



ReCAP
Research for Community Access Partnership



Assessment of the SEACAP-WB LVRR Pavement Trials as Knowledge Resources for ASCAP/ReCAP Uptake

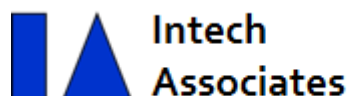
Scoping Study Report



**Intech Associates Ltd. in association with
Transport Development and Strategy Institute**

RECAP Project Reference Number: RAS2078A

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**Intech
Associates**

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<i>Quality assurance and review table</i>			
Version	Author(s)	Reviewer(s)	Date
1	Robert Petts	Les Sampson	10 June 2016
2	Robert Petts & Dr J Cook	Les Sampson	20.August 2016

ReCAP Project Management Unit
Cardno Emerging Market (UK) Ltd
Oxford House, Oxford Road
Thame
OX9 2AH
United Kingdom



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Abstract

The objective of this assignment is an assessment of the current status and content of the Vietnam Rural Road Surfacing Research (RRSR) database in particular and other regional surfacing trials knowledge, to assess the value in utilising it as a data resource for increased dissemination and uptake in AsCAP and possible AfCAP countries.

Low Volume Rural Road (LVRR) surfacing and paving trials construction was carried out between 2001 and 2012 in Vietnam, Cambodia and Laos under various initiatives. A range of materials and surface/paving types were trialled in various environmental and climatic conditions. There is a considerable amount of un-analysed performance data for a range of low cost surfacing types that is unique and could benefit the design and construction of low volume rural roads in the region and elsewhere. Analysis of this data could lead to guidance and significant cost savings in the provision of affordable and sustainable access to rural and poor communities in whole-life-cost orientated rural infrastructure asset management. The LVRR surface options could offer greater climate resilience than the currently widely used unpaved options.

This Scoping Report describes the background research carried out under SEACAP and other initiatives, the current status of the surfacing research data. It presents the rationale for the compilation, analysis and dissemination of the surfacing and paving research knowledge in the region and elsewhere.

Key words

SEACAP, LVRR, surfacing, paving, trials, performance, review, Cambodia, Lao PDR, Vietnam

Acknowledgements

Intech Associates would like to acknowledge the support and cooperation of TDSI and the Vietnamese, Cambodian and Lao PDR Government organisations that participated in the original SEACAP surfacing and paving trials and this follow up review. We would also like to acknowledge the contributions of Dr Jasper Cook who played a leading role in the original SEACAP trials and the establishment of the performance monitoring and database development. The personnel involved with the original SEACAP trials in Cambodia and Vietnam have also made valuable contributions to this study.

Acronyms, Units and Currencies

\$	United States Dollar (US\$ 1.00 ≈ provide conversion to local currencies)
ADB	Asian Development Bank
AfCAP	Africa Community Access Partnership
AsCAP	Asia Community Access Partnership
CDI	Individual Condition Deterioration Index
DBM	Dry Bound Macadam
DBST	Double Bituminous Surface Treatment
DCP	Dynamic Cone Penetrometer
DDF	District Development Fund
DEI	Defect Extent Index
DFID	Department for International Development
DRVN	The Directorate for Roads of Vietnam
e	Emulsion
EngKaR	Engineering Knowledge & Research (DFID programme)
ENS	Engineered Natural Surface
EOD	Environmentally Optimised Design
esa	Equivalent standard axle (80kN)
FY	Financial Year
LIC	Low Income Country
LMIC	Low and Medium Income Country
LVRR	Low Volume Rural Road
m	metre
km	kilometre
MERLIN	Machine for Evaluating Roughness using Low-cost Instrumentation
MOT	Ministry of Transport (Vietnam)
MRD	Ministry of Rural Development (Cambodia)
MSME	Micro, Small or Medium Enterprise
PDoT	Provincial Department of Transport
PMU	Programme Management Unit
RCDI	Road Condition Deterioration Index
ReCAP	Research for Community Access Partnership
RRGAP	Rural Road Gravel Assessment Programme
RRSR	Rural Road Surfacing Research
RRST	Rural Road Surfacing Trials
RT3	Rural Transport Program 3 (World Bank & Vietnam Government project)
SBST	Single Bituminous Surface Treatment
SEACAP	South East Asia Community Access Programme
TDSI	Transport Development and Strategy Institute (Vietnam)
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)
WBM	Water Bound Macadam

RESEACH FOR COMMUNITY ACCESS PARTNERSHIP (ReCAP) *Safe and sustainable transport for rural communities*

ReCAP is a research programme, funded by UK Aid, with the aim of promoting safe and sustainable transport for rural communities in Africa and Asia. ReCAP comprises the Africa Community Access Partnership (AfCAP) and the Asia Community Access Partnership (AsCAP). These partnerships support knowledge sharing between participating countries in order to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources. The ReCAP programme is managed by Cardno Emerging Markets (UK) Ltd.

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1. Executive Summary

The objective of this assignment is an assessment of the current status and content of the Vietnam Rural Road Surfacing Research (RRSR) database in particular and other regional surfacing trials knowledge, to assess the value in utilising it as a data resource for increased dissemination and uptake in ASCAP and possible AFCAP countries.

LVRR surfacing and paving trials construction was carried out between 2001 and 2012 in Vietnam, Cambodia and Laos under various initiatives; including EngKaR; SEACAP; World Bank Rural Transport Programme RT2 and RT3 in Vietnam and ADB 8 in Laos. A range of materials and surface/paving types were trialled in various environmental and climatic conditions. There is a considerable amount of un-analysed performance data for a range of low cost surfacing types that is unique and could benefit the design and construction of low volume rural roads in the region and elsewhere. Analysis of this data could lead to guidance and significant cost savings in the provision of affordable and sustainable access to rural and poor communities in whole-life-cost orientated rural infrastructure asset management. The LVRR surface options could offer greater climate resilience than the currently widely used unpaved options.

This Scoping Report describes the background research carried out under SEACAP and other initiatives, the current status of the surfacing research data, and presents the rationale for both the wider adoption of local-resource-based surfacing and paving options for LVR and in particular the compilation, analysis and dissemination of the SEACAP surfacing and paving research knowledge in the region and elsewhere.

