Surface: 20mm emulsion and chip seal Base/Sub-base: 120mm lime (6%) stabilised soil	20mm **6%** 120mm

Figure 2.4: ITST(South) Trial Pavements Design

There are significant environmental benefits from use of lime stabilised road base in the delta areas; the insitu materials are utilised and material haulage is minimised.

3 THE RURAL ROAD SURFACING TRIALS

3.1 Overall Objectives

Under the general goal of supporting the Vietnam Government poverty alleviation and road maintenance policies, the original Terms of Reference (March 2003) defined the purpose of the Rural Road Surfacing Research as:-

> *"To provide relevant information on the actual construction methods, costs and characteristics, and the in-service real-time performance of various rural surfacing options in response to a representative selection of Vietnamese road environments."*

Specifically, the objectives of the RRST programme were described as:

- To test selected rural road surfacing and paving types in a range of road environments encountered in Vietnam.
- To develop knowledge of various rural road surfacing and pavement types with respect to:
  - Adequacy to bear rural road traffic over various subgrade conditions,
  - Construction costs depending on local circumstances,
  - Maintenance needs and costs, and thus Whole Life Costs,
  - Works Productivity,
  - Technology options, including use of locally manufactured equipment,
  - Suitability for small scale contractor implementation,
  - Labour and employment creation potential,
  - Quality control and supervision requirements,

The technical outputs of the trials project were defined as:-

- Recommended revisions to the Vietnam Rural Road Construction and Maintenance Standards,
- Revised Guidelines on the selection of Rural Road Surfacing for PDoTs.

3.2 RRST-I

The background, structure and programme of the RRST-I trials work are presented in detail in the RRST-I Trials Construction Report [4]. Table 3.1 summarises the extent of the work. The following paragraphs summarise the technical aspects of the work as they relate to the overall RRSR programme objectives.

The RRST-I strategy was based on the design, construction and monitoring of short lengths of a range of new options and control sections constructed under tight supervision and control conditions; Figure 3.1. This approach allowed the comparison of differing options and control sections within the same road environment; Table 3.2.

Key to this approach was the construction of control sections comprising standard or commonly used Vietnamese rural road paving options, namely:

- Unsealed natural gravel,
- Penetration macadam,
- Unsealed water bound macadam.

[4] Intech-TRL; July 2006

Sections Constructed	**Tien Giang**		**Dong Thap**		**Hue**		**Da Nang**	
Category	No.	Length(m)	No.	Length(m)	No.	Length(m)	No.	Length(m)
Training	2	200	3	300	4	400	3	300
Monitoring	5	1000	7	1300	5	975	3	525
Control	3	300	2	190	2	200	2	200
Total	10	1500	12	1790	11	1575	8	1025

Table 3.1: Extent of RRST-I Paving Trials Programme

	Training	**Monitoring**	**Monitoring**	**Training**	**Monitoring**	**Control**
Surface/Base	**Option A**	**Option A**	**Option A**	**Option B**	**Option B**	**Option C**
Sub-Base	**Option A1**	**Option A1**	**Option A1.2**	**Option B.1**	**Option B.1**	**Option C**
SubGrade						
	100m	**200m**	**200m**	**100m**	**200m**	**200m**

Figure 3.1: Basis for RRST-I Trial Layout Designs

Parameter	**Trial Road Variability-RRST-I**	**Trial Road Variability-RRST-II**
Climate	Constant	Constant
Terrain	Constant	Can be variable
Hydrology	Constant	Can be variable
Sub-Grade	Constant (minor variation)	Can be variable
Road Surface	Varied	Limited variability
Road-base	Varied	Limited variability
Contracting regime	Constant	Constant
Maintenance regime	Constant	Constant

Table 3.2: Trial Parameter Variability – RRST-I and RRST-II

Apart from site characterisation constraints, trial option selection was based on a number of key strategic issues and objectives:

- Reduced maintenance burden,
- Low expected whole-life-costs,
- Improved sustainability,
- Traffic load spreading properties,
- Durability in the expected traffic & environmental conditions,
- Use of locally available or produced materials,
- Techniques with low capital investment (limited or simple equipment requirements), & manageable by local contractors,
- Use of local labour and skills,
- Socially and environmentally acceptable use of materials.

3.3 RRST-II

The background, structure and programme of the RRST-II trials work is presented in detail in the RRST-II Trial Design Report (Intech-TRL; May 2006) and the RRST-II Construction Summary Report (September 2006). The following paragraphs summarise the technical aspects of the work as they relate to the overall RRSR programme objectives.

The RRST-II programme was seen as an important step in the roll out and mainstreaming of sustainable and appropriate rural surfacing solutions, Table 3.3 summarises its scope. The scientific and engineering objectives of RRST-II were a logical follow-on from those of the RRST-I programme and may be summarised as follows:

1. Trialling of alternative surfacing options within additional Vietnam road environments,
2. Construction trialling of RRST-I options under longer-length, standard construction contract conditions,
3. Trialling a knowledge-based selection process for rural road designs which included a more detailed weight being given to road environment factors such as sub-grade condition, topography and hydrology,
4. Integrating appropriate options from RRST-I into the PDoT selection, design and supervision processes,
5. Wider involvement of local consultants and contractors in techniques and practices associated with sustainable rural road design and construction,
6. Only representative sections of the trial roads have been selected for long term monitoring.

The construction trialling of longer lengths of pavement has meant that single options in many roads have been constructed in differing road conditions. Therefore, in contrast to RRST-I, RRST-II does not trial differing options within similar environments but is designed to gather information on a more limited range of options in variable environments; Tables 3.2 and 3.3.

Province	Road	Number of Trial Sections and Total Length (m)		Number of Control Sections and Total Length (m)		Number of Monitoring Sections and Total Length (m)	
		No	(m)	No	(m)	No	(m)
Tuyen Quang	**Lang Quan**	4	3500	1	1000	5	600
	Hoang Khai	1	310	3	2000		
	Nong Tien	1	500	1	1400		
	Thang Quan	1	1000	1	750	1	100
	Y La	1	500	2	1150		
Ha Tinh	Chu Le	1	200	1	2300	2	200
	Ghenh Tanh	1	1782	0	0		
	Hong Loc	2	2350	2	4600	3	300
	Thac Minh	3	2300	2	4600	5	500
Quang Binh	**Cam Lien**	6	5561	2	939	5	500
	Loc Ninh	1	966	1	470		
	Ngu Hoa	4	4649	2	1006	3	300
Hung Yen	**Nhat Quang**	2	2500	2	1006	6	600
	Hung Long	1	500	2	1750	3	300
	Tan Hung	2	2182	0	0	2	200
	Thuy Loi	1	420	1	990		
	Van Hhue	1	850	2	1317		
Ninh Binh	Do Quy	1	500	1	1500		
	Dong Huong	1	500	1	1500	2	200
	Gia Phu	1	500	2	670		
	Ninh Giang	1	500	2	1982		
	Ninh Van	2	1000	2	2915		
	Thu Trung	1	1000	2	2990		
	Tien Phong	1	540	3	3172		
	Trai Giong	2	1000	1	1770		
	Yen Trach	2	1000	2	1330	6	700
	Yen Tu	1	500	1	855	3	300

Note: Shaded boxes denote roads surveyed by Intech-TRL.

Table 3.3: Listing of RRST-II Trial Roads

Province	Road	Number of Trial Sections and Total Length (m)		Number of Control Sections and Total Length (m)		Number of Monitoring Sections and Total Length (m)	
		No	(m)	No	(m)	No	(m)
Gia Lai	**Ia Pnol**	3	3000	1	1000	4	400
	Xa Kroong	2	1100	1	900		
	Xa Song An	2	1000	1	1500		
	Xa Trang	2	1000	1	500	5	500
	Ya Hoi	2	1400	0	0		
Dak Lak	**Buon Ho**	4	5380	2	682	4	400
	Cu Ne	2	1500	2	2800	2	200
	Ea Soup	1	500	2	3500	3	300
Dak Nong	**Kien Duc**	9	10510	2	1300	11	1100

Notes:
1. Shaded boxes denote roads surveyed by Intech-TRL

2. Two additional roads were surveyed by Intech-TRL; Chu Poh in Gia Lai and Dia Loi in Ha Tinh, but were subsequently removed from the programme by the PDoTs.

Table 3.3: Listing of RRST-II Trial Roads (Continued)

3.4 Trial Option Designs and Costs

In addition to the general road environment factors which influenced the selection of trial options, the design of the RRST-I pavement took into account the following key aspects:

- In situ sub-grade conditions
- Existing pavement conditions
- Flooding history
- Gradient
- Traffic – assumed design value of 50,000 esa

The detailed design of the pavements took into consideration the minimum strength requirements for Class A Rural Roads as defined in relevant MoT publications. In addition a cross check was undertaken on equivalent road strengths designed on the basis of current TRL and ARRB documented research; Figure 3.2 .

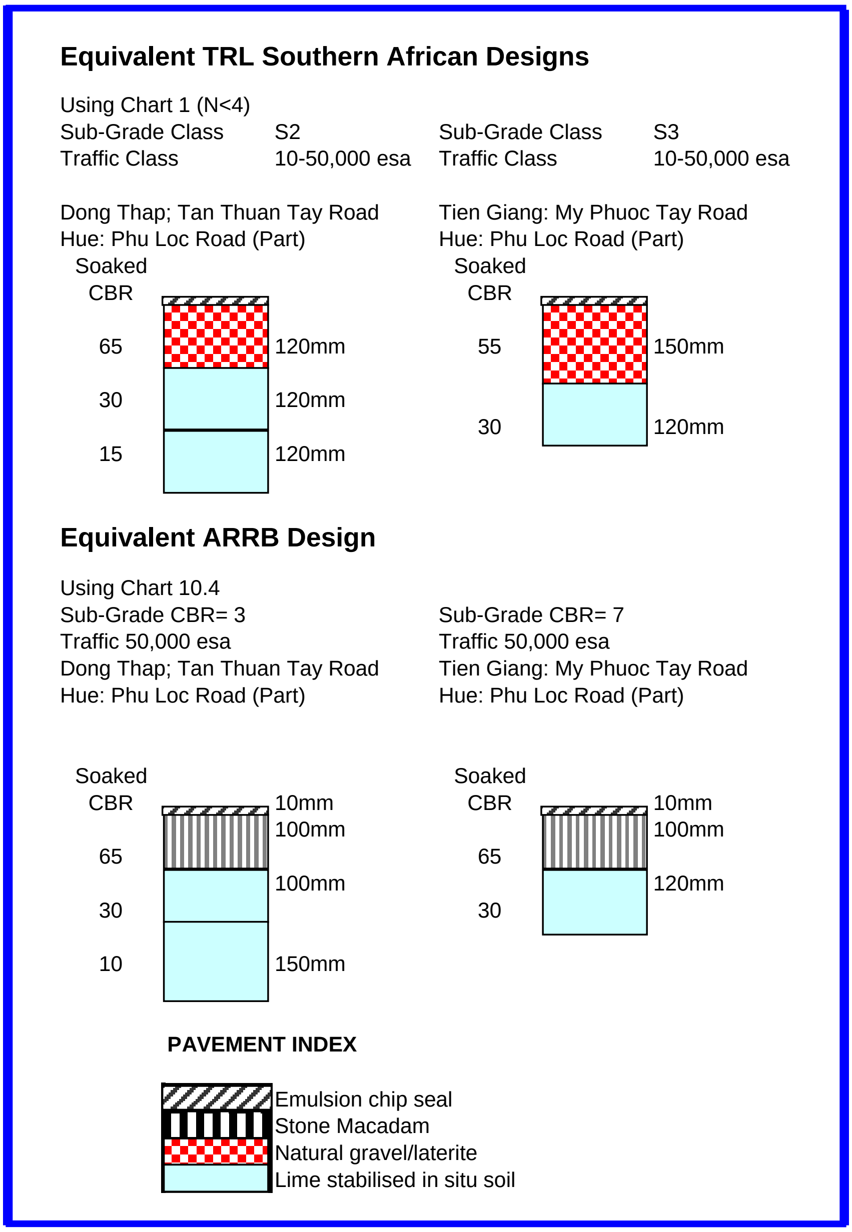


Figure 3.2: Equivalent RRST Designs Based on Current Documented Research

The RRST-II design process was similar to that of RRST-I with the additional input of local design decisions by the PDoTs and Local Consultants, particularly for those roads outside the original Intech-TRL selected list.

The combination of RRST-I and RRST-II trials construction has resulted in a wide selection of rural road options being built in a representative selection of Vietnam road environments. Figure 3.3 illustrates the range of layer options that have been trialled under the RRST programmes and Table 3.4 lists the trialled pavement options in relation to the five selected geographical regions.

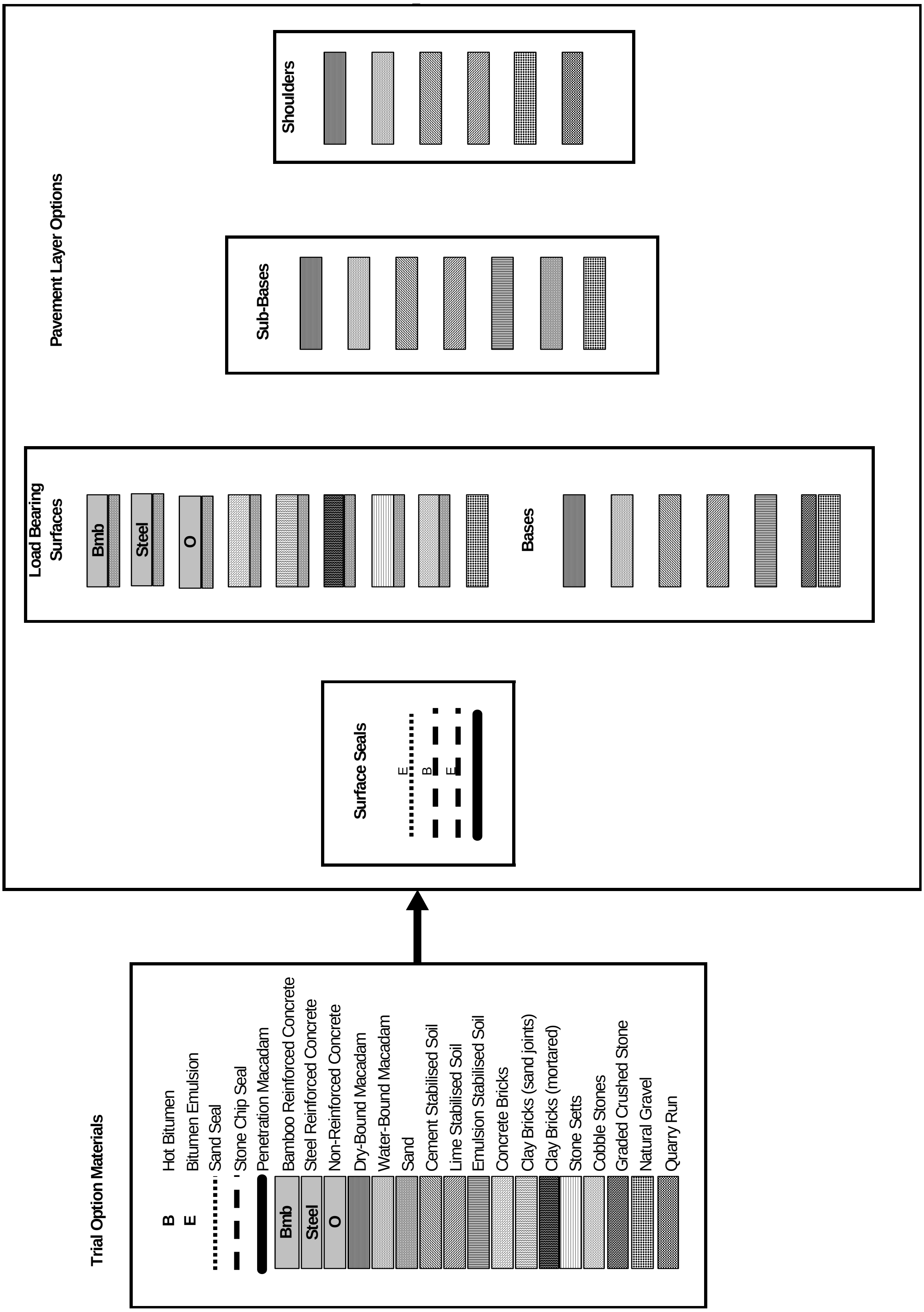


Figure 3.3: RRST Pavement layer Options

	RRST-I		RRST-II		
	Mekong Delta	**Central Coast**	**Central Highlands**	**Red River Delta**	**Northern Highlands**
Seals and Load Bearing Surfaces					
Emulsion sand seal	■	■	■	■	■
Emulsion Chip seal	■	■	■	■	■
Penetration macadam	■	■	■		■
Steel reinforced concrete	■	■	■	■	■
Bamboo reinforced concrete	■	■	■	■	■
Unreinforced concrete			■	■	■
Engineering clay bricks	■			■	
Concrete bricks	■			■	
Dressed Stone		■			
Cobble stones				■	
Bases and Sub-Bases					
Drybound macadam	■	■	■	■	■
Natural gravel		■	■		■
Armoured gravel		■	■		
Cement stabilised soil	■	■		■	
Lime stabilised soil	■				
Emulsion stabilised soil		■			
Graded quarry-run				■	
Control Sections					
Unsealed gravel	■	■	■	■	■
Penetration macadam	■	■	■		■
Unsealed waterbound macadam	■	■		■	
Hot bitumen chip seal			■	■	■
Waterbound macadam			■	■	■
Shoulders					
Unsealed waterbound/dry macadam			■	■	■
Sealed waterbound/dry macadam			■		■
Natural gravel	■	■	■	■	■
Cement stabilised soil		■		■	
Lime stabilised soil	■				
Graded quarry-run				■	

Table 3.4: Matrix of RRST Options and Regions

The extensive range of trial road surface options within the 12 RRST provinces, many of which contained differing road environments, resulted in a consequently wide variation in construction costs, even for similar pavement options. This variation has important implications for pavement option selection and the application of the final Cost Model (Chapter 6). Table 3.5 summarises this design cost variation for a range of typical RRST pavement options. This data is based on the current provincial cost norms, adapted where necessary for the trial designs. Fuller details of designs and construction costs are included in Appendix E to this report.

Option	Road	Province	Terrain	Cost(US$/km)
150mm Bamboo reinforced concrete	Long Quan	Tuyen Quang	4	19,606
	Gheng tang	Ha Tinh	1	25,624
	Xa Krooi	Gia Lia	4	40,500
200mm Non-reinforced concrete	Lang Quan	Tuyen Quang	4	21,747
	Gheng Tang	Ha Tinh	1	28,828
	Xa Krooi	Gia Lia	4	42,913
100mm Dry Bound Macadam	Thac Minh	Ha Tinh	3	7,600
	Cam Lien	Quang Binh	1	8,778
	Ia Pnol	Dak lak	4	13,350
Bitumen emulsion Double Chip Seal	Long Quan	Tuyen Quang	4	7,147
	Thac Minh	Ha tinh	3	7,616
	Ia Pnol	Gia Lai	4	10,990
Unsealed Gravel	My Phuoc Tay	Tien Giang	1	7,682
	Kien Duc	Dak Nong	3	2,918
	Cu Ne	Dak Lak	3	2,667

Table 3.5: Range of Typical Pavement Layer Costs

3.5 Training and Technology Transfer

RRST-I and RRST-II both incorporated components of training and knowledge transfer to the PDoT staff and contractors. This was achieved through a combination of formal workshop events to present and discuss the trials and the new construction techniques, and on-site mentoring. Workshops were also held on completion of the construction phases of the trials in order to obtain feedback and comments from key stakeholders. Table 3.7 summarises the key workshop events organised.

The details of the events and training materials produced are found in the relevant progress and completion reports.

Date	Workshop	Objective
3 March 2004	RRST-I Knowledge Exchange Workshop: Tien Giang	Explanation of trial objectives and procedures to contractors and supervisors; Tien Giang and Dong Thap
5 March 2004	RRST-I Knowledge Exchange Workshop: Hue	Explanation of trial objectives and procedures to contractors and supervisors; Hue and Da Nang
5 September 2005	RRST-I Knowledge Exchange Workshop: Hanoi	Feedback on construction phase of RRST-I from key stakeholders
19 January 2006	RRST-II Knowledge Exchange Workshop: Hanoi	Explanation of trial objectives and procedures to contractors and supervisors; Red River and Northern Highlands RRST provinces
9 February 2006	RRST-II Knowledge Exchange Workshop: Dak Lak	Explanation of trial objectives and procedures to contractors and supervisors; Central Highlands RRST provinces
14 February 2006	RRST-II Training Seminar	Detailed description of supervisor requirements to ITST engineers
19 September 2006	RRST-II Knowledge Exchange Workshop: Hanoi	Feedback on construction phase of RRST-I from key stakeholders; Red River and Northern Highlands RRST provinces
21 September 2006	RRST-II Knowledge Exchange Workshop: Dak Lak	Feedback on construction phase of RRST-I from key stakeholders: Central Highlands RRST provinces
6 – 7 December 2006	SEACAP 1 Trials Dissemination Workshop: Hanoi	Final presentation of SECAP 1 data and results and recommendations for continued research

Table 3.7: Summary of Key RRST Workshops and Seminars

4 TRIALS DATA COLLECTION

4.1 General Road Environment Data

General road environment information was collected prior to the trial design phases in both RRST-I and RRST-II. Key data sets were as follows:

Climate: Rainfall data was obtained from provincial statistical yearbooks and the Institute of Hydrology and the General Statistics Office website (www.gso.gov.vn).

Terrain: Information on road gradient was collected as part of the geotechnical surveys.

Hydrology: Information on apparent water levels and liability flooding was collected as part of the geotechnical surveys.

Sub-grade: Information on sub-grade and existing pavement strength was collected from all RRST-I roads and from the originally identified RRST-II roads. The local consultants and PDoTs were encouraged to supply information on the additional roads, however apart from general comments little data was received.

Traffic regime: Traffic counts were undertaken for all RRST-I and all the originally designated RRST-II roads. Traffic counts for RRST-I were based on 12hr – 6 day surveys; those on RRST-II on 12hr – 3 day surveys. Figure 4.1 shows the standard form developed and used for this purpose. Traffic counts have been converted to 24hour counts using the standard factor of 1.2. Average daily traffic (ADT) figures were calculated using standard conversion factors (ORN 20 TRL, 2003) Data was summarised and is presented in further detail in Appendix B.

Post-construction, axle load surveys and Falling Weight Deflectometer (FWD) surveys were carried out on the RRST-I trial roads. These are discussed in this Chapter and details are provided in Appendices C and F.