2. Introduction

This project is concerned with reviewing the potential applications of investments in Low Volume Rural Road (LVRR) surfacing and paving trials by DFID, World Bank, ADB and the partner road agencies in Vietnam, Cambodia and Laos, implemented under the South East Asia Community Access Programme (SEACAP). All of the trials focussed on the use of local resources, particularly materials, and the optimisation of whole-life-costs of the infrastructure assets.

The objective of this project is an assessment of the current status and content of the Vietnam RRSR database in particular and other regional knowledge to assess the value in utilising it as a data resource for increased dissemination and uptake in AsCAP and possible AfCAP countries. The subsidiary knowledge bases in Laos and Cambodia have also been assessed. The Laos trials monitoring reports by OtB and Roughton have been reviewed. The status of the Cambodia Puok Market trials was investigated through a visit to the trials and discussions with senior officials at the Ministry of Rural Development in Phnom Penh.

The assignment has been carried out by Intech Associates in association with TDSI, Vietnam, between March and June 2016. The team leader visited Vietnam and Cambodia, and with the team members reviewed the available data, visited selected sites, discussed the trials and desirable follow up with relevant authorities. An assessment of the benefits of consolidation and analysis of the paving and surfacing research data and experiences has been made. The views of stakeholders on the best way forward were appraised. This assignment report documents the findings and dissemination material prepared.

The scoping study methodology has included the following activities:

1. Review of status of RRSR and other relevant databases (Chapter 7)
2. Review of relevant documents, papers and other relevant outputs (Chapter 8)
3. View representative sections of the trials in Vietnam and Cambodia (Chapter 7)

4. Set out the rationale for wider adoption of local-resource-based and climate resilient surfacing and paving (Chapter 5)
5. Identify how a final monitoring and analysis could cost-beneficially add significantly to the ASCAP/ReCAP evidence base (Chapter 5 & 9)
6. Identify a potential way forward by drafting an outline programme for undertaking final monitoring review (Chapter 9)
7. Consult with regional stakeholders and the upcoming AFCAP regional “Back Analysis” project regarding wider cooperation and dissemination possibilities (Chapter 9)
8. Recommend how to take this work forward as data resource for other ReCAP country and regional projects (Chapter 9)
9. Draft a short technical paper and associated PowerPoint presentation for use in future workshops and general dissemination purposes (separate documentation).

The linkages and support for the ReCAP logframe are particularly relevant. These are set out in Annex B.

3. Background

3.1 Overview

The Asian Community Access Partnership (AsCAP) is a programme of research and knowledge dissemination funded by the UK government through the Department for International Development (DFID). AsCAP is promoting safe and sustainable rural access in selected countries in Asia through research and knowledge sharing between participating countries and the wider community. AsCAP commenced on the 1st August 2014 with the management contracted by DFID to Cardno UK. One of the aims of the AsCAP initiative, under the overall Research for Community Access Partnership (ReCAP) umbrella, is to build on the programme of high quality research initially established under the SEACAP, (2004-2009) and a first phase of AfCAP (2008-2014) and take this forward in a sustainable manner so that the results of the research are adopted in practice and influence future policy.

The current AsCAP Regional Steering Committee has recognised the potential usefulness of the SEACAP research and basic data in terms of contributing to the current AsCAP programme. In this context the significant amounts of data on Low Volume Rural Road (LVRR) performance collected and analysed under SEACAP is seen as being particularly relevant.

3.2 Project Context

Because of increasing recognition that gravel surfacing was not always the best solution for rural roads in South East Asia, a series of DFID-funded surfacing trials were initiated in Cambodia in 2001 at Puok Market under the EngKaR programme, and extended to Vietnam (2003) and Laos (2006) under the SEACAP initiative. The vast majority of the research was undertaken between 2003 and 2012 in Vietnam where three phases of trial road selection, design and construction were undertaken under the Vietnam Rural Road Surfacing Trial (RRST) programme, under joint DFID-World Bank funding in cooperation with the Ministry of Transport. From 2009 to 2012 the monitoring and analysis was funded under the World Bank Rural Transport 3 Programme (RT3).

Under RRST, 156 km of trial roads have been constructed within a range of road environments in 16 provinces, from which representative sections were selected for ongoing performance monitoring.

In Cambodia, the initial trial road at Puok Market was subjected to severe overloading through unplanned and unauthorised exploitation of a local sand deposit. Under SEACAP 8 rehabilitation and repair was initiated and started in May 2005, with the major surface work items completed in late

July 2005. Monitoring of the trial continued until March 2006 with a regular visit programme at intervals of 2 months.

In Laos, the SEACAP 17 project designed and constructed in 2007 a series of trial sections along rural access roads being upgraded as part of the ADB funded section of the Northern Economic Corridor (NEC) within the Huay Xai district in Bokeo Province.

3.3 Related projects

The following projects are of particular relevance:

- In Vietnam: SEACAP projects 1, 4, 27 and the associated World Bank RT3, RT3 AF programmes.
- In Laos: SEACAP projects 3, 17, 17.02 and 31 and follow-on take up by KfW RIP Phases 1-V
- In Cambodia: SEACAP projects 2, 8, 19.

3.4 Project Partners

Intech Associates has established links with the relevant sector authorities in Vietnam, Cambodia and Laos.

Transport Development and Strategy Institute (TDSI) was a partner to Intech-TRL in the Vietnam surfacing trials planning, preparation and implementation. As an arm of the Ministry of Transport (MOT), Vietnam, the organisation provides access to the decision making system and knowledge uptake in the MOT and provincial administrations.

Ministry of Rural Development (MRD), Cambodia partnered the Puok Market rural road paving trials with DFID support through the EngKaR programme with Intech Associates designing and implementing the trials. MRD is responsible for policy and standards for rural roads in Cambodia.

AsCAP partner countries Nepal and Bangladesh have agreed that a project to capture and analyse SEACAP LVRR data could contribute significantly to a regional database of performance-based information that can be used and updated for research and practical low volume road projects both at national and regional level. Myanmar, a proposed new AsCAP partner, has also expressed interest in accessing the SEACAP outputs.

One of the tasks of this scoping study has been to establish support within AsCAP countries for a main follow-on phase of this project. There may well also be potential partners in AfCAP countries through the AfCAP regional “Back Analysis” project. There are considerable synergies in the technical, economic, environmental and operational challenges in the provision of affordable and sustainable LVR rural access in both regions.

4 Study Workplan

The work plan was essentially unchanged from the submitted proposal and is included in Annex A, with some additional detail and refinement on exact timing.

- This project was scheduled for completion within 14 weeks from start date during which time the service provider would work in cooperation with local organisations or personnel well acquainted with the SEACAP projects. The overall programme has been extended to allow for the ReCAP response to the Inception Report, and existing ReCAP and other commitments.

- The involvement of key players and stakeholders, particularly from the Vietnam RRST programmes, was an essential element of this work.
- Transport Development and Strategy Institute (TDSI) had a vital role as an interface with the MOT road sector responsibilities in Vietnam. Following on from its role in the original surfacing trials planning and construction, it facilitated access to the data and documentation relating to the trials and liaison with stakeholders regarding site visits. TDSI was also a key resource in identifying the decision making processes and identifying the follow up and uptake paths for the research within the MOT, provincial administrations and educational fora.
- MRD Cambodia has formally expressed support for the initiative and is eager to arrange for the surfacing research results to be reviewed and mainstreamed in its own Standards and Specifications.
- Because of his unique knowledge of all three trial programmes, including the post-SEACAP Vietnam work, it was agreed that the ReCAP Team Leader, Dr J R Cook separately contributed to the technical outputs of this programme through the PMU.
- In-country time of around 3 weeks for the Intech Team Leader was to be focussed on Vietnam with a short visit to Cambodia included.
- The Consultants arranged for the supply of in-country administration back-up, translation services and facilitate any necessary visas, letters of introduction etc., as well as any required in-country transport. Office accommodation was arranged by the Consultants.

The acquisition of relevant information and reports from World Bank, Asian Development Bank and KfW and the relevant local Ministries was the responsibility of the Consultants and their associates.

5 Rationale for LVRR Local Resource Based Surfacing & Paving

5.1 The Effectiveness of Unpaved Roads

Engineered Natural Surface (ENS) roads are the most basic, and low cost, form of road transport infrastructure. They utilise existing or immediately adjacent materials along an alignment to form a shaped and drained low cost basic rural access road. The nature of these natural materials can vary from clayey/sandy soil to weathered rock. Materials with a CBR of about 12 or more are usually suitable for motorised traffic of up to 50vpd or greater. The surface may be effectively un-serviceable in periods of heavy rain. However, essential annual routine maintenance of camber reshaping and drainage is required to keep the surface serviceable at other times. Even this low cost level of regular intervention is beyond the resources and capacity of many road authorities in emerging nations for minor routes.

The next level of investment, and widely used by many road authorities, is a natural gravel or laterite surface. However, most authorities have found difficulties in sustaining gravel surfaces and few manage to resource and carry out the high levels of routine maintenance and periodic re-gravelling required. There is little evidence of periodic maintenance re-gravelling on the extensive unpaved road networks of Cambodia, Laos and Vietnam in the SEACAP region. The problem is also common and has been longstanding in many African countries (Annex E).



Figure 5.1 - Rural gravel road in Cambodia after one rain season and without maintenance.

In many countries there are now serious problems with sourcing natural gravel deposits within reasonable haul distances, and that comply with acceptable grading and plasticity criteria.

Realisation of the problems associated with gravel surfaces in Vietnam led to the Rural Road Gravel Assessment Programme (RRGAP) performance study by Intech-TRL (Cook & Petts, 2005), funded by DFID under SEACAP4. The main RRGAP investigations, carried out by Intech-TRL at 766 road sites, found

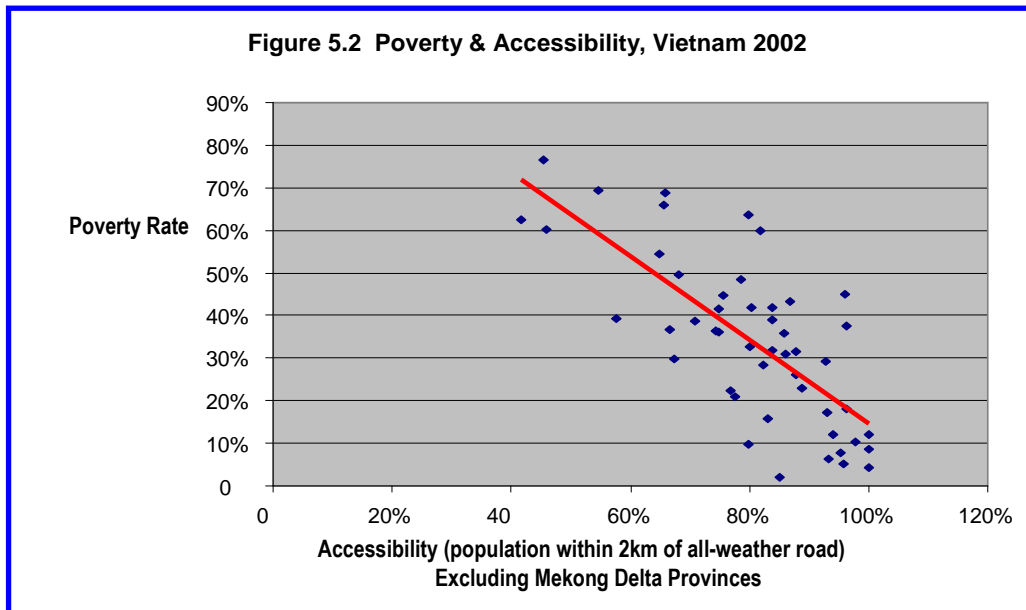
serious constraints to the use of gravel in most of the studied 16 programme provinces due to factors relating to material quality, material availability, climate, terrain, drainage provision and maintenance. Overall gravel loss figures indicate that around 58% of the surveyed sites were suffering unsustainable deterioration, while 28% were losing surface material at twice the sustainable rate. From the RRGAP investigations, and consideration of other complementary research and knowledge of the performance of gravel roads elsewhere, guidelines were proposed for the restriction and use of gravel as a rural road surfacing.

These guidelines highlighted the limitations of gravel surfacing applications and the need for robust, researched criteria for the range of local resource based surfacing and paving options that generally provide lower maintenance, and certainly better whole life cost attributes, than unpaved surfaces in a weak maintenance environment typical of emerging economies.