FORM : Manual Classified Traffic Count

Province	Thua Thien Hue				SURVEYOR
District	Phu Loc				LOCATION

Daily 12 hour counts *DATE (2003)*

Traffic Class	Tuesday 25th November	Wednesday 26th November	Thursday 27th November	Friday 28th November	Saturday 29th November
MOTORCYCLE	92	79	56	61	55
CAR, 4WD, PICKUP					2
CONG NONG & Tractor	2			2	
LIGHT TRUCK =< 5 TONS GVW					
TRUCK > 5 TONS GVW					
Mini-bus/Bus					
PEDESTRIAN, WALKER	272	281	284	309	170
ANIMAL/HAND CART					
BICYCLE	254	168	255	147	142
TOTALS	620	528	595	519	369
Rain This Period?	Rain morning and afternoon	Light rain all day	Rain early morning & late afternoon	Light rain afternoon	Light rain all day
Daily Survey Period:	6.00 hours to 18.00 hours		*GVW = Gross Vehicle Weight*		

Figure 4.1: Standard Form used for RRST Traffic Counts

4.2 Construction Data

For the RRST-I programme the collection of information relevant to construction costs and procedures was undertaken by the Intech-TRL-ITST site engineers in parallel with their technical advice and supervisor roles. A standard daily worksheet form was developed for use and collected such key information as:

- Plant usage,
- Labour usage,
- Work completed in each day,
- Weather,
- Sampling and testing,

Under the RRST-II programme similar functions were preformed by ITST engineers under a separate SEACAP contract to provide overall supervision and data collection services. Information obtained from the daily worksheets has been used to modify the cost norms for the new pavement options.

The laboratory testing of as-used materials and the in situ testing of completed pavement layers were an integral part of the trials monitoring programme. Information from this monitoring programme is contained within the RRSR database.

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4.3 Construction Materials

Information on construction materials was obtained in three general phases:

1. Prior to trials design: Available construction materials were visually assessed, sampled and tested as to their appropriate use within pavement options. In the case of RRST-I, significant care was taken with assessing the suitability of local soils for stabilisation by lime, cement or bitumen emulsion. The availability and nature of the local materials had a fundamental impact on the trial option selection. Hence the use of soil stabilisation in the Red River and Mekong deltas, the preponderance of crushed stone options in the highland areas and the use of natural gravel as a sub-base in the Hue trials.

2. As a materials source approval process: Prior to construction all materials proposed by contractors were required to be tested and approved as being suitable with respect to the relevant specifications.

3. As part of on-site quality control: During construction all as-delivered materials were required to be tested for contract compliance, based on the types and frequency of testing defined within individual specifications.

The three-phase testing regime worked well under the strict controls possible under RRST-I, but less well under the very tight time scales and less well defined responsibilities of RRST-II. Nevertheless considerable amounts of relevant data were obtained from both projects. Data from RRST-I is collated in electronic format within the RRSR database. Data from RRST-II is largely in hard copy format within as-bult contract reports; apart from the limited amounts of Phase 1 data, which are also within the RRSR database.

4.4 Pavement Condition Data

4.4.1 As Built and Monitoring Surveys

Monitoring of the condition of the selected trial and control sections and their deterioration over time is an integral part of the overall RRST programme. This was recognised at the very outset of the project when an ongoing, long-term monitoring element (Module 6) was included as part of the original RRSR programme.

Pavement deterioration is a complex phenomenon which can manifest itself as distress of various inter-related kinds; hence the requirement for the monitoring programme to recover a range of time series data, the analysis of which can then be used to provide clear evidence on which to base deterioration and to develop whole-life costing model relationships.

Pavement condition should be monitored in terms of strength, roughness, deformation; surface condition deflection, and in situ moisture condition. Table 4.1 provides a general summary of the techniques adopted for the RRST as built and monitoring surveys and Figure 4.2 illustrates the layout of a typical RRST monitoring system arrangement.

The frequency of data collection should reflect the characteristics of the climatic environment. For example, in seasonally wet areas, the minimum programme of monitoring should reflect the end of dry and wet seasons.

As-built condition surveys serve as the base line for the trials monitoring interpretation; these have been completed for both RRST-I and RRST-II The initial short-term monitoring for three out of the four RRST-I provinces has also been completed, These surveys were planned to generally coincide with dry-wet seasonal change; Condition monitoring has not been possible in Da Nang due to the late completion of the contract works; Table 4.2.

Details of the scope of the surveys together with summaries of recovered data sets are contained with Appendix D to this report. All relevant detail is contained within MS-EXCEL and ACCESS files as part of the RRSR database.

The results and implications of the as-built surveys form part of the review of the trial options (Chapter 7) and also supplied for part of the information input to the Cost Model (Chapter 6).

Deterioration mechanism or parameter	Techniques, Equipment and Source Reference	Derived Information	Application to Trial Surfaces
Surface Condition	Standard Visual Condition Survey (ORN 18; TRL, 1999).	Type, intensity, width and position of cracking. Potholes and patching. Edge failures. Surfacing defects.	All trial options
Roughness	MERLIN (Cundill, 1996)	Derivation of standard measure of road roughness; International Roughness Index (IRI).	All trial options
Deformation	2m Straight edge (ORN 18; TRL1999)	Load associated deformation, in terms of rutting.	All trial options excluding concrete surfacing
Deflection	FWD (SHRP, 1993; ORN 18,1999))	Strength of the road pavement is inversely related to its maximum vertical deflection under a known vertical load.	All trail options
Layer/ pavement Strength	Dynamic Cone Penetrometer, DCP (ORN 18; TRL, 1999)	Relationship between DCP readings and CBR established.	Gravel, and sealed stabilised base options. All shoulders
Moisture	Small disturbed samples	Variation in moisture content	
Destructive sampling	Trial Pitting (ORN 18; TRL 1999)	Used to confirm layer thickness and to retrieve samples of surfacing, pavement, Also used to collect samples for moisture content. .	All trial options excluding concrete surfacing (shoulder confirmation of edge thickness)

Table. 4.1: Techniques Used to Collect Pavement Condition Data.

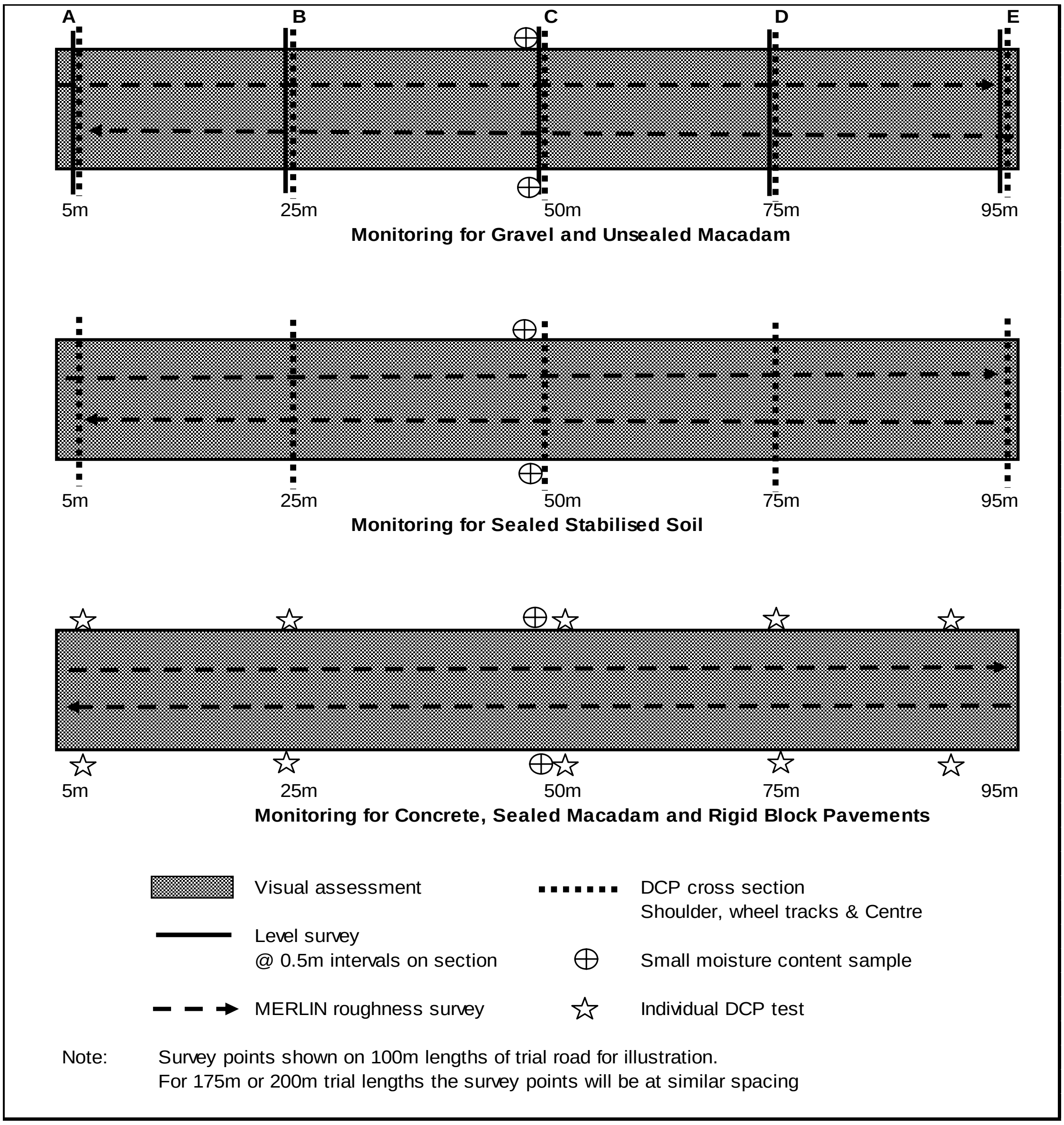


Figure 4.2: Schematic Layout of Monitoring System

Province	Construction Completion	As Built Survey (Monitoring I)	Monitoring -II	Monitoring-III
Hue	20th May 2005	13th June 2005	16th February 2006	July 2006
Tien Giang	15th May 2005	21st July 2005	3rd January 2006	July 2006
Dong Thap	10th July 2005	20th July 2005-18th August 2005	5th January 2006	July 2006
Da Nang	June 2006	July 2006		

Table 4.2: RRST-I Short-Term Monitoring Programme

4.4.2 RRST-I FWD Surveys

Falling Weight Deflectometer (FWD) surveys were carried out on the completed pavements of the trial roads in the 4 RRST-I provinces in July 2006. These surveys have provided valuable baseline data on the layer strength characteristics of the various trial pavements and will act as a reference for future surveys and investigations on the performance of the trial sections. The details of the surveys are contained in Appendix F and are summarized in Tables 4.7.

TRIAL SECTION	LAYER 1	LAYER 2	Effective Resilient Modulus Ep (Mpa)
Hue Province			
H2	Bamboo Reinforced Concrete on sand bedding layer	Natural Gravel Sub - base	437
H4	Penetration macadam	Water bound macadam	205
H6	Sand emulsion seal on concrete bricks on sand bedding layer	Natural Gravel Sub - base	125
H7	Sand emulsion seal on concrete bricks on sand bedding layer	Dry bound macadam	163
H9	Sand emulsion seal on stone chip emulsion seal on 7cm armouring layer	Natural Gravel Sub - base	126
H11	20cm Mortared dressed stone on sand bedding layer	Natural Gravel Sub - base	334
H3	Natural Gravel base	Natural Gravel Sub - base	218
Da Nang Province			
DaN2	Steel Reinforced Concrete on sand bedding layer	Sand Sub - base	356
DaN3	Sand emulsion seal on stone chip emulsion seal on cememt stabilised local	Cement stabilised local soil Sub-base	340
DaN4	Sand emulsion seal on stone chip emulsion seal on cememt stabilised local	Emulsion stabilised local soil Sub-base	230
DaN5	Penetration macadam	Water bound macadam	221
Tien Giang Province			
T2	Bamboo Reinforced Concrete on sand bedding layer	Lime stabilised local soil Sub-base	312
T3	Steel Reinforced Concrete on sand bedding layer	Lime stabilised local soil Sub-base	311
T5	Sand emulsion seal on stone chip emulsion seal on Dry bound macadam	Sand Sub-base	160
T6	Sand emulsion seal on stone chip emulsion seal on lime stabilised local soil	Lime stabilised local soil Sub-base	57
T7	Penetration macadam	Water bound macadam	157
T9	Bamboo Reinforced Concrete on sand bedding layer	Sand Sub-base	322
Dong Thap Province			
D2	Bamboo Reinforced Concrete on sand bedding layer	Lime stabilised local soil Sub-base	359
D3	Steel Reinforced Concrete on sand bedding layer	Lime stabilised local soil Sub-base	455
D5	Sand emulsion seal on stone chip emulsion seal on Dry bound macadam	Fines stone Sub-base	137
D6	Sand emulsion seal on stone chip emulsion seal on lime stabilised local soil	Lime stabilised local soil Sub-base	74
D7	Penetration macadam	Water bound macadam	109
D10	Mortared fired clay bricks on sand bedding layer	Cement stabilised local soil Sub-base	258
D11	Sand emulsion seal on fired clay bricks on sand bedding layer	Cement stabilised local soil Sub-base	142
D12	Sand emulsion seal on fired clay bricks on sand bedding layer	Dry bound macadam Sub-base	228

Table 4.7: Summary of FWD Survey Data

4.5 RRST-I Axle Load Surveys

Axle load surveys were carried out for three of the RRST-I trial road locations to assess the types of loading and magnitude that could be experienced in service. The surveys were carried out using a set of portable weigh bridges temporarily imported from Cambodia.

The results of the axle load surveys are contained in Appendix C.

There are particular factors that prevent a "free loading" situation on some of the trial roads, and axle loading characteristics vary for the following reasons:-

i) Dong Thap – the absence of a motor vehicle capacity bridge at the start of one section of the trial road restricts the current traffic to two wheeled vehicles on part of the road.
ii) Da Nang – the function of the road is farm area access and at the time of the proposed survey, no motorised traffic was using the route.
iii) Tien Giang – Currently the road is not a through route, so that by agreement with the provincial authorities, surveys were carried out on a nearby provincial road to gain valuable data on traffic axle loading characteristics.

Some valuable knowledge has been gained from the axle load surveys as follows:-

- There are substantial differences in the traffic types and loadings experienced between the various RRST-I trial roads (see also the traffic survey data).
- There are regional differences in the types of vehicles in use. Some locally made vehicles of various types are available.
- Loadings of two wheeled and locally made vehicles are generally not of concern with regard to pavement design and performance of rural roads.
- Physical width limitations and active control of access can prevent overloading of some rural roads.
- Heavy two and three axle trucks (particularly for primary construction materials haulage) have the physical capacity to be loaded well above the legal load limits of all road categories in Vietnam. This has important consequences for particular trial roads, especially some of the RRST-II routes, and for the future design of rural roads in general. The overloading experiences of the trial roads in Cambodia are particularly relevant (SEACAP 2 and 8).
- In view of the very limited data available on high/over- loading of commercial vehicles in Vietnam, and its potential for causing very extensive and expensive damage to existing road and bridge infrastructure, the incidence, extent and effects of this phenomenon should be further investigated.

Due to the very limited data available on high/over- loading of commercial vehicles in Vietnam, and its potential for causing very extensive and expensive damage to existing road and bridge infrastructure, it is recommended that the incidence, extent and effects of this phenomenon should be further investigated.

	Surveyed Axle Load - heaviest axle								
PROVINCE	Hue			Dong Thap			Tien Giang #		
VEHICLE CATEGORY	Number of vehicles surveyed	Class average (tonne)	Highest Recorded (tonne)	Number of vehicles surveyed	Class average (tonne)	Highest Recorded (tonne)	Number of vehicles surveyed	Class average (tonne)	Highest Recorded (tonne)
Motorbike with trailer	–	–	–	7	1.00	1.24	–	–	–
Bagac mày	–	–	–	1	0.68	0.68	18	1.28	1.88
Small Cong Nong/Truck	17	1.19	1.80	–	–	–	31	2.03	3.26
Small Bus	4	1.40	1.74	–	–	–	11	1.35	1.80
Medium Bus	1	3.50	3.50	–	–	–	2	3.38	3.56
Large Bus	–	–	–	–	–	–	2	6.36	9.16*
2 axle Truck	18	4.21	10.3*	–	–	–	40	5.15	12.4*
3 axle Truck	–	–	–	–	–	–	7	9.95*	18.4*

Key: * Legality and pavement damage issues.
\# Survey on Provincial road near trial road.
No vehicles of these categories were using the Da Nang trial road at the time of survey.

Table 4.8: RRST-I Axle Load Survey - October 2006

Figure 4.3: Motorcycle-trailer

Figure 4.4: Bagac mày

4.6 Socio-Economic Impact Surveys

Socio-economic surveys were undertaken on the RRST-I provinces in order to ascertain local stakeholder views on the social and economic issues relating to the various surfacing and pavement options. These surveys and their subsequent interpretative reporting were undertaken by the Transport Development Strategy Institute (TDSI) under a sub-consultancy agreement with Intech-TRL. The report is included as Appendix F in the RRST-I Trials Construction Report.

Local stakeholder opinions were also gathered following the RRST-II construction phase by ITST, using standard forms similar to those developed by TDSI. No interpretation has been undertaken on this work, which is factually recorded in the ITST provincial data reports. Intech-TRL has, however, undertaken some tabulated collation of this work, which is presented in Appendix O to this report.

4.7 Trials Data Management

Information from the trials construction monitoring together with as built and ongoing condition surveys has been collated into the RRSR database; which is a combination of ACCESS relational database files and related MS-EXCEL files. Table 4.9 presents a summary of the relevant key files in the database.

As noted above additional detailed formation on construction procedures and materials from the 47 separate RRST-II contracts is currently contained in hard copy format within separate Provincial reports.

4.8 Data Collection - Long Term Monitoring

It will be important to plan and establish the long term monitoring of the RRST-I and RRST-II trial sections and provide the resources necessary to carry out these key activities in a timely manner. The guidelines for this work are currently being developed. This important issue is discussed further in Chapter 10.

Data Set	File Type	File Name and Location within Folder “RRSR-Database”	Description
SEACAP 4: rural road gravel field assessments	ACCESS	SC4/RRGAP-2005.mdb	RRGAP related tables on location and condition of selected road sections
SEACAP 4: rural road gravel laboratory results	EXCEL	SC4/Lab_data/Ca Mau Lab.xls etc	Series of xls files each containing laboratory grading and plasticity data, listed by province
SEACAP 1, RRST summary data	ACCESS	SC1/SCAP1_Trials.mdb	Related tables containing data on location and design and cost of each option, including details of monitoring progress.
RRST-I. Construction data.	EXCEL	SC1/Construct	Series of EXCEL files containing DCP results undertaken during construction
RRST-I. Monitoring data.	EXCEL UKDCP	SC1/Monitoring/RRST-I/1.Hue….etc	Series of provincial folders containing EXCEL and UKDCP files with data on RRST-1 monitoring information.
RRST-II Monitoring Data	EXCEL	SC1/Monitoring/RRST/1.Tuyen Quang etc	Series of provincial folders containing EXCEL files with data on RRST-II monitoring information. Also

Table 4.9: Summary of RRSR Computer Database Files

5 TRIAL CONSTRUCTION ISSUES

There are a number of Rural Road Construction issues that should be addressed to improve the performance of the sector and improve value-for-money for the considerable volumes of public funds invested. These include aspects of training and guidance for contractors and supervisors, contract documentation, contractor selection procedures, involvement and training of local consultants, improved supervision arrangements, promotion of appropriate plant hire, promotion of the optimal use of local materials, improved payment arrangements, improved quality assurance and testing regimes. A number of the issues raised are of particular importance to the forthcoming RT3 project and other major programmes, as well as the day to day management of the rural road networks by the provincial administrations.

Issues relating to the selection and design of surface options are discussed in Chapters 6, 7 and 8.

5.1 Rural Road Contracting Regime

The following issues have been identified with regard to contractor capability, attitude and selection:

1. Clear training and guidance will be required for contractors using some of the new trialled options in wider general application of the techniques.
2. A straightforward contractor assessment procedure was employed in both the RRST-I and RRST-II projects; this approach is recommended for other large construction programmes. In particular there is need to ensure that the contractors have read and understood the technical specifications.
3. Small contractors are generally not used to following technical specifications closely and may require a combination of easy-to-follow guidelines and initial close supervision.
4. There was an evident wide range of contractor quality, from very good to incompetent. This reinforces our recommendation for a more effective review of contractor capability before contracts are awarded.
5. There appeared to be a general initial resistance to new procedures, with many contractors, especially in RRST-II, tending to use locally established practice as default procedures without reference to contract specifications.
6. Despite the initial resistance noted above, most contractors using new procedures, such as Dry Bound Macadam, Emulsion Sealing and Cement Stabilisation, agreed on the usefulness of these procedures once they had gained experience with these techniques.
7. Provincial level local consultants do not yet generally have design and supervision experience outside current standard designs and procedures. PDoTs have made recommendations that local consultants should be more involved in provincial level projects and that there is a need for them to gain experience through taking on more responsibility in using and enforcing specifications.
8. Small contractors generally have limited plant resources; for example, they rely heavily on the standard 8-10 tonne, 3 wheel, static rollers for compaction, which have limitations for certain types of materials.
9. There is an apparent reluctance to consider plant-hire options within the existing small contractor environment.

10. Contractor performance and progress is frequently inhibited by severe cash-flow difficulties, which are not helped by unrealistic delays in processing agreed payment certificates. This may partly explain the reluctance to consider the plant-hire option.
11. Some new option procedures are likely to be best controlled by a tightly overseen method specification approach. This is particularly true of operations where control testing may involve significant delays, e.g. concrete surfaces and lime or cement stabilisation.
12. Simplified guidelines or handbooks on the important features and precautions/requirements for each surface/paving layer type would assist both technical and non-technical personnel involved with the planning, approval, design, construction supervision, and maintenance of rural roads.
13. Appropriate materials testing is a very cost-effective way to assure value-for-money for the considerable investments made in road surfacing and paving. There is a noticeable problem in ensuring contractors undertake the required sampling and testing of as-used materials. Intech-TRL had strongly recommended the use of a provisional lump sum in the contract for payment of laboratory work to encourage contractors to undertake this testing. This should be considered as a standard practice.
14. Some construction procedures were significantly affected by wet weather; particularly cement stabilisation and emulsion sealing.
15. From the foregoing it is clear that a national programme of training of contractors AND supervisory staff and local consultants is desirable for the mainstreaming of the alternative surfacing options. It will also be necessary to ensure that international consultants appointed to carry out project planning and design are also made aware of the full findings of the RRSR programme.