5.2 Poverty Alleviation

A further and vital consideration is the relationship between poverty incidence and access to an all-weather road. Un-maintained earth and gravel roads cannot be categorised as 'all weather'. 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 5.2 from the SEACAP 1 Final Report).

The essential link between poverty incidence and all season access is clearly demonstrated.



Source: Vietnam 2002 Living Standards Survey

5.3 Technical, Social and Economic Issues

There is a range of alternative low-cost surfacings which are already proven and used in various locations around the world. Unfortunately, many national Specifications do not recognise or exclude these surface options and therefore they cannot be specified or used under normal contract arrangements.

Many of these options optimise the use of local materials and other available resources and could have superior durability and whole life cost attributes, compared to unpaved, and certainly un-maintained, surfaces.

Many of the options can use labour-based approaches, and can generate up to 1,500 worker-days per km during construction. The local communities (particularly the poor and otherwise un- or under-employed) would benefit considerably from their adoption in terms of productive work creation, empowerment of groups that currently are severely disadvantaged, and local enterprise creation. These advantages are in addition to the economic benefits to the poor communities through provision of improved infrastructure that would otherwise not be provided, and tackling poverty through creation of increased social and economic opportunities in the communities. Appropriate use of the various surfacing options would depend on local circumstances.

The labour-based techniques can create equal opportunities for female employment where properly managed and social traditions are approached sensitively with suitable consultation. The alternative surfacings are often low maintenance so that they would considerably ease the financial and (often intractable) institutional burdens on road authorities and communities. Organisations, enterprises and community groupings with limited resources and skills could use them. The alternative surfacings would also provide considerable environmental benefits. They should be more sustainable and climate resilient.

There is also considerable potential to use the alternative surfacings on short particular problem sections such as through villages, on weak subgrades and hill sections; effectively a 'spot improvement', 'Environmentally Optimised Design – EOD', or basic access approach, for situations

when resources are particularly constrained. Considering the wide range of circumstances and factors, which usually vary along a road route, it is often appropriate to specify different surfaces and paving thicknesses for sections of different characteristics.

A particular constraint is that the alternative surfacing techniques are often not properly documented and accessible; decision makers are usually not aware of the options, potential, requirements, appropriate specifications, cost and benefits.

The DFID funded Systematic Review of technology selection for low-volume, rural roads in low-income countries (Burrow et al, 2015) made an important Policy and Practice recommendation:

‘To appreciate the very different resource environment in LICs/LMICs, which is characterised by the scarcity and high cost of finance/capital for the private sector, low labour costs, the availability of usable non-standard materials, typical overdependence on imported materials, skills and equipment, and a weaker institutional support framework. This necessitates the development of more sustainable and local resource-based technologies, such as those identified in this review, and operationally effective asset management systems.’

There is therefore an urgent need to document the extensive local-resource-based SEACAP surfacing trials experiences and develop usable guidelines to enable road authorities to be informed of, review, adapt, adopt and mainstream the range of alternative, affordable, robust and sustainable surfacings suitable for their physical and operational environment.

5.4 Capital Requirements

The road sector in many emerging economies is usually dominated by a relatively small number of large, locally owned or foreign enterprises using capital intensive methods. Predatory pricing by foreign or subsidised enterprises can even undermine established local capacity. There are large capital investment requirements in terms of specialist equipment, such as asphalt hot mix plant, dedicated single function heavy plant and large haulage fleets. Typical conventional roadworks fleet capital requirements are usually well in excess of US\$1 million equivalent. In an economic environment where credit is severely restricted or very expensive (typical interest rates of 15-35% p.a. – recent research by Intech), this can lead to an imperfect market with distorted prices and great difficulty for Micro, Small and Medium Enterprises (MSMEs) to enter or compete.

The SEACAP trialled surface options are generally very low in equipment capital requirements and intermediate equipment options are available (Petts, 2012) and are ideal for MSME implementation. Furthermore, many of the equipment items required have commonality with other sectors (e.g. concrete mixing and small compactors for the building sector, or tractor hauling, mixing etc. with the agricultural sector) and are often available to hire on the local market. Dry hire rates of the order of US\$ 10 -50 per day are often achievable for the limited number of individual intermediate equipment items required for the alternative surface techniques. This substantially reduces the MSME capital requirements, as they can often hire in such equipment only when they have contract work requiring their application if contract arrangements allow.

The opening up, and promotion, of the LVR sector to local MSMEs and the adoption of alternative surfacing and low capital equipment methods would make road provision and maintenance more competitive, affordable, achievable and sustainable in many emerging economies.

The considerable benefits of the permissible use of low capital and intermediate equipment use needs to be recognised and allowed in Surfacing and Paving Specifications and contract arrangements/documentation.

5.5 Climate Resilience

The climatic environment in S E Asia, with its variability and frequency of extreme weather events, makes AsCAP and former SEACAP partner countries highly susceptible to climate impacts. At the same time, it is increasingly acknowledged that rural transport infrastructure is particularly vulnerable to climate threats and associated impacts. The risks arising from these impacts are considerably increased when the likelihood of increasing climate threats from future climate change is taken into account. There is therefore an increasing focus on identifying and applying cost-effective approaches to increasing the climate resilience of rural roads that takes in account the local road environments and the constrained budgets within which most road authorities have to work.

There is wide range of possible interventions required to make roads more climate resilient (Table 5.1) and one of these is the replacing existing earth or gravel surfaces with more erosion resistant options such as bituminous seals, concrete, stone, bricks or concrete blocks. It is important to note that improved surfacing is only one of a number of potential interventions, there has nevertheless, recently been an appreciation that the SEACAP surfacing trials, and the Vietnam RRSR trials in particular, are a valuable source of information on the climate resilience of surfacing options.

Table 5.1 Engineering Climate Resilience Options

Ref.	Adaptation Option	Comment
1	Pavement sealing	Pavement sealing particularly recommended for steep gradients (>8-10%).
2	Additional or enlarged culverts	Additional or enlarged or improved existing cross culverts considered essential to improve overall road drainage.
3	Side drainage.	Additional side drains and associated turn-outs. Scour checks where necessary, Lined drains required with gradients >6%.
4	Raised embankments	Raising of earth embankments where the alignments are low and is being impacted by flooding and/or the weakening of the pavement by saturation.
5	Culvert or bridge abutment protection.	Gabion, concrete, masonry or bioengineering protection where erosion of abutments is identified as a significant risk.
6	River/stream erosion protection	Gabion, concrete, masonry or bioengineering protection where erosion of the alignment by rivers or streams is identified as a significant risk.
7	Cut and fill slope protection	Gabion, concrete, masonry or bioengineering protection where erosion or deterioration of existing earthwork slopes is identified as a significant risk.
8	Re-alignment	Re-alignments where an identified climate impact hazard and consequent engineering risk may be most cost-effectively overcome by avoidance.
9	River/stream crossing	Existing fords or low level bridges might be replaced by climate resilient structures such as vented fords, or submersible multiple culverts.

The specific threats and impacts will vary from country to country but the overall scenario holds true not only for Asia but also for Sub-Saharan Africa.

There are currently a series of ReCAP projects, potential projects and associated projects where climate resilience is of central importance and where further assessment and analysis of the SEACAP trials could provide a cost-effective source of additional climate resilience data:

- AfCAP regional project: GEN2014A: Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access.
- AsCAP regional project: P170, Increasing Rural Access sustainability through climate-focused LVR maintenance
- Myanmar: AsCAP National Project (Planned) on developing appropriate rural standards and specifications.

- Myanmar: KfW funded Rural Road Development programme, Taunggyi, Shan State, 2014-16
- Myanmar: ADB funded rural roads programme, initially in three trials areas and including road trial, 2017-2020 (Linked to AsCAP).

The funding, resourcing and delivery of road maintenance is now one of the greatest challenges for governments and road authorities for low volume roads in emerging nations. For decades the leading agencies in the sector have been promoting the economic justification for effective maintenance. However, in 1981 a World Bank study reported that *“The evidence is abundant that satisfactory basic systems (of road maintenance) can seldom be established in less than fifteen or twenty years and that help may still be needed thereafter to deal with expansions of maintenance workload and avoid retrogression”*.

The road maintenance problems have been extensively investigated since. However, they are still almost universally prevalent in emerging nations. The complexity and range of interconnecting political, financial, economic, technical, human resources and technical issues make the maintenance challenges seemingly intractable. However, one of the approaches that could substantially reduce the LVR network maintenance burden and increase climate resilience, would be the wider use of more durable and sustainable, and intrinsically lower maintenance surface options. Often, these alternative surfaces have significant net benefits in whole-life-costing terms. However, political and management decision makers often do not have access to the compiled knowledge that would facilitate the uptake and application of these options.

5.6 Need for International Guidelines based on the available Knowledge Base

From the foregoing considerations it is evident that there would be considerable economic, social and climate resilience benefits in South East Asia and in Africa from the compilation and analysis of the extensive and unique SEACAP surfacing and paving trials data into an international guidance document to facilitate and enable local-resource-based alternative techniques to be considered, adapted and adopted for local LVR application by national road authorities.

5.7 Whole-Life Costs and Cost-Benefit

A simple Cost Model was developed under the RRST SEACAP 1 project which considered only the costs associated with the road agency; that is construction and maintenance costs. The aim was to facilitate the assessment of Whole Life Asset Costs for the for the options trialled. Construction costs and Norms were developed for Phases I and II of the trials that were 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 model was developed in terms of Whole Life Road Assets; that is excluding vehicle operating costs (VOCs) due to the difficulties at that time obtaining truly representative VOCs for Vietnam. The cost model was designed with the intention that a later edition would be able to accommodate an optional VOC sub-model. The model introduces a menu of appropriate rural road pavements with the road /asset/ agency whole life cost details (construction and maintenance costs) of each option, suggesting the most appropriate options for each defined local road environment.

The essential inputs for the model are

- 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, related to region,
- Material sources and haulage distances to the site.
- Traffic volume
- Axle load
- Costs associated with the above

And outputs are:

- Construction cost of the selected option per km (with defined surface width),
- Maintenance cost per km in terms of present cost,
- Maintenance cost per km in terms of NPV.
- Whole Life Asset Costs for the road agency

The model was 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 model introduced a menu of appropriate rural road pavements with the whole life cost details (construction and maintenance costs) of each option, suggesting the most appropriate options for each defined local road environment. The initial menu was based on the early research findings of the RRGAP, and RRST-1 and RRST-II trials.

The Cost Model was complete to a functional state and could be used to analyse a range of options based on the RRST trials experiences. Further work was intended to fully develop the model to encompass all surfacing options for all possible environments encountered in Vietnam. The maintenance relationships were tentative only and needed to be refined in the light of the planned RRST long term monitoring data capture. The development of a VOC cost sub-model was also recommended to achieve a total transport whole life cost model capability.

It was expected that the further work on the model would have followed with later phases of SEACAP. This did not occur and hence the model requires further development work; nevertheless, the basic cost-norm data and initial model framework exists. Together with the accumulated performance data, this provides an ideal low-cost base from which to undertake additional whole-life cost and cost-benefit analyses on a range of sealed and unsealed LVRR options within a series of low volume rural road environments that could be of significant use to AsCAP and AFCAP partner countries.

6 Study Inception Phase

6.1 General Information Identification

During the inception phase, the project partners were engaged and briefed on the assignment aims and activities. The locations, nature and extent of the Vietnam RRSR database were investigated and the relevant documentation has been identified and consolidated. The following sections summarize the information identified.

6.2 Trials Constructed

The bulk of the trial construction was undertaken between 2003 and 2012 in Vietnam where three phases of trial road selection, design and construction were undertaken under the Vietnam Rural Road Surfacing Trial (RRST) programme, under joint DFID-World bank funding. In RRST I short sections (100m to 200m) of different trial option were constructed on single roads whilst in the second RRST II phase longer sections (0.5km to 2.0km) were constructed with less variation on each road. A third phase of trials construction (RRST III) in five further provinces was completed in early 2012. These additional trials mean that there is an almost complete coverage of typical rural road environments found within Vietnam.

In Cambodia, the original Pouk market trials were contracted in 2002 on a rural road at Puok in Siem Reap province, under the DfID funded EngKaR programme in a cooperation with ILO and MRD. SEACAP later took over the rehabilitation and monitoring of 10 short sections of pavement and surfacing options.

In Laos SEACAP funded the design, construction and some limited monitoring of 26km of LVRR trials, constructed under ADB funding, consisting of eight options within one northern hill region.