5.2 Construction Supervision

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

1. The role of site supervisors in controlling the contractors' procedures and material usage is not yet generally accepted in the rural road sector in Vietnam. Current practice appears to be concerned largely with observation and reporting of progress rather than technical control.
2. As with the contractors, there was a wide range in supervision performance. In general there was a lack of experience in the application of specifications and associated testing requirements.
3. There appears to be a significant lack of awareness of the importance of Quality Assessment in the rural road sector and a consequent lack of a quality control ethic.
4. There was in most cases an initial lack of appreciation of the importance of as-used materials testing, in situ testing and daily records.
5. The above issues highlight the need for appropriate **training** and **guidelines** on construction supervision.
6. It is apparent that supervisors had a general problem in being able to exert influence on the contractors to abide by specifications. This to some extent was a result of the complicated contractual arrangements for these particular projects. However it is probable that the unwillingness of contractors to heed

advice from supervisors is a significant overall problem in the rural road sector in Vietnam.

7. There is a need to introduce independent check-testing of materials testing as some provincial laboratories exhibited weak data management control.

5.3 Quality Control

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

Quality Control should not be an onerous administrative burden within the rural road sector, but rather it should comprise a few simple straightforward procedures as set out in Table 5.1.

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

Table 5.1 Essential Quality Control Procedures

5.4 Construction Materials

For overall cost-effectiveness and minimization of environmental impact, road designs and specifications must take into account locally available materials. Hence the use of flexible specifications that acknowledge local material variations should be encouraged at this level. It is not realistic to attempt to force contractors to meet inappropriate or unobtainable standards.

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

1. Adapting the specification and road design to suit local materials, or
2. Adapting or modifying the materials to suit a realistic specification.

Table 5.2 summarises some of the main material issues that arose during the RRST-I and RRST-II programmes.

Material	Issue	Comment
Sand (sub-base)	Available local sand of uniform grading did not allow effective compaction.	Substitution of either a stabilisation procedure or crushed fine aggregate. The latter was selected as more cost-effective.
Sand (stabilisation)	Similarly graded sands may actually require differing amounts of cement to be added. Eg Da Nang and Hung Yen.	Testing of the sand to be actually used is essential. Cross-check on site mixed strengths with laboratory mixed strengths.
Sand (emulsion seal)	Available sand in Tien Giang: sand initially contained too much coarse material.	On site screening can be used to attain correct grading.
Natural gravel	Very variable material within identified sources for same road length.	Recommended stricter selection at source before transporting to site and regular checking of laid material.
Fired clay bricks	Initially specified brick sizes not normally produced locally.	Recommended use of local brick sizes provided strength requirements are adhered to.
Fine aggregate (chippings)	Frequently poor initial grading and shape from quarries.	On site screening can be used to attain correct grading. Adjustment of aggregate crusher settings can improve shape.
Cobbles, stone setts and dressed stone	Fine surface smoothness of stone blocks, setts or cobbles can only be achieved by mechanical grinding or cutting.	Use of natural split surfaces preferred on grounds of the high cost of mechanically produced options.
Local clay soil (stabilisation)	Local variability of clay content and inclusion of organics led to cracking in stabilised material. (Tien Giang, Dong Thap).	Recommended strict control on selection of soil.
Crushed stone for dry or water bound macadam	Consistent difficulty during RRST-II in ensuring contractors supplying the specified aggregate sizes.	Quality control on as-delivered materials required. Also need to ensure an appropriate link between what local quarries can produce and the contract specifications.
Bitumen emulsion	Some variation in bitumen contents between suppliers.	Specifications and spray rates should be in terms of residual bitumen content.
Concrete coarse aggregate	Local use of un-crushed rounded natural gravel materials not prohibited by current standards.	Specifications should be amended to achieve more durable concrete.

Table 5.2 RRST Materials Issues

5.5 Technical Specifications

The draft technical specifications have been reviewed by Intech-TRL in the light of the experiences gained during the trials construction as well as taking into account the valuable comments received from the contractors and PDoT/PPMUs. The revised specifications, as listed in Table 5.3, are included in this report as Appendix L.

Reference	Specification
RRST 1-01	Bituminous Emulsion – Surface Dressing Chip Seal
RRST 1-02	Bituminous Emulsion – Sand Seal
RRST 2-01	Gravel Sub-Base/Base
RRST 2-02	Lime Stabilised Sub-Base/Base
RRST 2-03	Cement Stabilised Sub-Base/Base
RRST 2-04	Emulsion Stabilised Sub-Base/Base
RRST 2-05	Armoured Gravel Roadbase
RRST 2-06	Sand Sub-Base
RRST 2-07	Quarry-Run Sub-Base
RRST 2-08	Graded Crushed Stone Sub-Base/Base
RRST 2-09	Sand Bedding Layer
RRST 2-10	Dry Bound Macadam Sub-Base/Base
RRST 3-01	Fired Clay Brick Pavement – Unmortared Joints
RRST 3-02	Fired Clay Brick Pavement – Mortared Joints
RRST 3-03	Cement Brick Pavement – Mortared Joints
RRST 3-04	Mortared Dressed Stone
RRST 3-05	Cobble Stone Paved Surface
RRST 4-01	Bamboo Reinforced Concrete
RRST 4-02	Steel Reinforced Concrete
RRST 4-03	Non-Reinforced Concrete
RRST 5-01	Gravel Shoulders
RRST 5-02	Lime Stabilised Shoulders
RRST 5-03	Cement Stabilised Shoulders
RRST 5-04	Quarry-Run Shoulders
RRST 5-05	Sealed Macadam Shoulders

Table 5.3 RRST Specifications

Design Issues

Issues relating to the selection and design of surface options are discussed in Chapters 6, 7 and 8.

There are a number of Rural Road Contracting Regime issues that should be addressed to improve the performance of the sector and improve value-for-money for the considerable volumes of public funds invested. These include aspects of training and guidance for contractors and supervisors, contract documentation, contractor selection procedures, involvement and training of local consultants, improved supervision arrangements, promotion of appropriate plant hire, promotion of the optimal use of local materials, improved payment arrangements, improved quality assurance and testing regimes.

6 WHOLE-LIFE COSTING

6.1 Introduction

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

a) **Whole Life Costs** for the Road Asset
b) **Whole Life** Transport **Costs**

Whole Life Road Asset Costs assessment would aim to minimize the costs of **Construction** and **Maintenance** of a particular road and pavement over a selected assessment period. This assessment would be of interest to an asset manager such as a PDoT, particularly in a severely constrained resource environment.

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

Any assessment will only be as good as the data and knowledge used in the relationships incorporated in the evaluation. It is evident that for Vietnam rural road evaluation, the confidence in the cost data is very good for construction components for the various regions of the country. This has been further enhanced by the construction knowledge assembled on alternative rural road pavements under the RRST initiatives. However, the knowledge and confidence are poor for both maintenance cost components of various road surface options and user VOCs. The latter aspect is particularly uncertain regarding the effects of different road conditions in Vietnam. The issue of VOCs is discussed in Section 6.5.

A Cost Model has been developed under the RRST SEACAP 1 project, to facilitate the assessment of Whole Life Costs for the rural road asset (Section 6.4).

Construction costs and norms, and maintenance issues are discussed in the following sections.

6.2 Construction Norms and Costs

Construction costs and Norms were developed for the RRST-I trials, extended for the RRST-II trials and have been reviewed and refined for proposed future use on rural road works from the experiences on the trials construction and feedback from the contractors and supervisors. The refined Cost Norms are contained in Appendix M.

It is suggested that discussions should be held with sector stakeholders regarding the use and adoption of the new Cost Norms for the range of rural road surface options developed under the RRSR programmes.

6.3 Maintenance Issues

6.3.1 Maintenance of the Trial Roads

Under the RT2 agreements reached for both the RRST-I and RRST-II trials, the responsibility for maintenance of the training, trial and control sections of roads has been assigned to the provincial/local authorities.

The unsealed control sections are being monitored for deterioration and after sufficient data has been gathered these will be rehabilitated with more durable surfacing by these authorities.

Records of road condition and maintenance interventions for the other trial sections need to be made on a systematic basis and analysed so that guidance on both maintenance of each surface type and feedback into the design process can be achieved.

These arrangements have still to be agreed.

Further monitoring of the performance and maintenance needs of the RRST-I and RRST-II trial roads is **essential** as an important follow up RRSR activity. In this way new and revised Maintenance Norms will be able to be developed for the range of surface options, as well as road deterioration relationships for use in economic models and refinement of the design recommendations.

6.3.2 General Maintenance Issues

All rural roads will require maintenance after construction, and throughout their serviceable life. The amount and frequency of maintenance requirements will depend on a range of factors, including type of road surface. Maintenance of rural roads is capable of being planned and should consist of two principal components (excluding emergency work incidents):-

Routine Maintenance (generally minor but frequent tasks[5]), and
Periodic Maintenance (infrequent but usually major and expensive tasks[6])

However the RT2 and RRSR experiences have shown that the capacity and delivery of rural road maintenance throughout Vietnam is severely deficient. This is due to a complex range of factors, however these can be characterised as:-

- Insufficient funding,
- Inadequate institutional arrangements and responsibilities,
- Insufficient awareness of the importance of maintenance (and economic and social consequences of the lack of maintenance),
- Insufficient capacity to carry out, report on and monitor maintenance activities,
- Limited and obsolete maintenance Cost Norms,
- Insufficient technical and management guidance: A commune maintenance handbook exists, however no suitable national or provincial technical or management guidelines on maintenance of the range of rural road surface options and other road features exist.

These factors result in a totally inadequate provision of routine maintenance on nearly all rural roads, and in addition an almost universal failure to make adequate

[5] Principally repair of minor surfacing/pavement defects, drainage and vegetation control.
[6] For example re-gravelling or resealing.

provisions and arrangements for the (expensive, extensive and vital) periodic maintenance re-gravelling required of the considerable network of gravel roads.

6.3.3 Routine Maintenance Grading

The MoT Routine Maintenance Cost Norms do not include an item for the activity of camber reshaping or grading. This is an essential component of earth and gravel road maintenance (recognized by PIARC[7] and many national road agencies in other countries). Routine maintenance grading is particularly important in tropical environments such as Vietnam. One of the problems of gravel roads in Vietnam is that the need for grading is commonly not recognized at the design stage, or in maintenance funding and implementation arrangements.

Surface grading is required to be carried out on earth and gravel roads to restore the camber and keep it within the desirable range of 3 – 7%. It is supposed to be a routine maintenance activity to supplement the other largely labour based routine maintenance activities. Unfortunately it is usually not carried out on the existing rural road network in Vietnam, leading to widespread premature deterioration of the roads.

A further common practice also prevents effective camber maintenance of gravel roads. This is the practice of providing earth shoulders on gravel roads. This arrangement traps surface water on the running surface thus accelerating deterioration, and the practice also prevents maintenance grading, because such an operation would contaminate the road surface with the shoulder soil.

Figure 6.1: Soil shoulders preventing rainfall runoff and effective maintenance grading.

It is suggested that further major initiatives are required to tackle the awareness, funding, institutional, technical, management and operational deficiencies of the current rural road maintenance system.

6.3.4 Periodic Maintenance Regravelling

The RRSR research programme has been driven by the widespread concern regarding the problems of maintaining gravel surfaces in the Vietnam environment. Gravel roads are popular with road authorities and agencies in many countries because of their low initial cost. However in the Vietnamese circumstances two major issues make gravel surfacing problematic, as demonstrated and documented by the SEACAP 4 investigations:-

- Very high annual gravel loss due to local conditions,

[7] PIARC (World Road Association) International Road Maintenance Handbook.

- Inability to replace lost gravel in a timely manner due to lack of maintenance resources and capacity as discussed in 6.3.2.

This situation leads to an inevitable cycle of construction and reconstruction which is uneconomic and a severe constraint to rural development and poverty alleviation. In practical terms for a road authority, a typical rural road with gravel loss of 50mm per year would have to be completely regravelled approximately **4 times** in a 15 year period.

Even in areas of easy gravel availability this translates into a gravel layer construction cost of about US$3,000 per km, and a regravelling cost over 15 years of about US$12,000 per km. It would anyway not be feasible for Vietnam to move to the situation in the foreseeable future of full maintenance funding being available and deployed in a timely manner on a network basis. The above assessment excludes the considerable additional routine maintenance liability which is currently almost universally unmet.

Gravel in many locations is scarce and haul distances are often excessive. The provision and maintenance costs of a gravel surface in such locations would be more than double the above example.

These levels of funds and resources are simply not available in the community or government system.

In addition to these concerns there are the issues of generally higher vehicle operating costs on a gravel surface compared to more durable surfaces. There are also the issues of depletion of limited natural resources, environmental concerns of dust pollution and damage to haul routes in repeatedly hauling gravel materials for the maintenance operations.

In an attempt to quantify these factors and develop a practical decision making tool for engineers and decision makers, the RRST Cost Model has been developed.

6.4 The RRST Cost Model

A decision support cost model has been designed based on MS-EXCEL spreadsheets in order to provide rural road authorities and design consultants with a supportive tool for their road surface and pavement selection process. The Cost Model is a required output of the RRST-1 contract. The model introduces a menu of appropriate rural road pavements with the whole life cost details (construction and maintenance costs for road managers)[8] of each option, suggesting the most appropriate options for each defined local road environment. The initial menu is based on the research findings of the RRGAP, and RRST-1 and RRST-II trials. It is expected that further options will be added in later model versions based on other investigations.

The cost calculation method within the model is pursuant to the current decrees and documents issued by the Government. Thus the model is also very helpful in preparing cost estimates.

The essential inputs for the model

Natural factors – which are to an extent uncontrollable:

[8] The cost model has been designed with the intention that a later edition will be able to accommodate an optional Vehicle Operating Cost sub-model.

- Sub-grade geological and hydrological conditions:
  - Types of soil,
  - Strength
  - Flood regime
- Road alignment longitudinal gradient,
- Terrain (mountainous, midland, plain etc.), related to region,
- Annual rainfall (impact to deterioration rates of some types of pavement), related to region,
- Material sources and haulage distances to the site.

Man-made factors - controllable:

- Traffic volume
- Axle load

Expected outputs

- ❑ Construction cost of the selected option **per km** (with defined surface width),
- ❑ Maintenance cost per km (15 year period) in terms of present cost,
- ❑ Maintenance cost per km (15 year period) in terms of NPV.

The Cost Model incorporates the logic diagram developed under the SEACAP 4 investigations on gravel road performance in Vietnam. The model suggests exclusion of the use of gravel under unsustainable circumstances, for example due to steep gradients or high rainfall.

Full details of the Cost Model are contained in Appendix B.

As discussed in the previous section, the knowledge of the maintenance requirements of the various rural road surface options is limited. Some preliminary monitoring has been carried out on the RRST-I trial roads since their completion. Further monitoring of the performance and maintenance needs of the RRST-I and RRST-II trial roads has been recommended as an important follow up RRSR activity. In this way new and revised Maintenance Norms will be able to be developed for the range of surface options.

Pending the results of these further investigations it is possible to demonstrate the use of the RRST Cost Model using the construction data derived from the trials, and some tentative road maintenance assumptions from experience in Vietnam and elsewhere.

The Cost Model is currently complete to a functional state and can be used to analyse a range of options based on the RRST trials experiences. Further work is required to fully develop the model to encompass all surfacing options for all possible environments encountered in Vietnam. The maintenance relationships are currently tentative only and will need to be refined in the light of the planned RRST long term monitoring experiences. The development of a VOC cost sub-model is also recommended to achieve a total transport whole life cost model capability, as discussed in Section 6.5.

Demonstration of the model

A number of typical paving options have been analysed using the latest version of the Cost Model to demonstrate it usefulness as follows:-

- Gravel (long & short haul), multiple bituminous seals and steel reinforced concrete paving,
- Delta and Mountainous terrain,
- With and without maintenance (for gravel only),

SCENARIO ANALYSIS OPTION SURFACE/PAVING		TERRAIN	MAINTENANCE PROVIDED	MATERIALS HAUL DISTANCE (km)	ROAD GRADIENT	RAINFALL (mm/year)	SUB- GRADE CBR	TRAFFIC	AXLE LOADING	COMMENTS
1	Gravel	Delta	Yes	5km	<4%	1,500	<5%	B1	2.5t	Good gravel application
2	Gravel	Delta	No	5km	<4%	1,500	<5%	B1	2.5t	Sort haul, no maintenance
3	Gravel	Delta	Yes	100km	<4%	1,500	<5%	B1	2.5t	Long haul with maintenance
4	Gravel	Delta	No	100km	<4%	1,500	<5%	B1	2.5t	Long haul, no maintenance
5	Gravel	Mountain	Yes	5km	5%	2,500	>15%	B1	2.5t	Adverse conditions with maintenance
6	Gravel	Mountain	No	5km	5%	2,500	>15%	B1	2.5t	Adverse conditions, no maintenance
7	DBST on Waterbound Macadam	Delta	Yes	5km	<4%	1,500	<5%	B1	2.5t	Low cost durable surfacing
8	DBST on Waterbound Macadam	Delta	Yes	100km	<4%	1,500	<5%	B1	2.5t	Low cost durable surfacing
9	DBST on Waterbound Macadam	Mountain	Yes	5km	5%	2,500	<5%	B1	2.5t	Low cost durable surfacing
10	Steel Re-Concrete on Cement Stabilised Base	Delta	Yes	5km	<4%	1,500	<5%	B1	2.5t	High quality, low maintenance surfacing
11	Steel Re-Concrete on Cement Stabilised Base	Delta	Yes	100km	<4%	1,500	<5%	B1	2.5t	High quality, low maintenance surfacing

Note: No-Maintenance options for paved roads to be re-assessed after Module 6 and further proposed investigations

Table 6.1: Whole Life Asset Cost Sample Analysis Parameters

Table 6.1 shows the analysis input parameters. The analysis is provided in Appendix I and yields the results discussed in the text of Section 6.6.

6.5 Vehicle Operating Cost Issues

The Whole Life Costs of rural roads in terms of national and community interests should include an assessment of vehicle whole life costs savings for road interventions or maintenance strategies, i.e. with the aim to minimize the sum of:-

- Road Asset Construction costs
- Road Asset Maintenance costs
- Vehicle (User) Operating Costs (VOC)

over the selected assessment period.

Various economic models have been developed to help decision makers assess the balance of road construction and maintenance investments and road user costs, including HDM4 and the World Bank's RED model.

With regard to future application of the RRSR knowledge using these models, there are a number of constraints to be considered:-

- HDM4 is primarily motor vehicle and roughness driven and is more appropriate for assessment of the higher category routes,
- VOC relationships for HDM4 and RED have been developed primarily from experience in Africa and South America, not South East Asia, where there are climatic, traffic, environmental, operational and cultural differences.
- "The models are limited in their ability to deal with the problems of very basic access; Many of the key road deterioration and VOC cost relationships tend to break down for rough earth roads and tracks and very poorly maintained roads"[9].
- The models do not have VOC relationships for motorcycles and bicycles, which account for most of the traffic on the rural roads (Refer to Table 6.2 following).
- There is a substantial component of pedestrian traffic on some Vietnam rural roads.
- The "commercial" vehicles commonly used on rural roads are mainly locally-made, light and slow moving trucks, for which VOC-road condition relationships are not researched.
- Robust VOC-road condition knowledge is not available for the Vietnam conditions[10].
- VOC-road condition relationships can vary by substantial factors[11]. It is likely that the fundamental factors of the local Vietnamese environment regarding **vehicle life and depreciation, repair capability and culture, spares availability and refurbishment, value of time** and **load carrying and personal/commercial decision making** would vary substantially between the previously researched regions and Vietnam, thereby influencing VOC relationships in a different way.
- The issue of seasonal passability is particularly relevant in the instances of roads that become flooded for short or long periods (particularly Mekong Delta), and

9 Source: TRL documentation.
10 Analysis of Vehicle Operating Costs on Rural Roads, Rural Transport Strategy Study, Vietnam, I T Transport, 1999.
11 Research by TRL found that unit road freight transport costs varied by factors of 4 to 6 between some African countries and Pakistan. Rizet, C and J L Hine, 1993.

gravel roads on weak subgrades that can become impassable to motorized traffic when severely deteriorated.

Some of these issues are illustrated in the following images.

Figure 6.2: Images of the characteristics of the Vietnam modes of transport and rural transport sector.

Total Daily Traffic (movements)	**Pedestrians** as Percentage of total movements	**Motorcycles** as Percentage of total vehicular traffic	**Bicycles** as Percentage of total vehicular traffic	**Other vehicles** as Percentage of total vehicular traffic
528 – 7,163	0 – 55%	10 – 92%	2 – 82%	0 – 39%

For traffic survey details refer to Table 8.5, the Appendix B and Progress Reports.

Table 6.2: Range of Traffic characteristics of the RRST-I & RRST-II trial roads

It is suggested that some further research is required into Vietnam VOCs before the RRSR experiences can be extended to full and robust Whole Life Costing using the established international economic models.

6.6 Results of example demonstration of the RRST Cost Model

In view of the absence of robust VOC relationships for Vietnam (as discussed in 6.5), for the purposes of this demonstration, the VOC tentative relationships developed under the RTSS and RT2 have been used to supplement the RRST modeling of construction and maintenance of various surface options to demonstrate Whole Life Costing application.

Even in its early state of development; with limited maintenance knowledge inputs and using the supplementary and tentative RT2 VOC relationships, the RRST Cost Model can be used to demonstrate a number of important issues and characteristics of the rural road sector in Vietnam.

The results of the demonstration analysis are contained in Appendix I and are summarized in Figures 6.1 and 6.2 using example traffic flows of 500 and 1,000 motorcycles per day.

The analysis usefully demonstrates the following important issues.

Road Maintenance is essential and justifiable
The RRGAP-developed knowledge on gravel road performance in Vietnam has allowed the importance of maintenance to be demonstrated. The three scenarios analysing the "No Maintenance" options (Scenarios 2, 4 and 6), clearly demonstrate the justification of road maintenance (corresponding to respective Scenarios 1, 3 and 5 – all with maintenance). Although it may be possible to defend "no maintenance" in some circumstances through the quirks of the discounting process (compare Scenarios 1 and 2) on a road authority view of <u>construction and maintenance costs only</u>[12], the inclusion of VOCs shows an overwhelmingly strong case for providing maintenance. Scenario 4 compared to 3, and 6 compared to 5, more clearly demonstrate the justification of maintenance on the assessment of construction and maintenance costs alone, with the huge savings in VOCs generated by maintenance being an added bonus. The planned RRST long term monitoring and proposed additional VOC relationship investigations would enable such analysis to be extended to all surfaces and environments of the RRST constructed trial roads.

Materials Haul Distance is an important influential factor
Materials haul distance adds substantially to both construction and maintenance costs. Scenarios 3 and 4 compared to 1 and 2 demonstrate this. Such an analysis can show the benefits of local resource use. The analysis does not include the damage inflicted on haul routes by usually heavily loaded materials haulage trucks (see also Section 4.5). This is a further issue that warrants investigation in the limited-resource and challenging environment of Vietnam.