The trialled options are listed in Table 6.1 and the range of trialled bituminous seals and their trial environments is summarised in Table 6.2.

Table 6.1 Range of Trialled Options

Trial Options	Cambodia	Vietnam			Laos
	Puok	RRST-I	RRST-II	RRST-III	Bokeo
SEALS					
Double emulsion chip seal - DBSTe			2006	2011	
Double bitumen chip seal - DBST	2002		2006	2011	
Emulsion sand seal over single chip seal - S/SBSTe		2005			
Single emulsion sand seal - SSe	2005	2005	2006		
Double emulsion sand seal - DSe					2006
Otta Seal - OTTA					2006
Double Otta Seal - OTTA2					2006
UNSEALED SURFACES					
Gravel Wearing Course	2002	2005	2006		2006
Water-Bound Macadam (WBM)		2005	2006		
Hand Packed Stone	2002				2006
Engineered Natural Surface					2006
SEALED BASES & SUB-BASES					
Water-Bound Macadam (WBM)	2002	2005	2006	2011	2006
Dry-Bound Macadam (DBM)		2005	2006	2011	
Emulsion Stabilised Sand		2006			
Cement Stabilised Sand		2005		2011	
Lime Stabilised Clay Soil		2005		2011	
Graded Crushed Stone				2011	
Natural Sand		2005			
Sand-Aggregate Mix	2002				
Natural Gravel	2002	2005	2006	2011	
BLOCK SURFACES					
Stone Setts/Cobble Stone	2002	2005	2006		2006
Fired Clay Brick		2005	2006	2011	
Concrete Brick		2005	2006	2011	2006
CONCRETE					
Steel Reinforced		2005	2006		
Bamboo Reinforced	2002	2005	2006		2006
Non-Reinforced			2006	2011	
Cast in Situ Blocks (Hysen Cells)					2006

Notes: 2005 etc. Year of original construction

Puok Trials upgraded in 2005 under SEACAP

Table 6.2 SEACAP, ADB and World Bank Trials in S E Asia

Region	Trial Terrain	No. of Bituminous Trials Sections per Geographical Unit							
		DBSTe	DBST	PMac	SSe	DSe	S/SBSTe	OTTA	OTTA2
Vietnam									
Mekong Delta	Flat deltaic			4	2		2		
South Central Coast	Flat coastal			4	2		2		
North Central Coast	Flat coastal-small hills	7	11						
Central Highlands	Rolling hills	9	3	2			4		
Red River Delta	Flat coastal-deltaic	7	18		4				
North East	Rolling hills	10	6						
Lao PDR									
North West	Rolling hills				1	1		1	1
Cambodia									
<i>Central</i>	Flat inland plain	1**		4	1				

6.3 Trials Monitoring and Database: Vietnam

Under the three phases of RRST a total of 156 km of trial roads have been constructed within a range of road environments in 16 provinces, from which a representative 123 sections of between 80m to 200m in length have been selected for ongoing performance monitoring,

Table 6.3 The RRST monitoring programme, Vietnam

Trial Phases	Provinces	Trial road completed	Monitoring times									
			SEACAP I				SEACAP 27			RT3	RT3 AF	
Monitoring survey round			AS built	I	II	III	IV	V	VI	VII	As built	I
RRST-I	Hue	May-05	Jun-05	Jan-06	Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Jul-10		
	Tien Giang	May-05	Jul-05	Jan-06	Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Jul-10		
	Dong Thap	Jul-05	Jul-05	Jan-06	Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Jul-10		
	Monitoring survey round				As built	I	II	III	IV	V		
	Da Nang	Jun-06			Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Jul-10		
RRST-II	Tuyen Quang	May-06			Jul-06	Mar-07	Jan-08	May-08	Jan-09	Jul-10		
	Ha Tinh	Jun-06			Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Jul-10		
	Quang Binh	Jun-06			Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Jul-10		
	Ninh Binh	May-06			Jul-06	Mar-07	Dec-07	May-08	Jan-09	Jul-10		
	Hung Yen	Jun-06			Jul-06	Mar-07	Dec-07	May-08	Jan-09	Jun-10		
	Gia lai	Jun-06			Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Aug-10		
	Dak Lak	Jun-06			Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Aug-10		
	Dak Nong	Jun-06			Jul-06	Mar-07	Jan-08	Jun-08	Jan-09	Aug-10		
	RRST-III	Cao Bang	Mar-12									Mar-12
Thai Nguyen		Mar-12									Mar-12	Sep-12
Thai Binh		Apr-12									Apr-12	Aug-12
Thanh Hoa		Apr-12									Apr-12	Sep-12

The monitoring of the completed RRST trial pavements involved the systematic collection of the following data:

- Visual condition: using numeric coded sheets.
- Roughness: using low cost simple apparatus (MERLIN¹).
- Strength: using Structural Number correlations derived from simple in situ tests (DCP²).
- Gravel loss (where appropriate): cross-sectional leveling.
- Traffic: 12 hour traffic counts (3 or 6 day).

1 MERLIN: **M**achine for **E**valuating **R**oughness using **L**ow-cost **I**nstrumentation

2 DCP: **D**ynamic **C**one **P**enetrometer

- Photographic records.

The condition monitoring of the Vietnamese trials has resulted in the assembly of significant amounts of data on the performance of a wide variety of pavement and surfacing types over a 6-7 year period. The RRST database was developed as a means of managing and analysing this wide range of data on rural road surfaces and pavements in Vietnam. The database includes information on:

- Trial pavement designs.
- Construction costs.
- As built condition.
- Change of condition with time.
- Traffic.
- Physical and climatic environments

The RRST information is being held principally in the Rural Road Surfacing Research (RRSR) database whose structure was set-up in 2009 under the SEACAP 27 project. This current scoping study defines the current status of this database which was handed over to the MoT in 2009. Additional data relating to the RRST III trials design and construction as well as data from WB- funded surveys in 2010 and 2012 has been added. This updated database is currently held by OTB Engineering Ltd, who were the principal consultants in the latter stages of the project.

The original RRSR database was made up of 3 principal components;

- Data from a parallel rural roads gravel assessment programme RRGAP (SEACAP 4) on unsealed rural road condition data
- The RRST condition monitoring data and additional RRSR support data
- Associated guides and specialist software.