The need to limit the application of gravel as a surfacing
The RRGAP investigations (SEACAP 4) developed guidelines for restricting the application of gravel as a rural road surfacing. The particularly severe gravel constraints in circumstances of long haul distance, lack of maintenance capability/funding, high rainfall and gradient can be clearly demonstrated by the model. The model can also demonstrate the implications of poor quality control; which

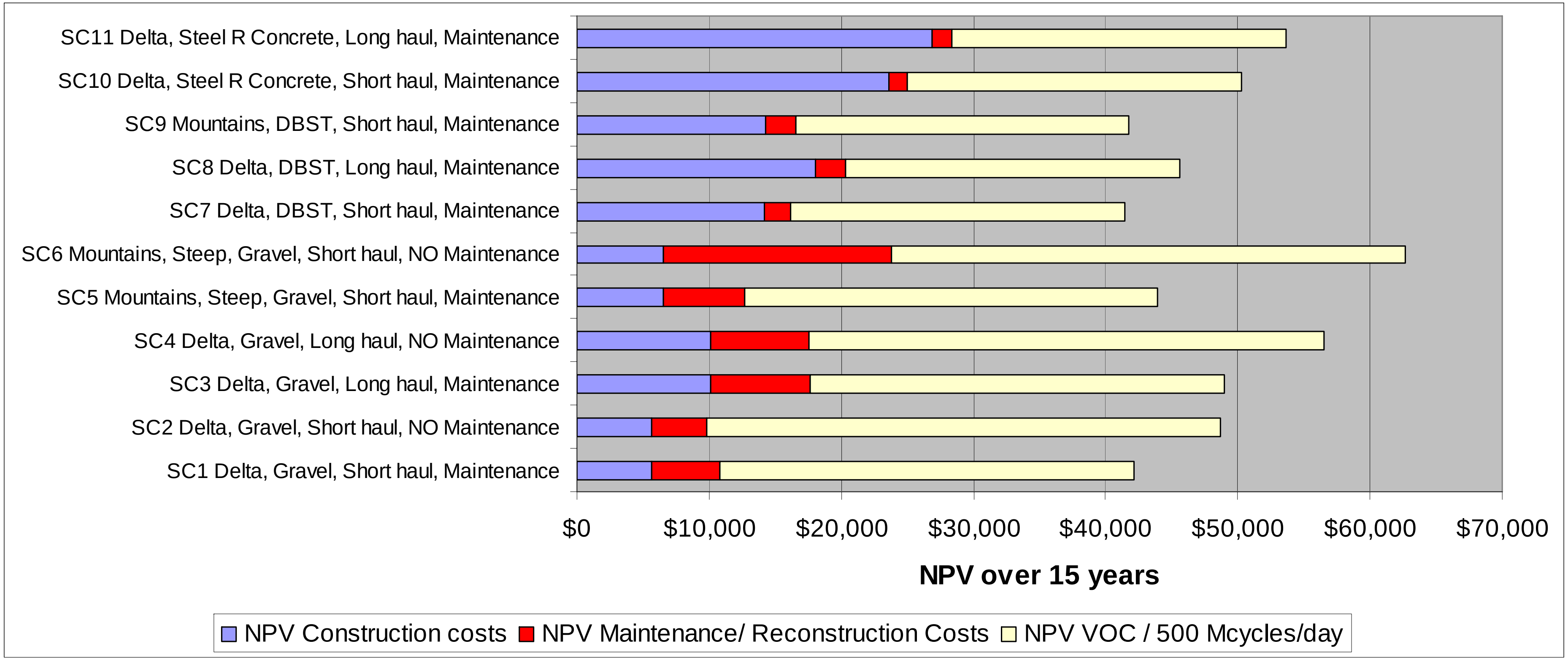
[12] The discounting process effectively reduces the value and hence importance of future maintenance interventions. However, on a current cost basis it is usually justifiable to carry out maintenance (if feasible and resourced) as the costs will invariably outweigh the reconstruction liabilities compared to a "no-maintenance" scenario. This is anyway more in accord with the assessments on the balance of road construction and maintenance costs made by road managers.

is common and more easy to obscure in gravel road works compared to other surface types.

Paving at relatively low traffic flows can be justified
Comparing Scenario 7 to 1, and 8 to 3, shows that paving of rural roads with, for example, low cost seals can be justified at relatively low traffic flows of about 500 motorcycles per day. When traffic flows increase to still modest levels (for Vietnam) of about 1,000 motorcycles per day, it is possible to justify high cost-low maintenance surfaces such as steel reinforced concrete (Scenarios 10 and 11) because of the very substantial VOC savings for scenarios of long materials haul. This is particularly relevant to the moderate rainfall conditions of the Mekong Delta, without even considering the other important factors of flood risk. This also provides the justification of the actions of a number of provinces in “sealing” the RT2 roads from local knowledge of the maintenance liabilities and service consequences for unsealed surfaces.

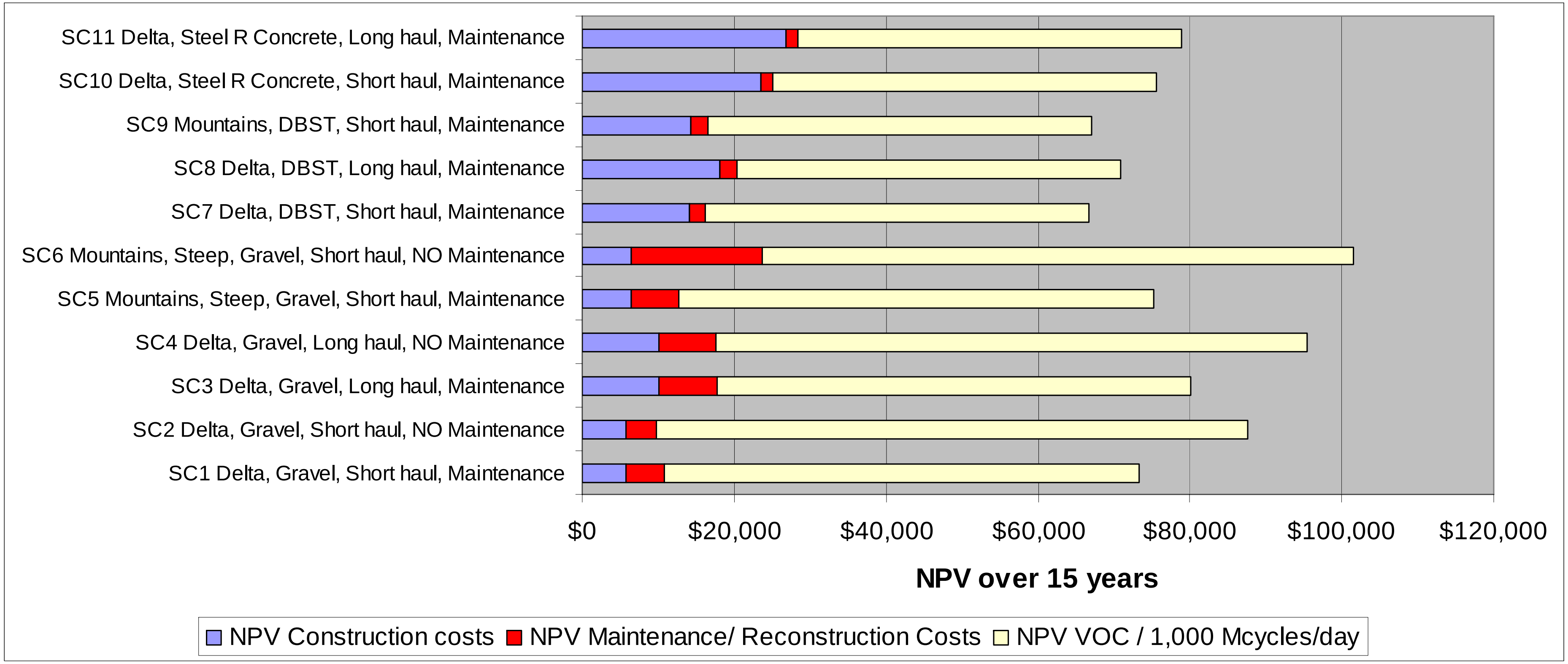
The need for strategies that limit maintenance liabilities to manageable commitments
The model demonstrates that maintenance costs can exceed construction costs in a relatively short (15 year) life assessment period in current cost terms (Scenarios 1 to 5). Scenario 6 shows that maintenance costs can far exceed construction costs in some circumstances even when the discounting of future maintenance costs by WLC analysis is considered. The use of the RRST Cost Model quantifies the likely maintenance liabilities for various surface options and environmental factors. It particularly demonstrates the high maintenance needs of gravel surfaces. In an environment of low maintenance capacity and severe lack of maintenance funding, the model can be used to develop local policies and strategies to limit the use of gravel to appropriate circumstances, and to optimize the use of alternative local resource based techniques.

VOC assessment is vital to achieve an informed and total assessment for Rural Road decision making
The analysis highlights the overall influence of VOC for rural roads compared to construction and maintenance costs even at modest traffic flows. It reinforces the importance of including VOC assessment in the procedures for surfacing selection and maintenance strategy development. As the current RTSS and RT2 VOC relationships established for Vietnam are acknowledged as tentative, further investigation and research of VOC for the range of Vietnam transport types and environments is clearly justified.



Note: NPV = Net Present Value

FIGURE 6.2 : WLC ANALYSIS FOR TRAFFIC FLOW OF 500 MOTORCYCLES PER DAY



Note: NPV = Net Present Value

FIGURE 6.3 : WLC ANALYSIS FOR TRAFFIC FLOW OF 1,000 MOTORCYCLES PER DAY

7 REVIEW OF RRST OPTIONS

7.1 General

The RRST-I and RRST-II programmes trialled a wide range of flexible, block, rigid and unsealed pavement options. Differing pavement layer options were frequently combined to produce a representative matrix of rural paving options appropriate to differing Vietnamese road environments.

The following sections review key issues relevant to the RRST options with summaries of advantages and disadvantages being presented in a series of tables. Each of the RRST options may be gauged against a range of relevant criteria, as in Table 7.1 to indicate the general suitability of likely options.

	Key Markers												
Key Trial and Control Pavement layer	Local material Use*	Labour-Based	Ease of Construction	Maintenance reduction	Sustainability	Resitance to Rainfall/Flooding	Load Spreading on Weak Sub-Grades	Small Contractor Suitability	Local Economy Advantages	Resistance to Axle Overloading	Local Women Employment	Likely Whole Life Cost Advantages**	User advantages (Low Roughness)
Emulsion Sand/Stone Chip Seals	0	1	0	2	2	2	0	1	0	0	2	2	2
Lime stabilised Base/Sub-base	1	0	2	0	1	0	X	1	0	0	X	2	0
Cement Stabilised Base/Sub-base	1	0	2	0	1	0	X	1	0	0	X	2	0
EmulsionStabilised Sub-Base	1	X	0	0	0	0	X	X	0	0	0	0	0
Sealed Dry-Bound Macadam	0	0	2	2	1	2	0	2	0	2	0	2	2
Sealed Water-Bound Macadam	0	0	2	2	2	2	0	2	0	2	X	2	2
Dressed Stone	1	1	2	1	1	1	1	1	1	1	2	2	X
Fired Clay Bricks	1	1	2	1	2	2	1	1	1	2	1	2	0
Concrete Bricks	2	1	2	1	2	2	1	1	2	2	1	2	0
Sealed Armoured Gravel	2	0	2	2	2	2	0	2	0	X	0	2	2
Steel Reinforced Concrete	0	2	0	1	1	1	1	1	0	1	0	0	1
Bamboo Reinforced Concrete	2	2	2	1	1	1	1	1	2	1	1	2	1
Non-Reinforced Concrete	2	2	2	1	1	1	2	1	2	2	0	2	1
Hot Bitumen Stone Chip seals	0	2	0	2	2	2	0	2	0	0	X	2	2
Unsealed Natural Gravel	1	0	1	X	X	X	0	1	2	0	0	X	X
Penetration Macadam	X	X	0	2	2	2	0	0	0	0	0	0	2
Unsealed Water-Bound Macadam	0	0	2	X	X	X	0	2	0	0	2	0	X

Notes : 1 Positive advantage 0 No advantage/disadvantage
2 Probable advantage X Definite disadvantage
* Assuming material locally available
** Anticipated "Best Performers".

Table 7.1: RRST Options in Relation to Key Criteria

Table 7.1 is an outline indicator only, to support preliminary option considerations. A more formal approach to pavement options selection is discussed in Chapter 8.

7.2 Stabilised Bases and Sub-Base Options

The stabilisation and consequent modification of locally available soils is frequently a reasonable option for sub-base and base layers, particularly in areas deficient in natural gravel or hard rock resources, such as the Mekong and Red River Delta regions. For the RRST programmes stabilisation options were trialled using hydrated lime, cement and bitumen emulsion.

The nature of the local material has a fundamental control on the type of stabilisation to be selected. Table 7.2 presents the general guidance on the selection of appropriate methods of treatment for natural materials based on their grading and plasticity characteristics. The usual range of suitability for applying the various types of stabilisation is defined by the percentage of material passing the 0.075mm sieve and the Plasticity Index (PI) of the soil.

Type of Stabilisation	Soil Properties					
	More than 25% passing the 0.075mm sieve			Less than 25% passing the 0.075mm sieve		
	PI < 10	10<PI<20	PI > 20	PI < 6 PP < 60	PI < 10	PI > 10
Cement	S	S	M	S	S	S
Lime	M	S	S	X	M	S
Bitumen/Emulsion	M	M	X	Yes	Yes	X

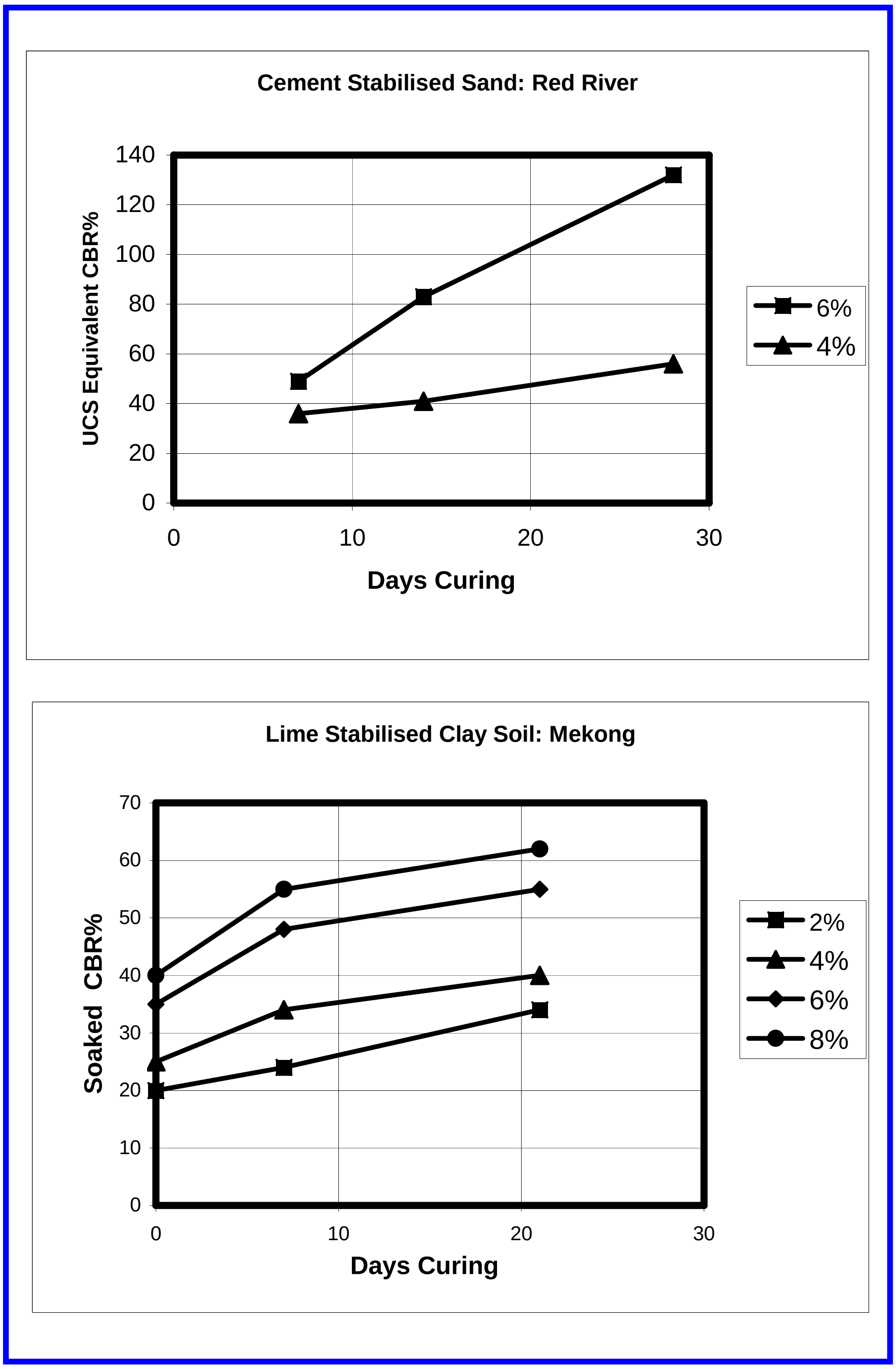
Note
S: = Normally suitable for stabilisation
M: = Marginally suitable for stabilisation
X: = Normally not suitable for stabilisation
PI:= Plasticity Index
PP= Plasticity product (PI x %passing 0.075mm)

Table 7.2: Guidance on Appropriate Stabiliser Selection

Cement can be used to stabilise most low plasticity soils and its addition results in a reduction in plasticity and swell, and an increase in strength and bearing capacity. Exceptions are those with a high organic content; which retards the hydration process, and those with a clay content outside the normal specification; where it is difficult to mix the soil/cement mixture evenly. Stabilised soil-cement pavement layers usually contain less than 5% cement. For rural roads this is usually mixed in situ with a technique that involves breaking up the soil, adding and mixing in the cement, then adding water and compacting in the usual way.

When lime is added to a plastic material, it first flocculates the clay and substantially reduces the plasticity. Addition of 2 per cent of lime can increases the plastic limit of a wet and sticky soil, changing it from one which is impossible to compact and impassable to traffic when wet, to one which is workable. Typically 3 to 5 percent lime stabiliser is necessary to gain a significant increase in the compressive and tensile strengths. The gain in strength with lime stabilisation is slower than that for cement and does not involve the "initial set" phenomenon, so that a much longer time is therefore available for mixing and compaction.

Cement or lime stabilised materials are usually approved on the basis of strength tests carried out on the materials after the stabiliser has had sufficient time to cure. The most commonly used methods are the Unconfined Compressive Strength (UCS) Test, for cement stabilised materials, and the California Bearing Ratio (CBR) Test for lime stabilised or modified materials. Figure 7.1 presents typical RRST laboratory test data.



Stabiliser % additions indicated

Figure 7.1: RRST Typical Laboratory Stabilisation Test Results

Assessment of in situ DCP monitoring results of lime stabilised soil sub-base and base layers in Tien Giang and Dong Thap indicates a deterioration in strength in the six months following construction. Strength deterioration has been reported from other lime stabilisation programmes as a consequence of carbonation. Further research is required but it is possible this is related to one or more of the following:

- Changes in water-table levels between wet and dry seasons,
- Inclusions of organic material in the local soil,
- Poor curing,
- Poor mixing.

The residual strength of the sub-base and base on the RRSR trials is nevertheless still adequate for the low volume traffic nature of these roads and within current MoT guidelines on resilient modulus. Further details relating to this phenomenon are included in Appendix D of this report.

Bitumen emulsion stabilisation of gravelly sands and silty sands may sometimes be a viable alternative to cement treatment, particularly in cases when bitumen is favourably priced with respect to cement. It may also be favoured in situations where resistance to cracking is required. Materials with high plasticity characteristics may be pre-treated with lime, but this will tend to be prohibitively expensive in the case of low volume sealed roads.

The strength of bitumen treated materials is usually assessed in terms of Marshall stability or Hubbard field stability at 60 degrees centigrade. Intech-TRL commissioned a series of Marshall Stability tests on emulsion-stabilised local sand. These were then related to indirect tensile strength (ITS) to give a value of resilient modulus (E), using the following expression:

$$E(MPa) = 2.2 \times ITS\ (kPa) + 168$$

Based on Vietnamese Standards, these modulus values indicated that the following percentages were likely to be appropriate.

Base	4% residual bitumen by weight
Sub-Base	3% residual bitumen by weight

Stabilisation was selected as an option for increasing local soil strength in 3 of the RRST-I provinces and 2 of the RRSRT-II provinces. Table 7.3 briefly summarises the experiences to date from the stabilisation options.

7.3 Non-Stabilised Bases and Sub-Base Options

In areas where there is an adequate supply of good natural gravel or crushed stone, the use of non-stabilised, or unbound, granular base and sub-bases is appropriate. Unbound granular material employed either as sub-base or base pavement layers has to perform a number of functions:

- Provide a working platform for construction
- Provide a structural layer for load spreading and protection of underlying layers
- Provide a layer with resistance to rutting
- Sometimes to act as a pavement drainage, or impervious layer.

The internal factors governing the engineering performance of an unbound gravel aggregate are: the engineering behaviour and geometric properties of its constituent particles, its mass grading and the plasticity of its fines.

Description	Trial Location(s)	Principal Advantages	Principal Concerns
Cement stabilised sand-	Da Nang; Dong thap; Hung Yen; Quang Binh	Utilises locally available materials with little haulage; cost benefits compared with long-haul crushed aggregate or gravel. Can use locally available agricultural equipment for on-site mixing. Straightforward and verifiable construction procedure. Less curing time than lime stabilisation (road closure)	Ensure adequate testing before use. Percentage to be added on site should be at least 1% greater that that indicated by laboratory testing if using agricultural mixing plant. Very difficult to construct during the rainy seasons. Requires an adequate supply of consistently suitable material.. Specific care needs to be taken to ensure correct dosage of cement, complete mixing, correct moisture addition and adequate curing.
Lime stabilised silty clay soil	Dong Thap; Tien Giang	Utilises locally available materials with little haulage; cost benefits compared with long-haul crushed aggregate or gravel. Can use locally available agricultural equipment for on-site mixing. Straightforward and verifiable construction procedure.	Very difficult to undertake during the rainy seasons. Requires greater curing and road closure time than cement stabilisation. Some indications of a deterioration in strength 6 month after construction; possibly related to water table variation influences and/or organic inclusions in soil and/or inadequate QA. Potential health issue with lime dust during mixing. Workers should be adequately protected against lime-skin contact. Requires an adequate supply of consistently suitable material. Specific care needs to be taken to ensure correct dosage of lime, complete and intimate mixing, correct moisture addition and adequate curing. Percentage to be added on site should be at least 1% greater that that indicated by laboratory testing if using agricultural mixing plant.
Emulsion stabilised sand	Dong thap	Utilises locally available materials with little haulage Can use locally available agricultural equipment for on-site mixing	Not possible to undertake during the rainy seasons A potentially difficult option to design, with conventional soil mechanics testing not being appropriate. Requires specialist knowledge. Specific care needs to be taken to ensure correct dosage of emulsion. Requires adequate amounts of water to be added to ensure effective mixing. Likely to be expensive unless local source of emulsion is established.