Data is held within 4 principal folders;

- 1. RRGAP:** Contains data files from the Rural Road Gravel Assessment Programme (SEACAP 4)
- 2. RRST-M:** Contains data files from the RRST-I and RRST-II trials construction and monitoring programme up to and including January 2009.
- 3. RRST-P3:** Contains data files from the preliminary design stages of the RRST-III programme up to June 2009.
- 4. RRST-Costs:** Contains information on the RRST construction costs and the draft RRSR Whole Life Cost Model from SEACAP 1

The relevant software and guidelines are contained in a separate folder.

Addition limited, but still valuable, condition data is available from the less regularly monitored trials in Laos and Cambodia.

The key references are listed in Annex C.

Trials History: Cambodia

The construction of Pouk Low Cost Surfacing Trials in Siem Reap Province, Cambodia was completed in September 2002 under a cooperation agreement between Intech Associates and ILO Upstream Project, utilising DFID funding provided under the EngKaR programme. The work was carried out under the authority of Ministry of Rural Development (MRD) and in cooperation with the Ministry of Public Works and Transport (MPW&T), Cambodia using local resource based approaches utilising

two local contractors with the aim of demonstrating techniques that maximise the use of local labour and materials.

An objective was to trial more sustainable rural road surfacing alternatives to problematic gravel/laterite, in view of the widespread scarcity of good gravel materials in Cambodia, long gravel haul distances, high rates of gravel losses from road surfaces and problems of funding and achieving maintenance of gravel roads.

The location of the Puok Trials is shown in Figure 6.1

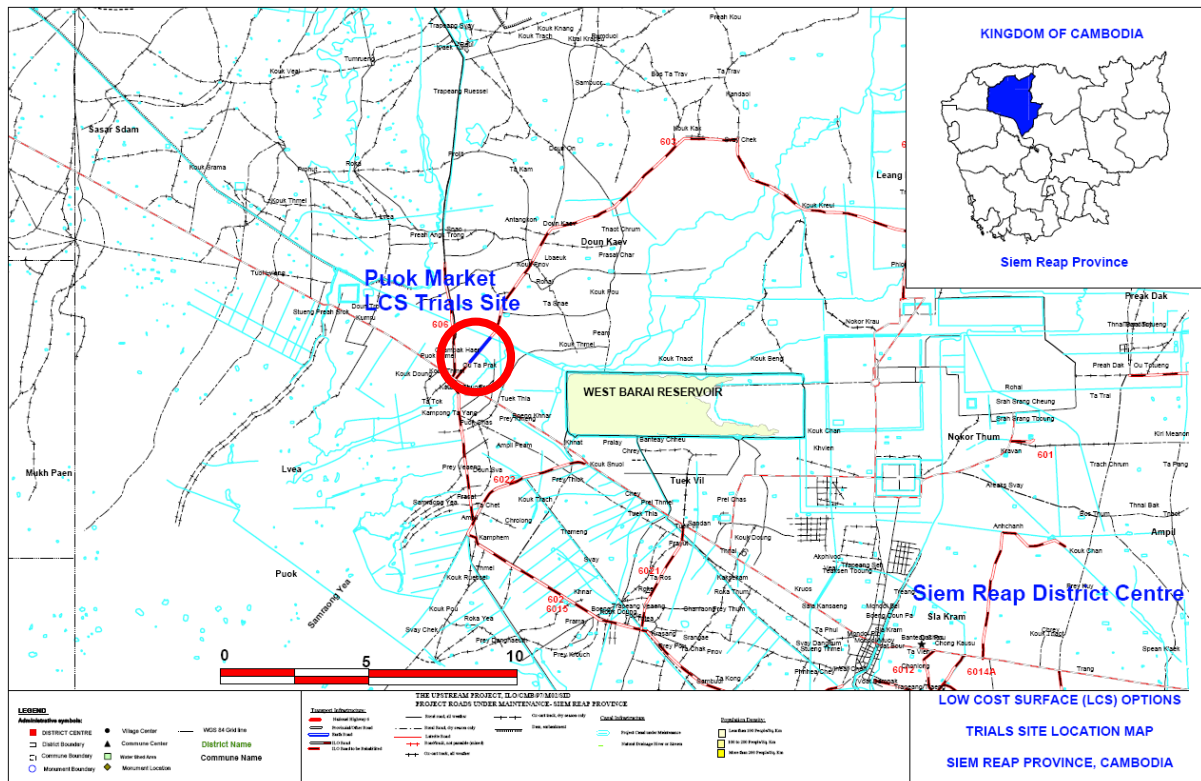


Figure 6.1 - Location of Puok Trials (marked in thick blue line –)

An initial monitoring of the surfacing trials was undertaken in April-May 2003, all trials road sections were found to be in good condition.

In February 2003, a sand deposit was discovered close to the road trial site and an unauthorised commercial extraction operation was commenced to exploit the sand to supply many of the buildings and hotels being constructed in Siem Reap; the large provincial town nearby. Large 3-axle trucks with extended bodies were used with excessive (and illegal) axle loading to haul along the trial road; well beyond the rural road design criteria used for the trials site. Discussions took place with the Puok District authority; the Project Research Engineer warned that the excessive overloading would damage the Trial Road and it was agreed that the District Authority would advise the principal haulage company to reduce their payloads. Despite these efforts the heavily overloaded trucks continued to carry sand through the LCS trials. This was exacerbated in the rain season as the sand was wet and the road was at its weakest state in the annual climatic cycle. In August 2003 during the routine monitoring visit, the first signs of failure appeared on Trial Section 4 with cracking affecting

two areas of approximately 4 square metres. By October 2003 the damage was already extensive and Intech carried out the first investigations of the pavement distress and causes.

In January 2004, an Intech Associates technical team visited the trial site to carry out a full survey. It was found that 80% of Trial Section No 4 and 20% of Trail Section No 9 had become severely damaged and some of the other sections were also showing signs of distress.



Figure 6.2 - Overloaded Truck on the Puok Trial Road (Section 4)

After the January visit, a rehabilitation and repair proposal was submitted to DFID through the SEACAP programme. The proposal was approved as “SEACAP-8 Cambodia Low Cost Surfacing Phase II”.