Table 7.3: Stabilised Base and Sub-Base Options

Unbound granular material layers were trialled in SEACAP 1 in the form of :

- Crushed stone aggregate (CSA)
- Natural sands and gravels (either "as-dug" or processed)
- Dry bound macadam (DBM) – Box 7.1
- Wet bound macadam (WBM) – Box 7.2

Box 7.1
Dry Bound Macadam: Comprises essentially a skeleton of single sized angular stone with voids in-filled with a dry cohesionless fine aggregate. The void filling to achieve a dense, stable matrix is achieved through the use of vibratory compacting plant with little or no use of water.


Dry Bound Macadam

Box 7.2
Water Bound Macadam: Internationally the term "waterbound macadam" implies a layer constructed with similar materials to dry bound macadam with, in this case , the fine aggregate being washed in and compacted by steel drum roller. In Vietnam, however, "water bound macadam" is specified as comprising a single sized angular stone skeleton with voids being in-filled by a series of varying single sized stone aggregate placements, with compaction by steel drum roller aided by the addition of water.


Water Bound Macadam (VN)

Dry and water bound macadam layers formed a significant percentage of the RRST-II trials, particularly in upland areas. Table 7.4 briefly summarises the experiences to date from the non-stabilisation options.

Standard grading and aggregate strength testing are key requirements in the selection and approval of suitable materials, with plasticity, particle shape and abrasion also being important considerations.

7.4 Block Based Options

Block based options (sometimes referred to as incremental paving) have a number of inherent advantages in the rural road context. They have good load spreading properties; they are well suited to labour-based and local small contractor construction; and they are relatively simple to maintain. In appropriate environments they can make good use of local materials and make a contribution to the local economy and community benefits.

Description	Trial Location(s)	Principal Advantages	Principal Concerns
Dry-bound macadam	Dong Thap; Tien Giang; Ninh Binh; Hung Yen; Gia Lai; Dak Lak; Dak Nong	Straightforward well-proven construction techniques. Local contractors are well able to undertake this procedure following initial guidance. Recommended for weak moisture-susceptible sub-grades and provides an appropriate base for bitumen emulsion sealing.	Requires the use of both static and vibrating compaction machinery; the latter may not be readily available for small contractors. New construction techniques for local Vietnamese contractors; a very different procedure from the Vietnamese "Water bound macadam" ; requires initial guidance. Requires quality control on materials and site procedures.
Water-bound macadam	Dong Thap; Tien Giang; Hue; Da Nang; Tuyen Quang; Ha Tinh; Quang Binh; Ninh Binh; Hung Yen; Gia Lai; Dak Lak; Dak Nong	Standard Vietnamese procedure understood by most contractors.	Surface of base may require special attention if it is to be emulsion sealed. Not appropriate over moisture-susceptible sub-grades Differs significantly from internationally accepted forms of water bound macadam. Requires 3-4 different sizes of crushed stone material; and hence requires quality control on material and site procedures.
Natural gravel	Hue; Ninh Binh; Gia Lai; Dak Lak; Dak Nong	Low cost use of locally available materials if of suitable quality. Covered by existing VN standards and cost-norms. Local contractors well experienced in using this option. .	Requires adequate testing control on variable natural materials (quality typically varies substantially with depth at pit locations). Some natural gravels may not achieve technical requirements unless stabilised.
Graded crushed stone (fine and coarse)	Hue; Dong Thap (fine) Quang Binh; Hung Yen	Potential sub-base and base alternative to stone macadam in areas where adequate supplies of quarried and processed rock are readily and cheaply available	Not generally used as an option for rural roads due to requirement for aggregate processing and the need for heavier compaction plant than normally available to small contractors..
Sand	Da Nang; Hue; Tien Giang	Potential sub-base alternative, providing that laboratory test on grading and initial site compaction testing indicate adequate compaction is possible.	Requires consistently well graded fine to coarse sand. The light compaction plant available to small contractors may require compaction in thin 8-10cm layers.
Quarry-run	Tuyen Quang	Low cost use of locally available materials for sub-base if suitable quality material meeting VN natural gravel standards is available.	Material likely to be highly variable in terms of grading and plasticity hence would require adequate control testing and site monitoring of delivered material. Oversize material and need to remove this is likely to be a significant problem.

Table 7.4: Non-Stabilised Base and Sub-Base Options

The RRST programmes have trialled a number of block-based options, namely;

- Fired clay bricks
- Concrete blocks
- Dressed stone
- Cobble stones

A general description of their utilisation is summarised in Box 7.3.

Box 7.3
Block paving is usually laid on a bed of loose sand or fine aggregate of thickness 50 – 100mm. In the case of cobble stone paving the individual stones should have at least one face that is fairly smooth; to be the upper or surface face when placed. Dressed stone requires that the upper and side faces of the stone are fairly smooth to allow effective jointing of these generally large stone pieces. Setts are small cubical stones of general dimensions of approximately 10cm.
Blocks should be placed to a regular pattern (to maximise interlock/load spreading) within a road edge restraint or kerb constructed (for example) of mortared stone or concrete to resist the side thrust forces caused by traffic wheel loading. Blocks/bricks are tapped into position and to the level of the surrounding stones and vibrated into final position with a plate compactor. Jointing of larger stones may be with coarse sand; however to avoid excessive moisture penetration the block/brick joints are usually cement mortared full depth or cement mortar sealed in the high rainfall environments of Vietnam. Alternatively, concrete blocks or bricks may be surfaced with a thin bituminous or bituminous emulsion seal.

The riding surface of dressed stone, stone sett or cobble stone pavements will tend to be rougher than most other RRST options (Table 7.5) as the cost of cutting a smooth upper surface on stone blocks would prohibitively escalate the cost.

Unconfined or un-axial strength and block shape are the principal considerations when selecting or approving block materials, whilst water absorption and bulk density form part of the Vietnamese standard for construction bricks.

Table 7.5 summarises the principal advantages and disadvantage of block based options.

7.5 Concrete (Slab) Surface Options

The use of concrete pavements has a number of important advantages within the rural transport sector, namely

- They are robust and able to cope with high vehicle loading,
- They require little maintenance,
- They have good load spreading properties and are suitable for weak subgrades,
- They are resistant to flood erosion,
- Concrete construction is a well known and tried procedure,
- The technique could be applied by a competent general building contractor.

However, there is the principal disadvantage of high initial construction cost, although in some flood prone areas the Whole Life Costs may make this an appropriate and sustainable option. Concrete surfacing can become a much more attractive option when used within a spot improvement or composite construction strategy or where axle overloading is an identified risk. Table 7.6 summarises the principal advantages and disadvantages.

The RRST programme trialled both bamboo and steel reinforced concrete, as well as non-reinforced concrete.

In the rural road environment, standard aggregate tests such as grading and particle strength are principally used to assess materials sources, in conjunction with some limited chemical testing. Concrete cube testing and on site slump testing are the principal means of site quality control in conjunction with procedural observation. The use of unbroken rounded alluvial gravels as coarse aggregate on some sections in Tuyen Quang was an issue that caused some concern, with only marginally acceptable cube strengths being achieved. It appears that this material is not prohibited under current Vietnam rural road specifications. Recommendations on this are included in the revised RRST specifications.

The RRST trials identified a number of quality control issues in respect to concrete road construction that required attention and in some cases improvement:

- Concrete mix control,
- Adequate curing following construction,
- QA on laboratory testing of concrete cubes,
- Regular slump testing to control water quantity in the mix (to avoid shrinkage cracking and low strength/durability).

7.6 Unsealed Options

The RRST programmes trialled both unsealed natural gravel and unsealed water bound macadam as control sections for performance comparison purposes. The associated Rural Road Gravel Assessment Programme (SEACAP 4) provided additional information on the conditions of existing gravel roads in Vietnam. Table 7.7 summarises the advantages and disadvantages of these types of surface.

The conclusions from the initial monitoring of RRST-I and the SEACAP 4 data clearly indicate that there are significant constraints to the sustainable and appropriate use of unsealed pavements in Vietnam; Box 7.4. It is however important to note that unsealed natural gravel or macadam pavements can provide an initially low cost option in appropriate circumstances that include either an effective maintenance regime or a staged construction strategy.

Box 7.4

Principal constraints on the use of unsealed gravel surfacing are for locations where:

- ❑ Gravel quality is poor *(Majority of sites surveyed did not comply with internationally recognised specifications),*
- ❑ Compaction & layer thickness cannot be assured,
- ❑ Drainage is not provided *(>50% of sites: camber & drainage defective),*
- ❑ Haul distances are long *(suggest WLC for >10km),*
- ❑ Rainfall is very high *(>2m),* or dry season dust problems,
- ❑ Traffic levels are high *(suggest WLC for traffic >100 motor vehicles (PCU)/day)*,
- ❑ Longitudinal Gradients *(> 4% if rainfall >1,000mm/year),*
- ❑ Adequate maintenance cannot be provided *(75% of sites surveyed not maintained),*
- ❑ Sub-grade is weak or soaked (flood risk), or
- ❑ Gravel deposits are limited/environmentally sensitive.

Description	Trial Location(s)	Principal Advantages	Principal Concerns
Fired clay brick	Dong Thap; Hung Yen;	Social and economic benefits to the communities through local brick manufacture. Local labour employment both in labour based construction and in ongoing maintenance. Good durability, load bearing and load spreading characteristics provided specification-compliant bricks are used. Currently produced brick sizes may be used, with smaller bricks being laid on edge in either "herringbone" or "stretcher" bond. Low maintenance and easy to repair.	Appropriate only when local brick manufacturing can supply bricks of consistently suitable quality. Current locally applied construction procedures for village roads need to be improved for Class A or Class B use. The mortared joint option may be more suitable than the sand sealed, sand joint, option. Adhesion between bricks and bitumen requires investigation prior to construction if the bitumen surface seal option is planned. Needs careful control of construction using string lines within pre-constructed edge constraints (kerbs).
Concrete brick	Hue; Hung Yen	Economic benefits to the communities through local brick manufacture. Local labour employment both in construction and in ongoing maintenance. Good durability, load bearing and load spreading characteristics. Appropriate in areas where concrete brick/block manufacturing is established. Low maintenance and easy to repair.	Needs careful control of construction using string lines within pre-constructed edge constraints (kerbs).
Dressed stone	Hue	Economic benefits to the communities through labour-based stone excavation and preparation. Local labour employment both in construction and in ongoing maintenance. Good durability, load bearing and load spreading characteristics. Suitable for staged construction options. Low maintenance and easy to repair.	High cost. Appropriate in areas only where suitable un-weathered stone (e.g. granite) is readily available. High roughness makes it unpopular with some local stakeholders. Not suitable for use with stone that polishes or is slippery when wet. Needs careful control of construction using string lines within pre-constructed edge constraints (kerbs).
Cobble Stone	Ninh Binh	Economic benefits to the communities through labour-based stone excavation and preparation. Local labour employment both in construction and in ongoing maintenance. Good durability, load bearing and load spreading characteristics. Suitable for staged construction options. Low maintenance and easy to repair.	High cost. Appropriate in areas where suitable un-weathered stone (eg granite) is readily available. High roughness makes it unpopular with some local stakeholders. Not suitable for use with stone that polishes or is slippery when wet. Needs careful control of construction using string lines within pre-constructed edge constraints (kerbs).

Table 7.5: Block Based Surface Options

Description	Trial Location(s)	Principal Advantages	Principal Concerns
Bamboo reinforced concrete	Dong Thap; Tien Giang; Hue; Tuyen Quang; Ha Tinh; Quang Binh; Ninh Binh	A realistic option where there is a plentiful supply of suitable mature bamboo. Employment of local labour, including women, in bamboo mesh preparation. Suitable for high rainfall and flood prone regions. A preferred option where there is high risk of axle overloading. Minimal maintenance if properly constructed and cured.	There is a significant lead-in time for this option as the bamboo has to be selected, cut and prepared (cured). Requires expansion and contraction joints to be incorporated with steel load transfer dowels. Wider pavements may be constructed in two side-by-side panels, however steel dowels will be required across the centreline joints to prevent differential movement under heavy loading. Requires significant curing time following initial construction; traffic diversion implications on narrow rural roads where traffic cannot be channelled alongside the concrete casting and curing work. High cost. Susceptible to price fluctuation of cost of cement.
Steel reinforced concrete	Dong Thap; Tien Giang; Hue; Da Nang; Gia Lai	Suitable for high rainfall and flood prone regions. A preferred option where there is high risk of axle overloading. Minimal maintenance if properly constructed and cured.	Requires expansion and contraction joints to be incorporated with steel load transfer dowels. Wider pavements may be constructed in two side-by-side panels, however steel dowels will be required across the centreline joints to prevent differential movement under heavy loading. Requires significant curing time following initial construction; traffic diversion implications on narrow rural roads where traffic cannot be channelled alongside the concrete casting and curing work. Potentially the most costly of the trial options. Susceptible to price fluctuation of cost of steel and cement.
Non reinforced concrete	Tuyen Quang; Ha Tinh; Ninh Binh; Hung Yen; Gia Lai; Dak Lak; Dak Nong	Suitable for high rainfall and flood prone regions. Commonly used option at commune level. Well understood by local small contractors. Minimal maintenance if properly constructed and cured.	Requires expansion and contraction joints to be incorporated. Wider pavements may be constructed in two side-by-side panels, however steel dowels will be required across the centreline joints to prevent differential movement under heavy loading. May be susceptible to shrinkage cracking unless well constructed and cured. Requires steel load transfer dowels to be installed at transverse joints, otherwise high risk of problems at joints and slab cracking caused by commercial vehicles. Requires significant curing time following initial construction; traffic diversion implications on narrow rural roads where traffic cannot be channelled alongside the concrete casting and curing work. High cost. Susceptible to price fluctuation of cost of cement.

Table 7.6: Concrete Surface Options

Description	Trial Location(s)	Principal Advantages	Principal Concerns
Unsealed Natural gravel	Tien Giang; Hue; Gia Lai; Dak Lak; Dak Nong	Low cost option where adequate supplies of suitable material are available within reasonable haul distance, certain criteria are satisfied and an adequate maintenance regime is in place.	Monitoring results confirm the unsuitability of this option in locations/road sections that experience high rainfall, long materials haul distances, steep gradients and in floodable areas. Should only be used with great care and knowledge of performance for surface applications, due to expected material losses in service. See SEACAP 4 (Cook and Petts 2005)[5] for details of appropriate use.
Unsealed water-bound macadam	Dong Thap; Tien Giang; Da Nang	Low cost option where adequate supplies of suitable material are available within reasonable haul distance and a maintenance regime is in place. Potentially advantageous use within a staged construction strategy.	Early monitoring indications indicate a rapid surface roughening and potholing in high rainfall and floodable regions. Safety issues raised by local stakeholders with regard to two-wheeled traffic.

Table 7.7: Unsealed Surface Options

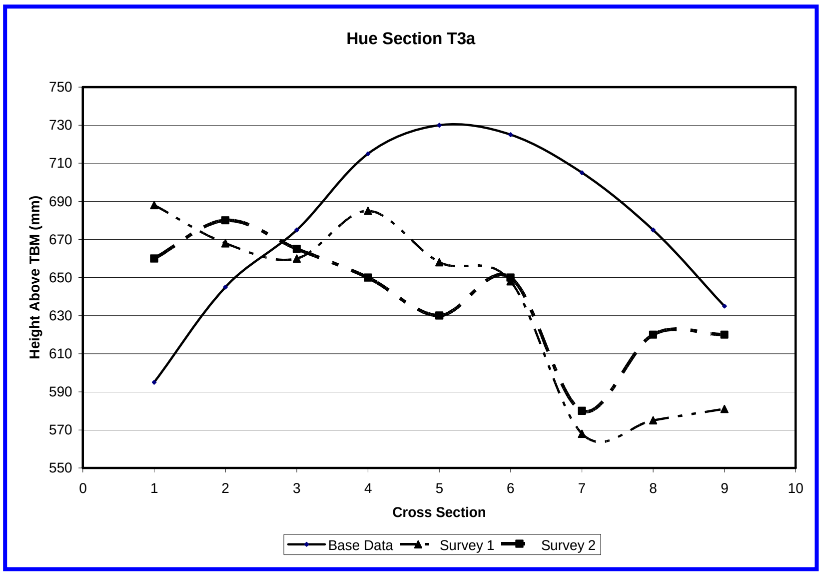
Controlled monitoring of the unsealed gravel sections has so far led to the following conclusions:

1. Within six months of construction there is significant loss of road shape and rutting; Figure 7.2.
2. During the rainy season the upper gravel layer (100mm) becomes saturated, weakens and is liable to “shoving” .
3. There is a significant material loss, although some of this “loss” may be attributed to material displacement.

The unsealed macadam sections showed less overall loss of material and shape but were observed to suffer from loss of fines and an unacceptable increase in roughness as regards the safety of the predominant two-wheeled traffic, Table 7.8, Figure 7.3.

In circumstances where gravel is an appropriate option, there are a number of issues with respect to material selection and quality control that require addressing:

- Gravel material specifications need to be practical and suited both to the available materials and their task in the road surface or pavement, (see also section 8.5)
- In the rural road environment, natural gravel tends to be used “as-dug” rather than from previously stock piled materials. If this is the case then, bearing in mind the natural variability of these materials, quality control on as-delivered material is essential.
- Supervisory control is essential on site to quality assure consistency with tested/selected source materials, layer thickness and layer strength.



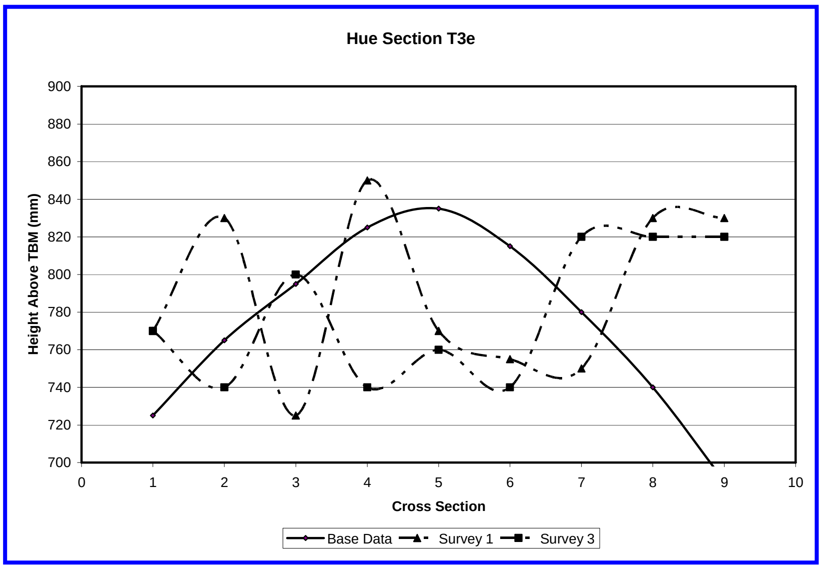


Figure 7.2: Cross Section Levels from Unsealed Gravel Control Section; Hue

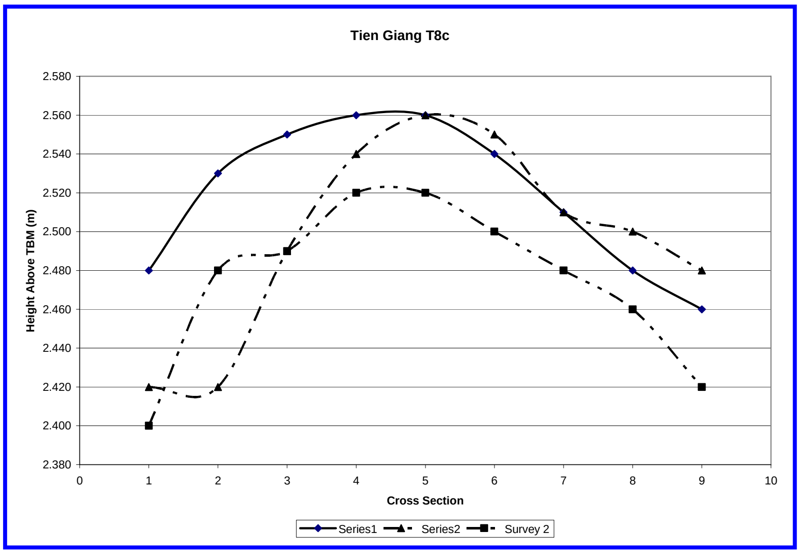


Figure 7.3: Cross Section Levels from Unsealed WBM Control Section Tien Giang

		Average IRI m/km		
Pavement Type	**Ref.**	**As Built**	**5-6 Months**	**12-14 Months**
Concrete	H2	2.21	4.12	4.84
	D2	4.31	4.31	4.36
	D3	4.43	4.49	4.92
	T2	5.39	4.03	5.08
	T3	4.66	4.08	5.13
	T9	5.11	4.33	5.34
Sand/Chip Seal	H9	3.83	3.76	4.27
	D5	4.96	5.45	5.17
	D6	3.41	3.60	4.01
	T5	8.22	8.74	8.38
	T6	5.39	4.33	5.17
Pen Mac	H4	3.63	3.81	4.28
	D7	5.14	5.89	5.12
	T7	7.40	7.69	8.17
Unsealed WBM	D8	6.41	5.87	7.99
	T8	7.32	6.93	9.74
Gravel	H3	6.58	17.98	11.38
	T10	4.99	3.84	3.76
Sand Sealed Concrete Brick	H6	5.27	5.25	6.42
	H7	2.83	5.26	6.28
Sand Sealed Clay Brick	D11	6.11	6.40	7.51
	D12	6.05	5.88	5.58
Unsealed Clay Brick	D10	6.11	6.40	7.51
Dressed Stone	H11	7.45	8.63	9.35

Table 7.8: Summary of Roughness Data from RRST-I Monitoring

7.7 Surface Seals

The RRST programmes trialled the following bituminous seals as options for a waterproof seal and running surface:

- Bitumen & bitumen emulsion stone chip seals (Surface Dressing, Box 7.5),
- Bitumen emulsion sand seal, Box 7.6,
- Penetration macadam,
- Triple bitumen seal.

Box 7.5

Surface Dressing consists of supply and application of a seal of bituminous binder material over the previously prepared road base or other surface. It is immediately covered with single sized stone aggregate chippings that are lightly rolled into the bitumen to form a weather proof matrix and running surface. When one application of bituminous material and aggregate is placed it is termed as Single Bituminous Surface Dressing (SBSD). When two applications of bituminous material and aggregate are placed it is termed as Double Bituminous Surface Dressing (DBSD).

Box 7.6

A sand seal consists of supply and application of a seal of bituminous binder material over the previously prepared road base or other surface. The seal is immediately covered with sand or fine aggregate chippings. The sand/fine aggregate completely covers the seal and is lightly rolled into the seal to form a weather proof matrix and running surface suitable for light vehicular traffic. It is therefore suitable for application in areas with poor access to hard stone sources.

Key material selection issues are ensuring adequate sand or aggregate grading and particle shape and absence of dust. Bitumen adhesion testing is recommended for aggregates without a proven record of use, as well as for sand seals over block paved bases.

Hot bitumen seals including penetration macadam and a local triple seal design were included as local controls for comparison with the bitumen emulsion trial surfaces. The RRST-I programme included only penetration macadam as a control, hence little comparative information is as yet available between hot bitumen and bitumen emulsion seals. However, data so far collected highlight the following issues:

- Penetration macadam has so far proved to be a robust local alternative to emulsion seals but carries a significant cost and resource penalty; Box 7.7
- General poor shape characteristics of the igneous aggregate as normally processed.
- Problems in the placement of emulsion sand seals on gradients.
- Susceptibility of sand seals to flood erosion.
- Potential problems with bedding-in surface dressing on very low volume roads.
- Potential difficulties in

Box 7.7

Penetration macadam consists of layers of broken or crushed stones of size up to 80mm, interspersed with applications of heated bitumen to grout and seal the surface. It is laid as a waterproof surface on a previously prepared road base. The effect is to achieve a matrix of keyed stones grouted and sealed with bitumen to a depth of about 60 – 80mm.
The overall applications of bitumen are as high as 7 – 9kg/m². This makes the surface a relatively high cost option.

combining voided Vietnamese specified water bound macadam bases with emulsion surface dressing seals.

- The need for close site control on the spreading rates and procedures for emulsion sand and stone chip seals.

Table 7.9 summarises key advantages and disadvantages.

7.8 Shoulder Options

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

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

Table 7.10 summarises key advantages and disadvantages.

7.9 Surface Options not Investigated/Trialled

A number of rural road surface options that are proven/in-use in other countries regions were not investigated or trialled for reasons of lack of resources or low local priority at the time of RRST selection. These include:

- Engineered Natural Surface (ENS),
- Stone chip blinding/mechanical stabilisation,
- Hand Packed Stone
- Natural/graded Gravel Seal
- Stone Setts/Pavé,
- Geo-cell paving

Some of these surface techniques may have potential application in suitable circumstances in Vietnam and should be considered for future further research into cost-effective, sustainable rural road surfacing.

Description	Trial Location(s)	Principal Advantages	Principal Concerns
Sand bitumen emulsion	Dong Thap; Tien Giang; Hue; Da Nang	Application suitable for labour based methods because of low health and safety risks. Suitable for low volume traffic roads in areas deficient in stone aggregate but with plentiful supplies of suitable sand. Suitable for commune based maintenance operations.	Best performance with the application of a second sand seal after 5-6 months road use, in order to provide a more durable surface. Procedures not well known by local contractors; requires good site control. Sand seal on brick options show a tendency to strip and crack at brick joints. Application procedures not suitable for steep gradients. Potential difficulties in obtaining small quantities of emulsion for local maintenance.
Sand and stone chip bitumen emulsion (sand seal on chip seal)	Dong Thap; Tien Giang; Hue; Da Nang; Dak Lak	Application suitable for labour based methods because of low health and safety risks. Suitable for commune based maintenance operations	Care required in matching emulsion spray/application rates to actually available stone sizes and aggregate shape. Procedures not well known by local contractors; requires good site control. Sand seal application procedures not suitable for steep gradients. Potential difficulties in obtaining small quantities of emulsion for local maintenance.
Double stone chip bitumen emulsion	Tuyen Quang; Ha Tinh; Quang Binh; Ninh Binh; Hung Yen; Gia Lai; Dak Lak; Dak Nong	Application suitable for labour based methods because of low health and safety risks. Suitable for commune based maintenance operations	Care required in matching emulsion spray/application rates to actually available stone sizes and aggregate shape. Procedures not well known by local contractors; requires good site control. Potential difficulties in obtaining small quantities of emulsion for local maintenance.
Double stone chip hot bitumen	Tuyen Quang; Ha Tinh; Quang Binh; Ninh Binh; Hung Yen;	Well known and established procedure in Vietnam.	Generally currently very poor site control on bitumen application temperature, which affects durability. Significant health and safety hazard.
Triple stone chip hot bitumen	Dak Nong	Locally developed procedure.	Excessive use of bitumen in what is effectively similar to a semi-penetration macadam in composition and thickness. Care required in matching application rates to actually available stone sizes and shape. Generally currently very poor site control on bitumen application temperature. Significant health and safety hazard.
Penetration macadam	Dong Thap; Tien Giang; Hue; Da Nang; Dak Lak; Dak Nong	Well known and established procedure in Vietnam. Low initial maintenance if well constructed.	Does not use either locally available materials or local labour. Health hazard issues as regards hot bitumen. Difficult to control quality. The use of bitumen at 7kg/m2 means that this option carries a high cost penalty.

Table 7.9: Surface Seals Options

Description	**Trial Location(s)**	**Principal Advantages**	**Principal Concerns**
Natural gravel	Hue; Tien Giang; Da Nang; Tuyen Quang; Ha Tinh; Quang Binh; Hung Yen; Gia Lai; Dak Lak; Dak Nong	Appropriate where suitable sources of specified quality gravel are locally available and where suitability criteria of rainfall and gradient are met.	Should only be used with great care and knowledge of performance for surface applications, due to expected material losses in service. See SEACAP 4 (Cook and Petts 2005)[5] for details of appropriate use.
Lime stabilised soil	Tien Giang, Dong Thap	See Table 7.1.	Care required in stabilisation and compaction at embankment edges and where pavements are already constructed.
Cement stabilised soil	Da Nang	See Table 7.1	Care required in stabilisation and compaction at embankment edges and where pavements are already constructed.
Un-stabilised local soil	Ha Tinh; Quang Binh; Ninh Binh	Potential low cost alternative Road Class B road in some environments.	Not generally recommend due to low strength and high erosion potential; consequently high maintenance costs and safety concerns.
Quarry-run	Tuyen Quang; Ha Tinh; Quang Binh; Hung yen	Appropriate where suitable sources of specified quality material are locally available.	Material likely to be highly variable in terms of grading and plasticity, hence would require adequate control testing and site monitoring of delivered material. Oversize material particles likely to be a significant problem.
Unsealed stone macadam	Hue; Tien Giang; Da Nang; Tuyen Quang; Quang Binh; Hung Yen; Gia Lai; Dak Lak; Dak Nong	Strong robust option when shoulders can be built as an extension of similar base construction.	Difficult to construct as shoulders separate from carriageway construction. Requires adequate edge buttressing by earthworks to allow adequate aggregate compaction. Can cause deterioration of moisture sensitive base/sub-base by easy ingress of run-off water.
Single chip sealed macadam	Tuyen Quang; Gia Lai	Strong robust option when shoulders can be built as an extension of similar base construction.	Difficult to construct as shoulders separate from carriageway construction. Requires adequate edge buttressing by earthworks to allow adequate aggregate compaction. In higher traffic environments in conjunction with a 3.5m wide carriageway, encourages motor vehicles to use and damage shoulders. Can add significantly to the cost.

Table 7.10: Shoulder Options

8 APPROPRIATE PAVEMENT SELECTION

8.1 Vietnam Road Environments

The principal elements in the design process are traditionally focussed on the choice of materials and their thickness within each pavement layer. Experience is increasingly indicating that in the case of low volume rural roads this traditional approach is inadequate. It is now appreciated that additional road environment factors must be taken into account if the selected designs are to be cost-effective and sustainable in engineering, social and economic terms. The design engineer, however, also needs to understand all other external impacts on the design, and to recognise the influence exerted by these other parameters. In reality the performance of a road depends on a whole range of factors that cumulatively can be described as the "road environment". Factors important to the road environment can be broadly grouped as follows and illustrated in Figure 8.1:

- Available Materials – locally and within economic haulage
- Natural Environment factors – largely uncontrollable
- Road Task
- Operational Environment – largely controllable

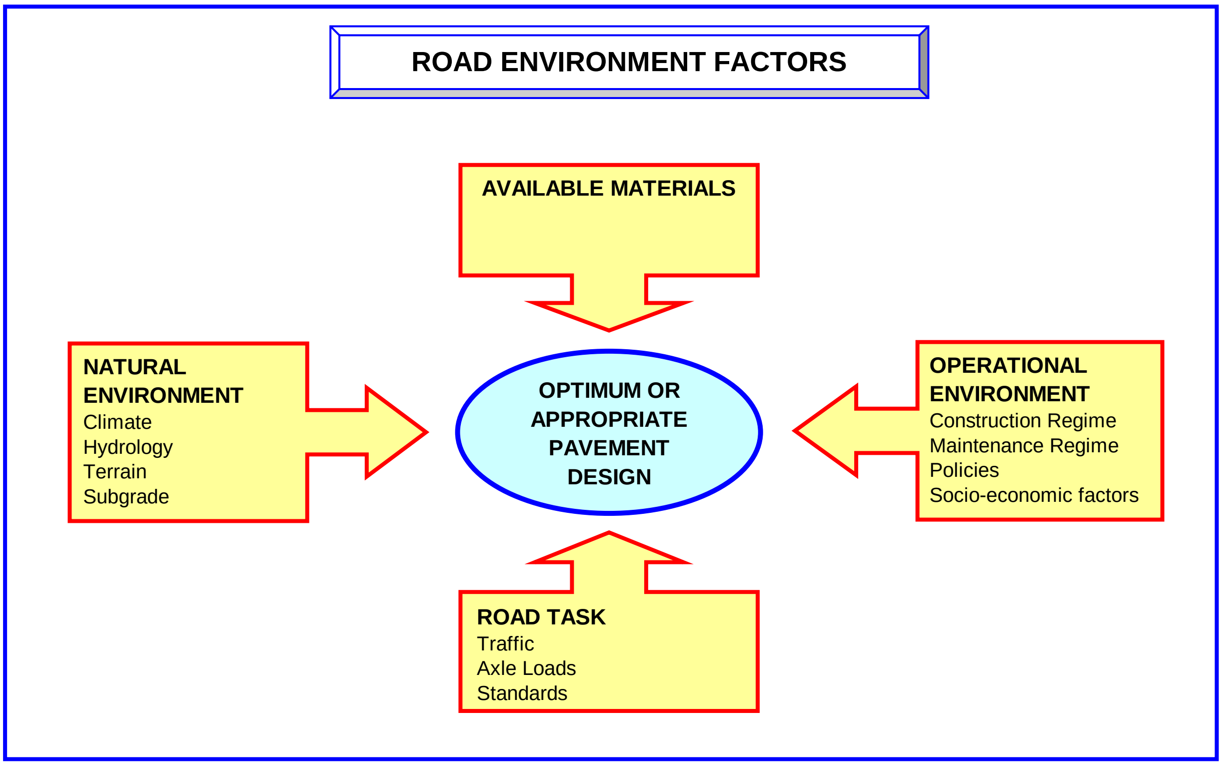


Figure 8.1 The Road Environment, Natural and Project Related Factors

Appropriate rural road design should take into account the impacts and influences of the various road environment factors and overall should be concerned with optimising the various road features of:

- Earthworks,
- Drainage,
- Structures,
- Pavement;

within the constraints and requirements of these factors, and to appropriate standards and specifications.

However, within the context of the RRST programme, it is the appropriate selection and design of pavement options that are the key issues, although there is an inevitable influence with respect to earthworks and drainage in particular.

An important element in the development of appropriate or adequate specifications is to ensure that they recognise local conditions of climate, terrain and the characteristics of materials actually available. The importance of the road environment becomes even more acute when considering the use of non-standard approaches to low-volume roads in developing rural areas.

Construction Materials. The inter-action of geology and geomorphology indicates that a wide range of natural road construction materials is available for exploitation in Vietnam, There is however considerable regional variation in their occurrence, with some areas being particularly scarce in construction materials. Table 8.1 illustrates this in terms of the 12 trial provinces. For example, the potentially considerable, but as yet undeveloped, resources of Mountainous regions like Tuyen Quang contrast with the largely non-existent construction materials resources within the Mekong delta.

Region	Province	Rock Quarries	Sand	Clay (bricks)	Suitable Gravel
Mekong Delta	Tien Giang				
	Dong Thap				
Central Coastal	Hue				
	Da Nang				
Central Highlands	Gia Lai				
	Dak Nong				
	Dak Lak				
Red River	Hung Yen				
	Ninh Binh				
Northern Highlands	Tuyen Quang				
	Quang Binh				
	Ha Tinh				

Table 8.1: General Construction Material Availability

Climate. . Although the Vietnamese climate has significant regional variations it may in general terms be summarised as being tropical monsoonal. Table 8.2 presents a summary of the rainfall figures collated for the 12 No. trial provinces.

General climatic data are useful in establishing general climatic trends, however, they will not indicate the nature of extreme climatic events, such as tropical storms. These extreme events may be the most damaging to the road structure and particularly in the coastal provinces this becomes an important consideration. Table 8.3 highlights the very high and potentially very erosive high daily rainfalls that have been recorded in the RRST provinces.

This climatic data indicates the following factors influencing rural road construction:

- Periods of intense rainfall with high erosion and flood potential contrasting with relatively drier periods when dust may be a significant problem on unsealed roads.
- Significant periods during the year when construction and maintenance are not likely to be possible; Figure 8.2.
- The climatic regime is significantly different from some current and recent areas of low-volume road research, e.g. Southern Africa. For example, a day's storm rainfall can be more than many African locations receive in a whole year.

		Yearly Rainfall (mm)						
	Location	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**Av**
Red River	Ninh Binh	1915	1906	1406	1633	1228	1710	1633
Red River	Hung yen	1257	2029	1144	1313	1059	1334	1356
N.Highlands	Ha Tinh-Huong Khe	2394	2401	2371	1583	1982	2389	2187
N.Highlands	Quang Binh	1512	2343	2054	1486	1791	2208	1899
N.Highlands	Tuyen Quang -Ham Yen	1476	1910	2073	1718	1615	1788	1763
N.Highlands	Tuyen Quang-Chiem Hoa	1415	1720	2167	1282	1626	1565	1629
N.Highlands	Tuyen Quang -Tuyen Quang	1461	2010	1705	1535	1340	1404	1576
Mekong	Dong Thap	2008	1328	1224	1738	1253	1497	1508
Mekong	Tien Giang	1640	1544	758	1489	1230	1704	1394
C. Highlands	Gia Lai -Pleiku	2470	2169	2159	2200	1895	2048	2157
C. Highlands	Gia Lai -An Khe	1488	1255	1053	1151	959	1712	1270
C. Highlands	Dak Nong	3081	2967	2711	2589	2704	2362	2736
C. Highlands	Dak Lak	2334	2044	1934	1976	1311	2036	1939
C. Coastal	Hue	3472	2481	3369	2391	3247	3055	3003
C. Coastal	Da Nang	2828	2750	2365	1739	1375	1871	2155

Table 8.2: Summary of RRST Rainfall Data 2000-2005

		Maximum Daily Rainfall					
	Location	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Red River	Ninh Binh	**293**	184	151	188	96	180
Red River	Hung yen	92	100	89	114	72	103
N.Highlands	Ha Tinh-Huong Khe	169	**205**	**302**	164	166	**289**
N.Highlands	Quang Binh	156	**204**	125	**248**	130	177
N.Highlands	Tuyen Quang -Ham Yen	156	172	179	110	131	87
N.Highlands	Tuyen Quang -Tuyen Quang	102	160	168	99	90	91
Mekong	Dong Thap	148	72	112	76	109	64
Mekong	Tien Giang	82	74	43	53	**273**	110
C. Highlands	Gia Lai -Pleiku	109	96	159	120	139	115
C. Highlands	Gia Lai -An Khe	86	84	89	105	57	194
C. Highlands	Dak Nong	119	184	83	124	56	129
C. Highlands	Dak Lak	**264**	184	83	124	56	129
C. Coastal	Hue	**354**	**201**	**360**	197	**683**	**311**
C. Coastal	Da Nang	140	185	157	136	11	**293**

Table 8.3: Maximum Daily Rainfall in mm

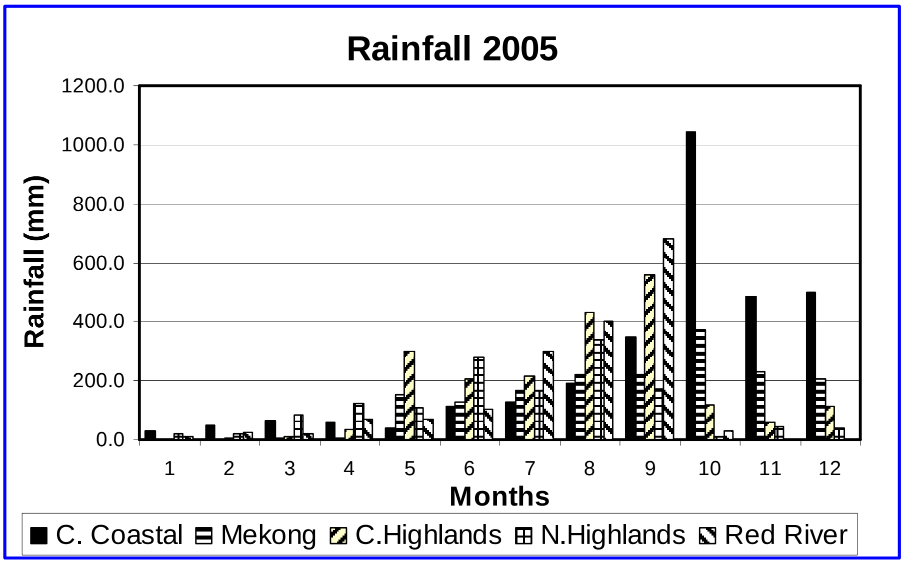


Figure 8.2: Typical Rainfall Distribution 2005

Hydrology. It is clear that certain types of surfacing are not appropriate for locations at risk of inundation and overtopping (unbound/unsealed materials). The experience of the Hue and Da Nang trials has also demonstrated the importance of appropriate design of shoulders and slope protection for tropical storm impacts.

Key points to note are:

- Potential high erosive run-off in hilly terrain,
- Potential flooding and sub-grade soaking in low-lying areas,
- Constant high water tables in flat rice growing areas,
- Tidal effects and potential storm surges in deltaic areas,
- Salinity of water table in deltaic areas.

Terrain. There is considerable contrast in terrain throughout Vietnam, from actively eroding mountain and hill systems to actively depositing large deltaic areas; Figure 8.3. Table 8.4 provides a brief outline of the terrain groups within the trial provinces. Terrain influences the drainage measures required for a particular road section. The evidence from the SEACAP 4 investigations is that considerably more attention is required to be paid to this important aspect of road design in a high rainfall environment.

Sub-Grade: In the light of the very variable geology, terrain and climate it is not surprising to note that natural sub-grade conditions in Vietnam are likely to be highly variable themselves. Highland regions such as Tuyen Quang or the Central Highland region are likely to produce generally good sub-grade conditions, if allowance is made for local unpredictability and localised flat-lying areas. In contrast, the deltaic terrain of the Mekong and Red river deltas are dominated by poor and saturated sub-grade conditions with potentially low CBR values; Figure 8.3.

Region	Province	Terrain
Northern. Highlands	Tuyen Quang	Predominantly upland hilly and mountainous, with occasional lowland valleys. Potentially steep grades.
	Ha Tinh	A distinct sandy coastal belt interspersed with some hilly areas (igneous intrusions). Terrain becomes lowland then upland hilly and mountainous towards the west. The higher western areas interspersed with significant valley areas.
	Quang Binh	A distinct sandy coastal belt. Terrain becomes lowland then upland hilly and mountainous towards the west. The higher western areas interspersed with significant valley areas.
Red River Delta	Ninh Binh	Largely deltaic and coastal but with some lowland and occasional limestone hills in the West.
	Hung Yen	Entirely low-lying deltaic.
Central Coastal Belt	Hue	A narrow coastal belt with adjacent igneous intrusions. Becomes lowland then upland hilly and mountainous towards the west. The higher western areas interspersed with significant valley areas.
	Da Nang	A distinct sandy coastal belt interspersed with some limestone hills. Terrain becomes lowland then upland hilly and mountainous towards the west. The higher western areas interspersed with significant valley areas.
Central Coastal Highlands	Gia Lai	Predominantly upland rolling terrain with some high hill and valley terrain.
	Dak Lak	Predominantly upland rolling terrain with some high hill and valley terrain.
	Dak Nong	Predominantly upland rolling terrain with some high hill and valley terrain.
Mekong Delta	Tien Giang	Entirely low-lying deltaic.
	Dong Thap	Entirely low-lying deltaic.

Table 8.4: Summary of Terrain of the RRST Provinces

Traffic

Traffic count surveys showed some significant variability in the provincial traffic patterns; Table 8.5.

From the engineering perspective, the key points to note are:

- The general preponderance of two wheeled traffic in most regions, with VPD equivalent rarely exceeding 150. The notable exception is Loc Ninh road in Quang Bing where an urban traffic regime predominates.
- The very low motor vehicle traffic in the Mekong Delta region is partly explained by the poor condition of the bridges on the trial roads, but more generally a consequence of the tendency for most of the goods traffic to be transported by river or canal.

Terrain	Key Character	Likely Sub-Grade Strength	No. of Trial Roads
Deltaic;	Low-lying, floods, silt, clay	Very Low	18
Coastal	Low-lying, sandy	Low-Moderate	3
Lowland	Irrigated agriculture; embankments	Low	8
Upland Hilly	Moderate erosion	Moderate	9
Mountainous	Steep slopes, high erosion	High	3

Figure 8.3: General Terrain Groups and General Sub-Grade Conditions

Axle Loading

For the majority of the RRST trials roads axle loading is not a serious concern. The preponderance of two wheeled traffic and small commercial vehicles do not raise a significant concern for rural road and pavement design.

However, for rural routes which are, or may be in the near future:

- adjacent to developing urban areas,
- subject to haulage of primary construction materials,
- subject to earthworks haulage associated with development projects, or
- timber extraction routes,

then it will be expected that heavy commercial vehicles will form an important factor in the design considerations. This will be of particular concern in the areas of weak subgrades and high water tables/flooding.

As discussed in Section 4.5, there is a need to investigate in more depth the current axle loading situation on the Vietnam road network so that appropriate measures can be taken to address this important and potentially seriously damaging and costly issue.

	Province: Road	24 hour Traffic: Motor vehicle/day	Motorcycle/day	Cycle/day	ADT	Survey Date
Mekong Delta	Dong Thap: Tan Thuan Tay	1	1327	1332	199	Nov. 2004
	Dong Thap: Tan Thuan Tay	0	1718	1085	226	Oct. 2006
	Tien Giang: My Phuoc Tay	5	893	824	131	Nov. 2004
	Tien Giang: My Phuoc Tay	2	1110	646	143	Oct. 2006
Central Coastal	Da Nang: Binh Ky	29	247	511	50	Nov. 2004
	Da Nang: Binh Ky	16	443	113	50	Oct. 2006
	Hue: Thong Nhat	2	83	232	20	Nov. 2004
	Hue: Thong Nhat	24	694	706	105	Oct. 2006
Central Highlands	Gia Lai: Xa Trang	102	838	102	89	July 2005
	Gia Lai: Ia Pnol	101	134	1064	67	Sept. 2006
	Gia Lai: Chu Pah	122	1224	403	143	July 2005
	Dak Nong: Kien Duc	119	1946	53	197	July 2005
	Dak Lak: Cu Ne	176	1150	106	120	Sept. 2006
	Dak Lak: Buon Ho	277	469	56	50	July 2005
Red River Delta	Hung Yen: Nhat Quang	130	176	229	29	July 2005
	Hung Yen: Tan Hung	272	140	154	22	July 2005
	Ninh Binh: Yen Trach	152	1760	2029	278	July 2005
	Ninh Binh: Thu Trung	168	2069	2123	313	July 2005
	Ninh Binh: Yen Tu	72	380	977	87	Sept. 2006
	Ninh Binh: Ninh Van	70	547	738	92	Sept. 2006
	Ninh Binh: Dong Huong	152	2094	1883	304	July 2005
Northern Highlands	Tuyen Quang: Lang Quan	101	907	1025	142	July 2005
	Tuyen Quang: Thang Quan	20	266	726	63	July 2005
	Tuyen Quang: Y la	148	1249	1304	190	Sept. 2006
	Quang Binh: Cam Lien	31	540	305	69	July 2005
	Quang Binh: Ngu Hoa	62	848	70	88	July 2005
	Quang Binh: Loc Ninh	524	509	36	53	July 2005
	Ha Tinh: Dia Loi	134	1050	401	125	Sept. 2006
	Ha Tinh: Thach Minh	67	572	776	96	July 2005

Table 8.5: Summary Traffic Count Information

Construction and Maintenance Regimes

These two important factors have hitherto been largely assumed to be adequate and that the construction and maintenance assumptions made at the design stage will be fulfilled.

The reality has been exposed by the SEACAP 4 and 1 investigations and trials. There are significant shortcomings in the construction contract process that are discussed elsewhere in this report. Furthermore the maintenance regime in Vietnam is relatively undeveloped and does not support the assumptions of adequate maintenance generally made in the current design process.

A more realistic assessment of these regimes is required in the design process so that either:

- Due consideration is made for the actual construction and maintenance regimes at the design stage, or
- Appropriate measures are taken to improve the construction and maintenance regimes to achieve better value-for-money for the rural road infrastructure investments.

8.2 Selection Procedure

A new paving selection procedure has been developed from the SEACAP 1 and 4 research initiatives, from the considerations discussed in Section 8.1 and experience gained in other regions. The proposed procedures for the selection of low volume rural road paving are based on two key principles:

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

The above two principles are an extension of the traditional approach to pavement design based on the above discussion. The key issues that need to be addressed in seeking appropriate selection procedures are in particular:

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

A two phase selection approach is proposed (Figure 8.4) as follows:

1. Phase I: Identification of appropriate pavement types compatible with the road environment.
2. Phase II: Detailed design of the selected pavement components (e.g. layer thicknesses) compatible with engineering standards and requirements – i.e. traffic, axle load and sub-grade strength.

Phase I - Key activities

1. Collect all road environment information.
2. Assess all data using relevant matrices and tables and carry forward a shortened list for Social, Economic and Stakeholder Review.
3. If unsealed gravel surfacing is an identified option, refer to the Guidance Gravel Surfacing Selection Flow Chart, Appendix H.
4. Undertake a Social, Economic and Stakeholder Review to produce a final short list of suitable design options and carry this forward to Phase II. (Figure 8.5).

5. The use of a Cost Model is recommended as part of a ranking process in terms of Whole-Life Costs.

The foregoing procedure may identify particular sections of the route which would justify a different paving approach (e.g. flood prone, steep hill, village housing, high water table, etc.). It may be appropriate to apply a differential or spot improvement solution to more demanding locations/sections.

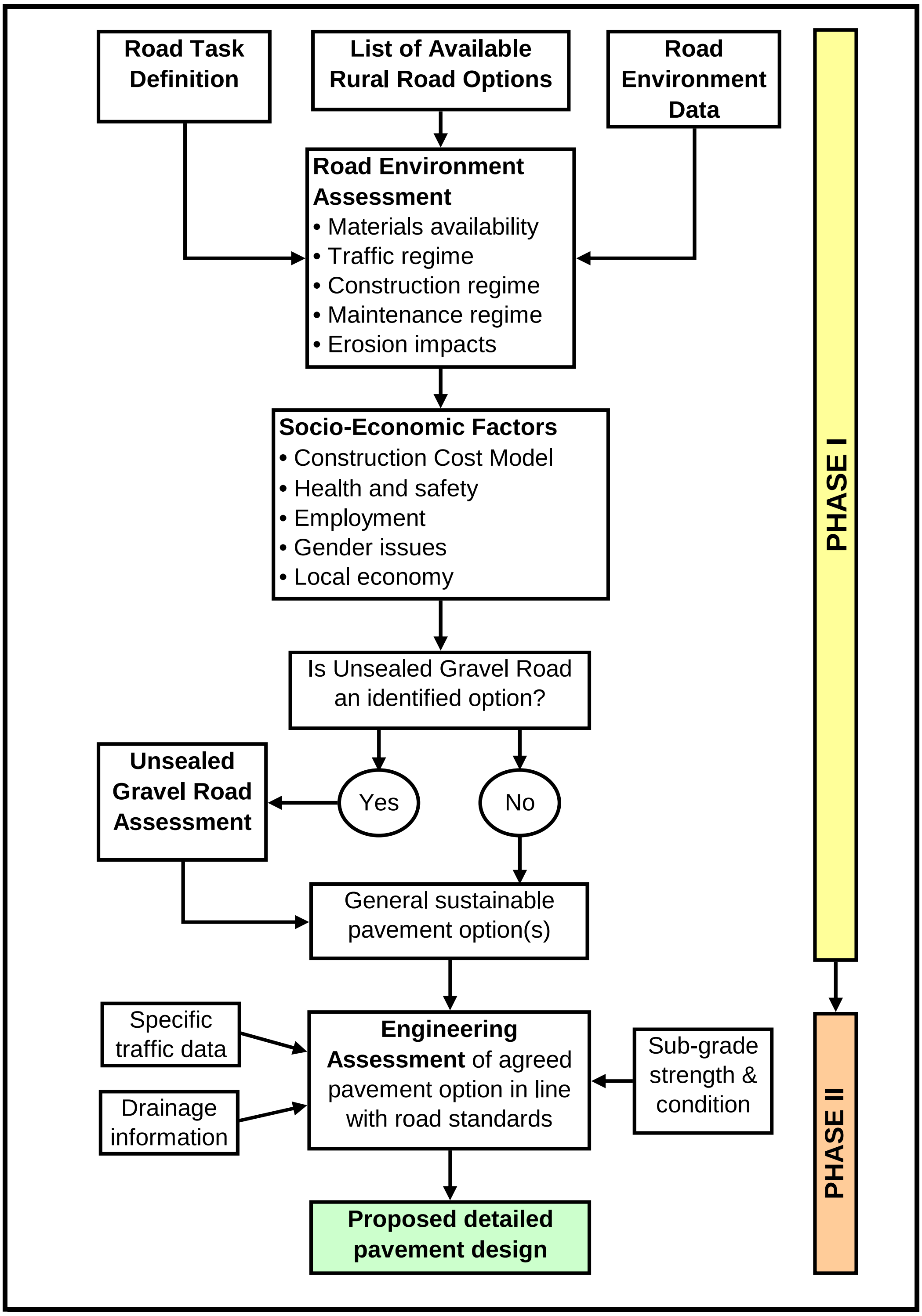


Figure 8.4: Outline of Proposed Rural Road Selection and Design Procedure

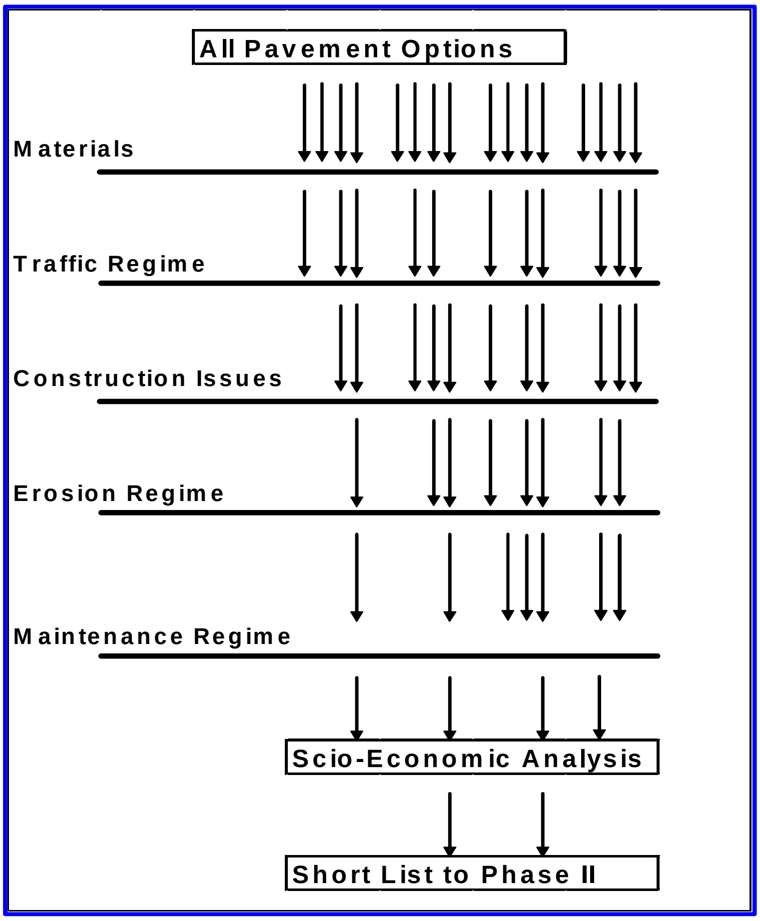
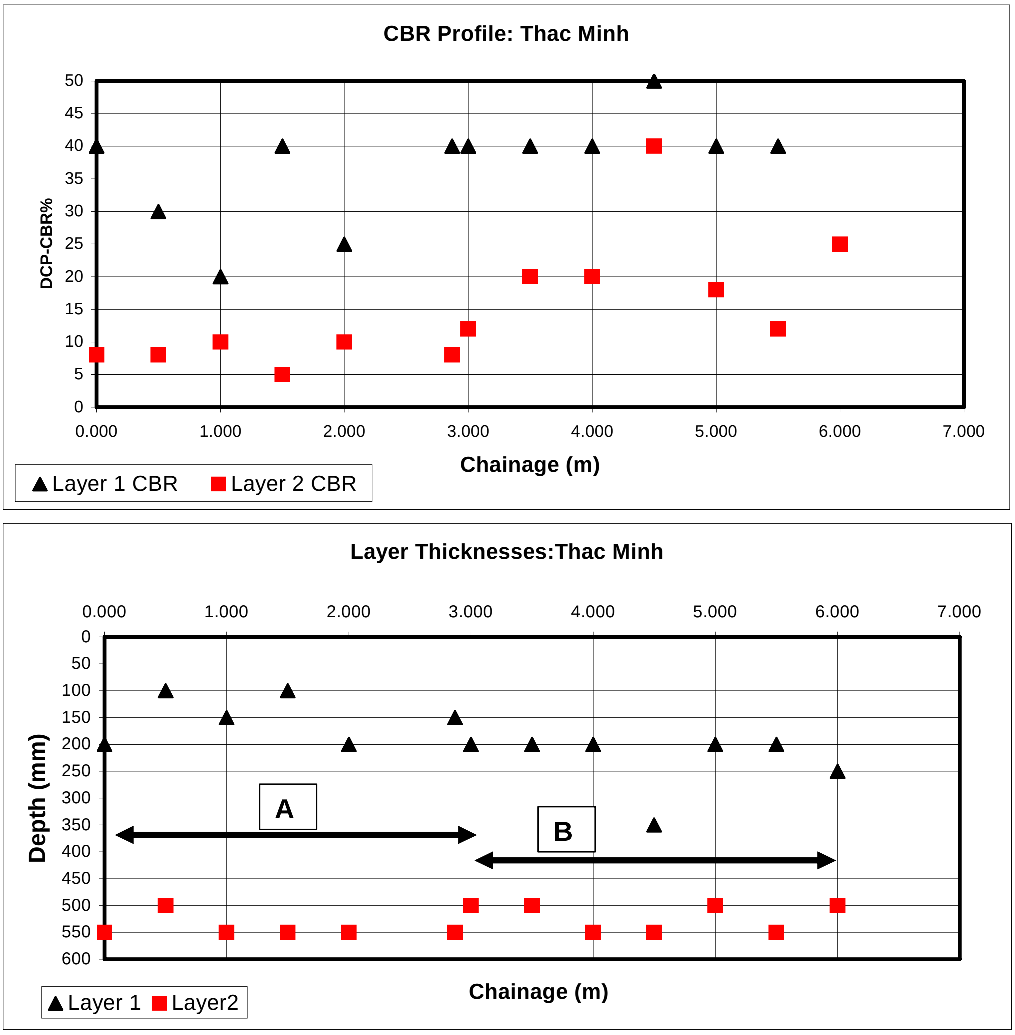


Figure 8.5: Schematic Representation of the Pavement Option Selection Process

Phase II - Key activities

1. Where relevant, use appropriate established local Road Standards to define pavement layer thicknesses.
2. Where this is not possible refer to specialist publications (for example SEACAP 1 Reports) on special case options (e.g. bricks, cobble stones, stone setts).
3. Design pavement drainage in accordance with relevant local Road Standards and the assessed drainage requirements. Figure 8.6 demonstrates an example from the RRST-II trials of the division of proposed roads into separate design lengths using collected geotechnical data.
4. For special cases, e.g. expected high axle loading, refer to international guidance documentation.

A more detailed description of the procedures together with related matrices, figures and tables is presented as a stand-alone document in Appendix H of this report.



Notes:

Section A Variable residual gravel surface (minimum in situ CBR 20%); existing sub-grade in situ CBR 7%.

Section B: Consistent residual gravel surface allow for minimum in situ CBR 35%; existing sub-grade allow for minimum in situ CBR 12-15%

Figure 8.6: Typical Analysis of RRST-II Geotechnical Pre-Design Survey

8.3 Rural Road Standards

Another important aspect of rural roads provision that requires review is that of the national standards used for rural roads. These have often been inherited from previous administrations or foreign environments and are rarely developed on the basis of technical and economic evaluation of the local conditions, and recognition of the existing and future constraints. The standards used for road access need to be affordable and meet the specific transport needs of the community and the types of vehicles used. For example, it is not necessary to provide a wide road when a 1.5 metre wide bicycle or motorcycle pavement will suffice.

8.4 Staged Construction

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

Examples of this approach are:-

Stage 1 - Engineered Natural Surface
Stage 2 - Gravel surface

Stage 1 - Gravel surface
Stage 2 - Un-reinforced Concrete Paving

This technique can be used in the circumstances where an existing gravel/laterite surface is to be upgraded to a bituminous sealed surface, or for a completely new roadbase. The intention could be the cost-effective use of suitable natural gravels where they occur close to the road site, and to improve them sufficiently to accept a thin bituminous surfacing. This activity has two components: an initial component of (typically 180mm compacted, unless otherwise stated in the Drawings or Bill of Quantities) laterite/gravel laid to camber, watered and compacted in two layers, followed by a (typically 70mm compacted) topping or armouring of crushed/broken stone aggregate laid to camber, watered and compacted. The first component may consist of the existing gravel/laterite road surface, scarified and with material added if necessary to achieve the required shaped and compacted thickness.

8.5 Composite Design Options

Another approach that maximises the impact of limited funds or resources is the use of a 'Spot Improvement', 'Composite' or 'Differential Improvement' strategy.

An example of this approach would be to provide an Engineered Natural Surface or even gravel surface along most of the route. However, on problem sections such as weak soils, hill sections, sections liable to flooding or next to housing, a higher grade (and higher cost) surface would be provided.

This approach allows a more appropriate, cost effective and flexible use of funds along alignments with variable road environments. It does however require an effective assessment of these environments prior to design and construction.

8.6 The Future Use of Gravel

The word gravel is used within this document to denote any naturally occurring granular material, including laterite gravel, used as a road surfacing material. The experiences also apply in many circumstances to (often more expensive) graded crushed rock aggregate. Gravel is a 'wasting' surface. Material is lost from the surface of the road due to the action of traffic and rainfall. The RRGAP (SEACAP 4) investigations quantified the performance of gravel as a road surface in a wide range of Vietnam environments. These investigations allowed guidelines to be developed advising that natural gravel should only be used for rural road surface applications in situations where certain conditions are fulfilled. In general, **gravel should not be used where**:-

- **Gravel quality is poor** – Gravel should comply with grading and plasticity requirements, and not break down under traffic, otherwise it will be lost from the surface at a high rate. Natural gravel quality varies substantially within each pit location and with depth. Great care is essential to ensure that only suitable material is selected, and that mixing of marginal/unsuitable material is avoided,
- **Compaction & thickness cannot be assured** – uncompacted surface gravel will be less durable. Supervision arrangements should ensure that the full specified compacted thickness is placed,
- **Haul distances are long** – if haul distances are longer than 10km, then other surface types may be cheaper in whole life cost terms. Hauling gravel for construction and periodic maintenance causes damage or further maintenance liabilities to the haul routes,
- **Rainfall is very high** – Gravel loss is related to rainfall and may be excessive with intense storms or where annual precipitation is greater than 2,000mm,
- **There are dry season dust problems** – long dry seasons can allow the binding fines to be removed from the surface by traffic or wind. This is particularly problematic where communities live beside the road or their crops and property are regularly coated in dust. Inhalation of road dust is unhealthy and there are also visibility-safety issues,
- **Traffic levels are high** – gravel loss is related to traffic flows. It is unlikely that a gravel surface will be cost-effective at traffic flows of more than 200 motor (2 or more axles) vehicles per day.
- **There are Longitudinal Gradients** – Gravel should not be used in low rainfall situations (< 1,000mm/year) on longitudinal road gradients of more than 6%. In medium rainfall areas (1,000 – 2,000 mm/year) gravel loss by erosion will be high on gradients of more than 4%.
- **Adequate maintenance cannot be provided** – Gravel is a high maintenance surface requiring both routine reshaping/grading and expensive periodic re-gravelling. Neither are achieved to adequate levels in many Emerging and Developing nations due to funding and operational constraints [13, 14] .
- **Sub-grade is weak or soaked (flood risk) –** Weak subgrades (in-situ foundations) require additional thickness of residual gravel to prevent traffic ‘punching through’ to the subgrade. Flooding can seriously damage gravel surfaces,

or,

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

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[13] In Cambodia it is estimated that a gravel rural road typically requires about US$1,600 per km per year for maintenance. These resources are simply not available on a national network basis - Rural Road Investment, Maintenance and Sustainability, A Case Study on the Experience in the Cambodian Province of Battambang, D Johnston and D Salter, May 2001.

[14] Roads 2000, a programme for labour and tractor based maintenance of the classified road network, paper for the RMI road maintenance policy seminar, Nairobi, R Petts, 2 – 5 June 1992.

Even in simple combinations of some of the above factors, gravel can be lost from the road surface at rates of more than 2cm per year[15], leading to the need to re-gravel at very frequent intervals[16]. The funding and resources are usually not available to achieve this and the surface will invariably deteriorate and revert to an earth surface.

These guidelines have been incorporated in the proposed surface selection procedures (Appendix H).

[15] 20mm per year of surface gravel assessed to be the limit of sustainable loss in Vietnam conditions.

[16] Required regravelling frequencies of 3 years or less are reported in some locations.

9 MAINSTREAMING AND DISSEMINATION

9.1 Current Status

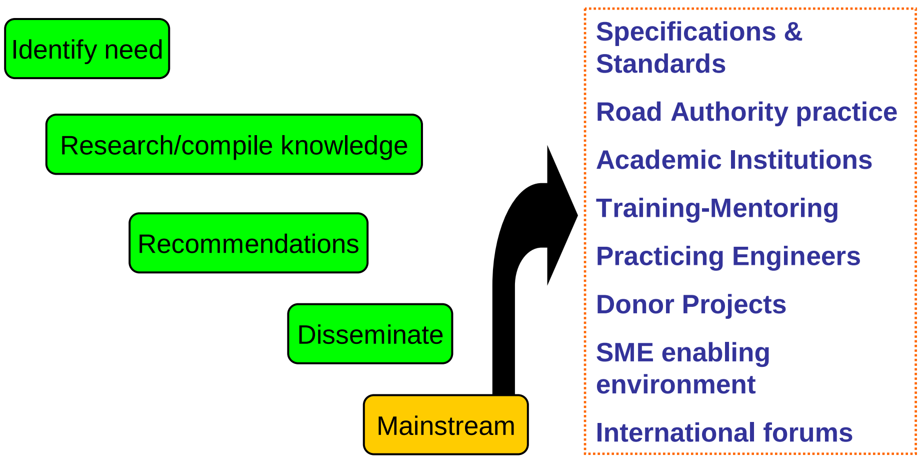
These activities were principally carried out under the arrangements for Modules 4 and 5 of the RRST-I, and Modules 1 and 2 of RRST-II.

9.2 Development of Project Linkages

Previous road sector research work has often been hampered in its application because of insufficient attention to the mainstreaming of the results and knowledge. Too often the outputs have been documents or reports which are in themselves insufficient to ensure the uptake and application of the knowledge.

Figure 9.1 shows the knowledge generation process and the need to develop improved dissemination as the final step.

Figure 9.1 – The SEACAP Knowledge Process



Mainstreaming has previously been the weak sector link!

Under the RRSR programme Intech-TRL has been working with the sector stakeholders to develop a framework suitable for mainstreaming the results of the research.

9.2.1 National Dissemination

The first mainstreaming target will be to incorporate the results of the RRSR into the Vietnam MoT National Standards. With this aim in mind, the Steering Committee was established with representatives of the key MoT departments and organisations. The composition of the Steering Committee is shown in Table 9.1. It is chaired by Dr Nhan, who is also head of the Department of Science and Technology (DST), which is the custodian of the Vietnamese national standards for rural roads. Acceptance of the results of the RRSR by the Steering Committee and DST will obviously be major steps in this mainstreaming process.

No.	Organisation	Name	Title
1	MoT	Dr Nguyen Van Nhan	Head of DST
2	TDSI	Dr Doan Thi Phin	Deputy Director
3	ITST	Dr Doan Minh Tam	Deputy Director
4	MoT	Tran Tien Son	RTU
5	MoT	Hoang Cong Quy	Head of RTU
6	PMU18	Tran Quoc Thang	Deputy Head of PID1
7	World Bank	Tran Minh Phoung	Senior Operations Officer
8	DFID	Ngo Quynh Hoa	Programme Officier
	Invited		
9	PMU5	Cao Van Hung	Vice General Director
10	VRA	Nguyen Trong Hien	Head of Local Transport Department

Table 9.1: RRST Steering Committee Composition

MoT policy development activities are supported by TDSI and the results of the RRSR will be able to be considered in future policy and strategy development through that forum.

Training of supervisory personnel is the responsibility of ITST and the follow up training initiatives will be facilitated by that organisation.

PMU18 has been instrumental in incorporating the RRSR research in the RT2 work programme of trials.

PMU5 will be the department responsible for the follow on Rural Transport Project 3 (RT3), into which it is intended that the rural road research will be incorporated. Representatives of PMU5 have been invited to recent Steering Committee meetings to facilitate this process.

Throughout the RRST-I and RRST-II, Intech-TRL have actively contributed to the dialogue on RT2 with MoT, World Bank and DFID as the programme was transformed from a principally gravel road construction initiative to ultimately a large scale trial of paved road surface and paving options roll out and as a foundation to RT3.

Through direct involvement with 12 provinces through the RRST-I and II (Table 1.1), Intech-TRL have facilitated the awareness creation, demonstration and support for alternative surface options.

The RT3 design consultants: Roughton International, were advised of the RRSR activities and preliminary findings so that this knowledge could be incorporated in the RT3 project preparation phase.

Papers have been prepared and disseminated to the Vietnam Road and Bridge Association.

Intech-TRL have identified a number of other agencies that are involved or interested in rural roads development and management in Vietnam. These are listed in Appendix J. Dissemination to this audience will be assisted by circulation of this Report to them.

9.2.2 International Dissemination

The results and knowledge developed under RRSR will be suitable for application or adaption elsewhere in the region and beyond. In recognition of this wider potential Intech-TRL has cultivated contacts with a number of organisations. Presentations and papers have been prepared and delivered to these sector interested bodies. The bodies and organisations include:-

- African Community Access Programme (AFCAP)
- ARRB
- Asia Development Review
- Asian Development Bank
- AusAid
- Cambodian Government and CNCTP
- Conference of ASEAN Federation of Engineering Organisations (CAFEO)
- Development Studies Association – UK (DSA)
- Global Transport Knowledge Partnership (gTKP)
- Government of Tanzania
- Greater Mekong Sub-region Academic and Research Network (GMSARN)
- ILO
- International Conference on Engineering Education (ICEE)
- International Focus Group on Rural Road Engineering (IFG)
- International Forum for Rural Transport Development (IFRTD)
- International Road Federation
- Lanka Forum for Rural Transport Development
- Government of Lao PDR
- Sri Lanka Government and various development projects
- Swiss Development Cooperation (SDC)
- UNOPS
- World Bank
- World Road Association (PIARC) Technical Committee 2.5 – Rural Roads and Accessibility
- Yunnan Province Highway Administration, Peoples Republic of China.

9.3 Utilisation of Information Technology

As part of the RRST-I programme, investigations were made into the options for website development for the knowledge developed through the RRSR. After extensive discussions and design, a RRSR website was developed and is now incorporated within the Rural Transport section of the MoT website (www.mt.gov.vn) with a direct click-on link from the MoT Homepage.

A good working relationship has been established between Intech-TRL and the website managers Informatic. Relevant news, RRSR reports and technical papers have now been uploaded and are available for viewing and downloading.

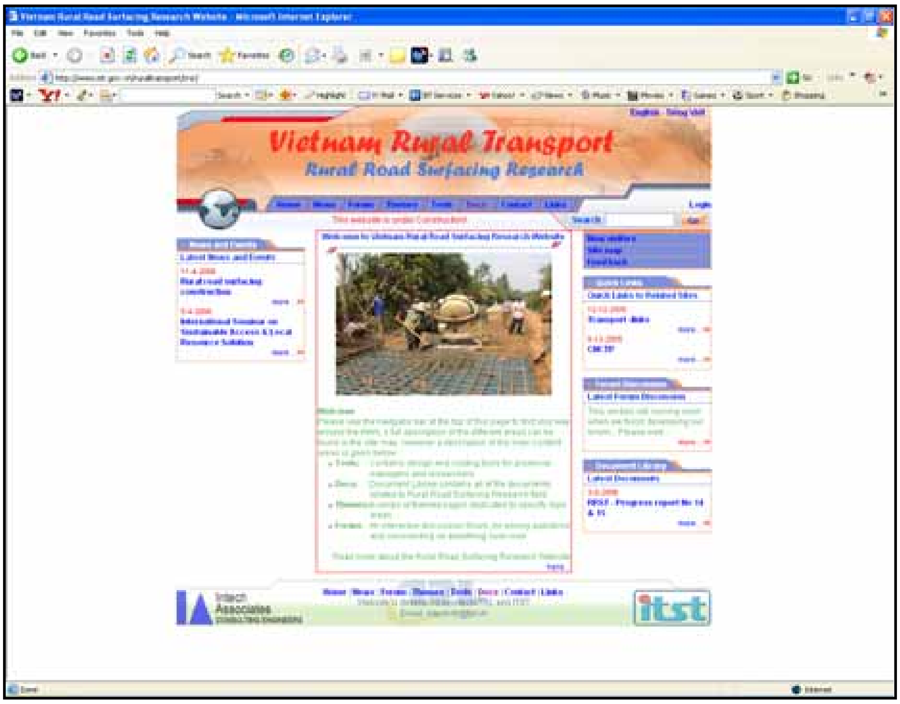


Figure 9.2: MoT Vietnam Rural Transport Website

Links to other relevant websites and sources of knowledge are also provided. Intech-TRL have actively promoted the web-posting and linkages to a number of important sector websites as exampled below:-

Figure 9.3: Innovation and Research Focus Website

Figure 9.4: gTKP Website

Figure 9.5: CNCTP Website

9.4 RRST Database

The RRSR database has been designed and compiled for holding, collating and disseminating Rural Road Surfacing Research information. This database is intended to eventually be the primary source of all RRSR information related to the following:

- RRST trial design layouts
- As-constructed trial designs
- RRST material testing and supervision results
- RRGAP field and laboratory information
- Short-term RRST monitoring
- Long term monitoring
- RRST trial specifications
- RRST cost norms
- Development of Vehicle Operating Cost data and local VOC relationships.

Data from the RRST-I and RRST-II works and investigations continues to be entered into this database.

9.5 Workshops and other Knowledge Events

The results and knowledge of the RRSR have been exchanged and disseminated at the following events in Vietnam and elsewhere (Table 9.2):

No	Date	Event	Participants
1	08 - 16 March 2004	Study tour in Kunming - China	RRST Steering Committee, ITST, Intech-TRL team
2	15-Jan-04	RRST-1 Knowledge Exchange Workshop in Da Nang	Intech-TRL team, RRST Steering Committee, PMU18, ITST, DaNang and Thua Thien Hue PDOTs, Local consultants and contractors
3	03-Mar-04	RRST-1 Knowledge Exchange Workshop in Tien Giang	RRST Steering Committee, PMU18, Intech-TRL team, ITST, Tien Giang and Dong Thap PDOTs, Local consultants and contractors
4	05-Sep-05	RRST-1 Knowledge Exchange Workshop in Hanoi	RRST Steering Committee, World Bank, DFID, SEACAP, PMU18, Intech-TRL team, ITST, PDOTs of 4 provinces of RRST-1 and PDOTs of 8 RRST-2, Local consultants and contractors
5	27 Nov - 1 Dec 2005	Study Tour in Siem Reap, Cambodia	RRST Steering Committee, Intech-TRL team, PMU18, DST-MoT; Representatives from Tien Giang and Hung Yen PDOTs
6	06 - 07 Dec 2005	RRST-1 Site Visit, DFID and AFCAP delegation visit to RRST-1 Mekong Delta trials	DFID and AFCAP personnel.
7	19-Jan-06	RRST-2 Knowledge Exchange Workshop in Hanoi	RRST Steering Committee, World Bank, DFID, SEACAP, PMU18, Intech-TRL team, ITST, PDOTs of 5 RRST-2 provinces of Tuyen Quang, Hung Yen, Ninh Binh, Ha Tinh, Quang Binh; Local consultants and contractors
8	09-Feb-06	RRST-2 Knowledge Exchange Workshop in Dak Lak	RRST Steering Committee, World Bank, PMU18, Intech-TRL team, ITST, PDOTs of 3 RRST-2 provinces of Gia Lai, Dak Lak and Dak Nong; Local consultants and contractors

Table 9.2: Workshops and other Knowledge Events

Appendix K lists the papers and presentations prepared and delivered by Intech-TRL personnel at various events to disseminate the knowledge developed under the RRSR.

9.6 Mainstreaming into MoT Policy and Practice

The Steering Committee is intended to be the principal instrument for Mainstreaming the knowledge developed under the RRSR and trials programmes. TDSI, through its membership of the Steering Committee will be able to facilitate adoption of the findings into MoT transport policy.

As with all trials and research work, the key mainstreaming activity will be the research follow up initiatives to ensure the assimilation of the findings of the research into the HQ and provincial practices and procedures, and professional, contracting and academic knowledge. This will require a longer term initiative associated with the intended Module 6 long term monitoring.

Discussions with stakeholders and through requests from the Steering Committee the Appendix H details the range of further initiatives that are required to facilitate mainstreaming of the RRSR outcomes.

9.7 Study Tours and Other Initiatives

A study tour was organised for a Vietnam delegation to visit the Cambodia Low Cost Surfacing trials in association with attendance at the PIARC – Royal Government of Cambodia seminar on Sustainable Access and Local Resource Solutions, 28 – 30 November 2005 (Details Table 9.2).

This was a major international initiative supported and facilitated by the SEACAP 1 project. The important international event attracted over 100 participants and the submission and presentation of 26 papers, giving the Vietnam delegation unique opportunities to meet and exchange with other sector practitioners.

An overseas delegation was invited to the Final RRST dissemination workshops in December 2006 to benefit from the Vietnam experiences.

The Intech-TRL team has made strenuous efforts to disseminate the experiences of the RRST-1 and RRST-II trials and SEACAP 4 gravel studies outside of the immediate project stakeholders:-

Papers and Presentations
The papers and presentations detailed in Appendix K were prepared and delivered to a range of forums and organisations including: gTKP, IFG, PIARC, AFCAP, The ILO, UNOPS, Sri Lankan Government, IFRTD, IRF, Laos Government, ARRB, AusAid, CAFEO, Development Studies Association, GMSARN, ITC Cambodia.

BBC Earth Report documentary transmission on Rural Roads
Intech-TRL provided advice and support to TVE for the scripting and filming of a documentary on rural road engineering using local resource based techniques. This documentary was transmitted worldwide in March 2006 as part of the BBC World Service Earth Report series. An accompanying bulletin was webposted relating to the documentary.

Vietnam Television Documentaries
With the assistance of the Intech-TRL team regarding scripting, background briefing and contributions to the filming process, VTV completed programmes for national television transmission on the work of the RRSR.

9.8 Further Work Required

The following key work components have been identified as required to complement and build on the already implemented RRSR initiatives, in order to improve the planning, design, construction and maintenance of rural roads in Vietnam in the future. These further research and knowledge initiatives are expected to have high benefit to cost ratios for the sector.

1. The current MoT Routine Maintenance Cost Norms are very basic and restricted in extent to a limited range of circumstances and surfaces. There are obvious inconsistencies in them. There is a need to update and extend these Norms and obtain official recognition so that they can be applied in their own right, and by the Cost Model users in justification of Construction and Maintenance planning, design and implementation.

2. The VOC relationships for Vietnam available through RT2 appear to have a limited research base. They can be used for designing the VOC sub-model in the next phase of model development, however it is recommended that further work is required to develop improved VOC- condition relationships in Vietnamese conditions.

3. Rural Sealed Road Assessment Programme (RSRAP) - This research is recommended as complementary to work undertaken on unsealed roads by the RRGAP. It would be aimed primarily at providing condition and performance data on RT1, RT2 and other rural roads that have been sealed using provincial funds and local designs. The research would be aimed at providing the following key outputs:
   - Information on the range of rural sealed pavement types and their costs,
   - The condition of sealed surfaces and their performance under current construction and maintenance regimes,
   - An assessment of the sustainability of current sealed surface types,
   - Recommendations on the use of local sealed designs as part of a staged construction strategy within RT3,
   - Added input in the rural surfacing selection matrix for use on RT3.

4. There is very limited data available on the current axle loading situation on the Vietnam rural road network. Further investigations are recommended in view of the potential very damaging effect of overloaded commercial vehicles.

No firm proposals are currently in place for this research. It is one of the activities listed as a possibility within a proposed extension to SEACAP1.

Appendix H provides a matrix and details of the further work recommended.

9.9 Future Dissemination & Mainstreaming in Vietnam and Internationally

As presented and discussed at the SEACAP 1 Dissemination Workshop (Section 9.10), a range of follow up initiatives are required to build on and maximise the benefit of the SEACAP rural road research carried out to date.

9.10 SEACAP 1 Dissemination Workshop

A workshop and site visit were organised to disseminate and discuss the outputs of the RRSR and RRST work, and to consider the necessary follow up initiatives to gain full benefit from this research and knowledge generation.

The Rural Road Surfacing Trials (SEACAP 1) Dissemination Workshop was organised in Hanoi on 6th December 2006. The event was attended by 103 domestic and international delegates from Vietnam, Lao PDR, Cambodia, Sri Lanka, UK, USA, Holland, Thailand, and from the International Development Agencies, Organizations & Consultants including World Bank, DFID, Asian Development Bank, UNDP, Crown Agents, ILO ASIST, IFRTD, UNOPS, WSPI, Scott Wilson etc..

19 presentations were made at the workshop concerning the rural road surfacing and gravel road research carried out by Intech-TRL and ITST under SEACAP 1 and 4. The participants were able to discuss a range of issues relating to the research and the required follow up to "mainstream" the findings into general road planning, design, construction and maintenance practice.

The participants were briefed that the research work has been guided by the MoT Rural Road Surfacing Trials Technical Steering Committee, and carried out under the Rural Transport 2 (RT2) project with funding provided by World Bank and DFID, and coordinated principally under the SEACAP programme.

Some of the delegates also participated in a site visit to selected trial roads in Hung Yen and Ninh Binh province on 7 December, including the opportunity to see and discuss a typical "gravel" road and discuss the issues and constraints related to their use in Vietnam.

The success of the Rural Road Surfacing Trials programme in Vietnam was acknowledged and it was agreed that the necessary follow up monitoring will be arranged to determine the performance and whole life costs of the various paving options. The intention is to use the research findings to update the existing Vietnam rural road standards.

The programme of the workshop is contained in Appendix N.

The various workshop presentations are available on:-

http://portal.mt.gov.vn:8089/ruraltransport/rrsr/

10 NEXT STEPS

10.1 Long Term Monitoring

The presentations and discussions at the SEACAP 1 Dissemination Workshop set out the progress and research results to date and emphasised the need to rapidly agree and establish the Long Term Monitoring regime to follow through on the initial phases of the RRSR programme. This will involve the monitoring of the performance and deterioration of the various RRST-I and RRST-II trial sections, the environments to which they are subject, and the maintenance requirements and arrangements made. As Figure 10.1 shows, the long term monitoring was envisaged and planned from the outset of the RRST initiative.

This assignment is not part of the currently contracted Intech-TRL work.

It will be essential that the monitoring work is planned and carried out in a systematic manner and that organisation(s) charged with this responsibility are both motivated and resourced to carry out the work to acceptable standards. Guidelines are currently being prepared for this work by Intech-TRL under an additional SEACAP commission.

It will be important to ensure that the monitoring work is implemented with an adequate QA arrangement to achieve the necessary quality and credibility with the Vietnamese and international stakeholders and beneficiaries.

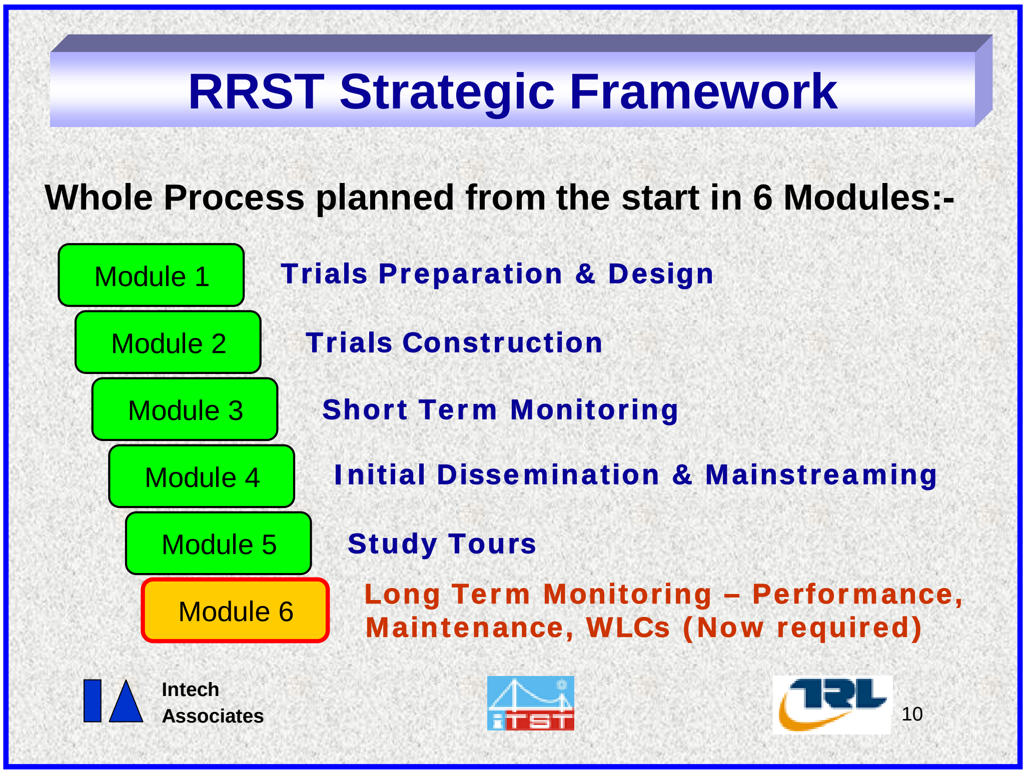


Figure 10.1: RRST Strategic Framework

10.2 Review of Dissemination Workshop and Final Report Recommendations

The contents of this report, the presentations of the 6 December 2006 SEACAP 1 Dissemination Workshop and the discussions and agreements at that event should be reviewed in detail and discussed by the principal stakeholders: MoT, RRST Steering Committee, DFID, World Bank, SEACAP management and the Vietnam provincial administrations.

Specific recommendations for building on the SEACAP rural road surfacing work and dissemination of the compiled knowledge have been made.

A concerted effort will be required to develop and resource the required follow on work.

The identified follow up initiatives are summarised in Appendix J.

11 CONCLUSIONS AND RECOMMENDATIONS

The RRST and RRSR research work has allowed the following Conclusions and Recommendations to be made regarding the planning, evaluation, design, construction and maintenance of rural roads in Vietnam:

- A substantial and valuable **database** of rural road surfacing knowledge has been established for the wide range of Vietnamese road environments, complementing previous rural road research,
- Further **monitoring** of the performance and maintenance needs of the RRST-I and RRST-II trial roads **is essential** as an important follow up RRSR activity. In this way new and revised Maintenance Norms will be able to be developed for the range of surface options, as well as road deterioration relationships for use in economic models and refinement of the design recommendations.
- The Rural Road **design** approach should be improved to incorporate issues of road task, road environment, local materials available, construction and maintenance regime,
- **Unsealed Gravel** surfacing is inappropriate for many road environment conditions. Clear criteria have been defined for its appropriate use.
- A wide range of **proven alternatives to gravel** surfacing is available – with better Whole Life Cost, Local Resource use & maintenance attributes in many situations,
- Some **paving techniques** are robust; others carry more risk,
- Improved **design of shoulders, drainage & earthwork slopes** is also desirable, It is commonly known to engineers that water or moisture is the enemy of roads. The trials have also highlighted the importance of designing all aspects of the road for the Vietnam environment: including drainage structures and system, earthworks, sub-grade, pavement, shoulders and slopes.

  Water needs to be prevented from entering the structure and foundation of the road pavement wherever possible, to avoid softening/weakening. Provision for subsurface drainage needs to be made for porous paving. Shoulders constructed of pervious materials should be sealed and maintained to prevent water ingress into the road pavement and sub-grade.
- A requirement has been identified for more appropriate **technical standards**,
- Greater emphasis on **appropriate surface and pavement selection** taking into account available resources, is desirable at PDoT level,
- A **Cost Model**, new **Cost Norms** and **Standard Specifications** have been developed for future management and technical application on rural roads in Vietnam.
- It is suggested that discussions should be held with sector stakeholders regarding the use and **adoption of the new Cost Norms** for the range of rural road surface options developed under the RRSR programmes.
- There are a number of **Rural Road Contracting Regime** issues that should be addressed to improve the performance of the sector and improve value-for-money for the considerable volumes of public funds invested. These include aspects of training and guidance for contractors and supervisors, contract documentation, contractor selection procedures, involvement and training of local consultants, improved supervision arrangements, promotion of appropriate plant hire, promotion of the optimal use of local materials, improved payment arrangements, improved quality assurance and testing regime.

- It is suggested that further major initiatives are required to tackle the awareness, funding, institutional, technical, management and operational deficiencies of the current **rural road maintenance** system.
- Due to the very limited data available on **high/over- loading** of commercial vehicles in Vietnam, and its potential for causing very extensive and expensive damage to existing road and bridge infrastructure, it is recommended that the incidence, extent and effects of this phenomenon should be further investigated.
- It is suggested that some further research is required into **Vietnam VOCs** before the RRSR experiences can be extended to full and robust Whole Life Costing using the established international economic models.

The **RRST Cost Model** developed under SEACAP 1 has demonstrated the following important conclusions regarding the planning and management of the rural road network:

- Road Maintenance is essential and justifiable,
- Materials Haul Distance is an important influential factor,
- The need to limit the application of gravel as a surfacing,
- Paving at relatively low traffic flows can be justified,
- The need for strategies that limit maintenance liabilities to manageable commitments,
- VOC assessment is vital to achieve an informed and total assessment for Rural Road decision making.