The rehabilitation and repair of Phase II was started in May 2005 and the major surface work items were completed in late July 2005. Monitoring of the trial continued until March 2006 with a regular visit programme of every 2 months. It was necessary to carry out deterrent measures to prevent the large trucks from continuing to use the route. Deterrent measures are still in place today to prevent passage by anything larger than a small truck.

The details of the trial sections and the rehabilitation works are detailed in Annex F.



Figure 6.3 – Heavy Vehicle restriction measures adjacent to the Puok Trial Road Sections

Trials History: Laos

SEACAP 17 aimed at identifying cost- effective methods of improving all-year access to the rural poor through low-cost, local resource based improvement of problematic lengths of road, resulting in effective and sustainable rural access roads in Lao PDR.

The project was implemented to carry out research on a group of rural access roads in Houay Xai district of Lao PDR in conjunction with the Asian Development Bank (ADB), which funded the associated Northern Economic Corridor Project (NEC) Route No 3 (R3). The project required close collaboration between the Ministry of Public Works and Transport, ADB, SEACAP and the Consultant.

The location of Route 3 and the SEACAP 17 project area is shown in Figure 6.4.

Figure 6.4 - Location of NEC and SEACAP 17 Project



The upgrading of R3, to which the project access roads connect, places additional emphasis on the need to upgrade the access roads so that the benefits of the R3 improvement are spread as widely as possible. For this reason, a set of 3 contracts were let, each covering a package of access roads, alongside the main contracts for R3 improvement.

The approach taken to setting up the project was that trial sections should not be isolated on different parts of a road, but should be assembled together on complete roads.. The selected roads were solely in Package 1 of the three construction package format used to construct the access roads along the R3 road. All roads that contain a trial section became a SEACAP Access Road in their entirety. The access roads selected, totalling 28.2 km, are listed in Table 1 and are shown graphically in Figure 9.4. The adopted approach was on selected links to replace standard NEC gravel pavement with SEACAP trial pavements.

The construction of 12 trials sections and associated seven gravel control sections was completed in August 2007. This was followed by an initial as-built condition survey which was also intended to provide the base-level data for a future condition monitoring programme.

A first monitoring survey was carried out by OtB Engineering and LTEC. The trials monitoring survey which followed-on from an initial training period, was completed during February and March 2009. A total of 2.75km of trial sections in 24 lengths on seven trial roads were surveyed. They are listed in Table 6.4.

Table 6.4 – Laos Trial roads, characteristics and lengths.

Roads					Monitored Lengths		
New Ref	Old Ref	From	To	Pavement Type	Start (km)	End (km)	Length (m)
1011	1-1	B.Phi Mon Sine	B.Chom Keo	Gravel	0+600	0+700	100
1013	1-3	B.Chan Sa Vang	B.Si Pho Sai	Gravel	1+270	1+370	100
102	2	B.Nam Phou Kang	B.Nam Sa Mok Neua	Gravel	0+450	0+550	100
				Packed Stone	0+700	0+800	100
				Packed Stone	0+940	1+040	100
1032	3-2	B.Bolek	B.Nam Tong Neua	Single Otta Seal	0+150	0+250	100
				Double Otta Seal	0+415	0+515	100
				Engineered Nat. Surface	0+800	0+900	100
				Mortared Stone	1+200	1+300	100
				Mortared Stone	1+300	1+400	100
				Gravel	1+520	1+720	200
1033	3-3	B.Nam Tin	B.Phou Vane Kao	Gravel	1+650	1+750	100
105	5	Gam Mining	B.Houay Sala	Paving Blocks	0+950	1+050	100
				Paving Blocks	1+250	1+350	100
				Bamboo Concrete (125mm)	2+000	2+100	100
				Bamboo Concrete (150mm)	2+350	2+450	100
				Geocells (75mm)	2+800	2+900	100
				Geocells (100mm)	2+950	3+050	100
				Geocells	3+050	3+125	75
				Gravel	3+175	3+275	100
108	8	B.Chom Chouk	B.Nam Kham Neua	Gravel	4+550	4+650	100
				Sand Seal	1+800	1+900	100
				Sand Seal	2+000	2+100	100
				Gravel	2+225	2+325	100
						Total	2,475

The following data sets were collected.

- Visual survey - using standard numeric based coded sheets;
- Cross sections – using standard levelling techniques;
- In Situ pavement layer strength – using Dynamic Cone Penetrometer (DCP);
- IRI Roughness - MERLIN;
- Pavement structure stiffness - Mini Falling Weight Deflectometer (FWD); and,
- Rut depth – using dipped measurements from a straight edge.

A further monitoring exercise was carried out by Roughton International in 2012 (Roughton, 2013).

In consideration of the range of surface options trialled in Laos and the monitoring data collected, it is recommended that a final round of surveys be carried out and the data analysed to complement the Vietnam and Cambodia surfacing trials database and recommendations development.

6.4 Data Analysis

To simplify the condition assessment of the RRST roads assessment two indices were set up; the Road Condition Deterioration Index (RCDI) and the Deterioration Extent Index (DEI). The Calculation of a Road Condition Deterioration Index (RCDI) for each trial section, which is based on key

indicators, allows assessment of the **level** of deterioration on a percentage basis, whilst the calculation of the Deterioration Extent Index allows assessment of the **extent** of deterioration for each trial section by summing all 5m blocks of the trial length of road showing any deterioration with respect to the key indicators.

Table 6.5 lists the key factors for the calculation of specific indices for each trial road group.

Table 6.5 Key Performance Indicators

Trial Group	Indicative Factors
Concrete	Joint condition Crack extent Surface condition Potholes
Bituminous seals	Crack extent Ruts Potholes
Blocks	Block condition Joint Condition Ruts Potholes
Control Group	
Unsealed	Erosion Ruts Potholes

The Road Condition Deterioration Index of a trial section is the ratio of Road Condition Deterioration (RCD) and maximum Road Condition Deterioration (RCD_{max}). This index shows the level of deterioration on each trial section for the features mentioned above. These indices were aimed for use in establishing the level of maintenance requirement as well as providing a starting point for the calculation of the whole life cost. In general terms it was considered that RCDs of around 10% should trigger routine level maintenance; 25% indicated a periodic requirement and anything greater than 50% would probably necessitate rehabilitation.

They can also be used to establish relationships between the performance of the trial surfacing options within a series of road environment in Vietnam. These simplified indices can be used at provincial or district level to monitor maintenance requirement.

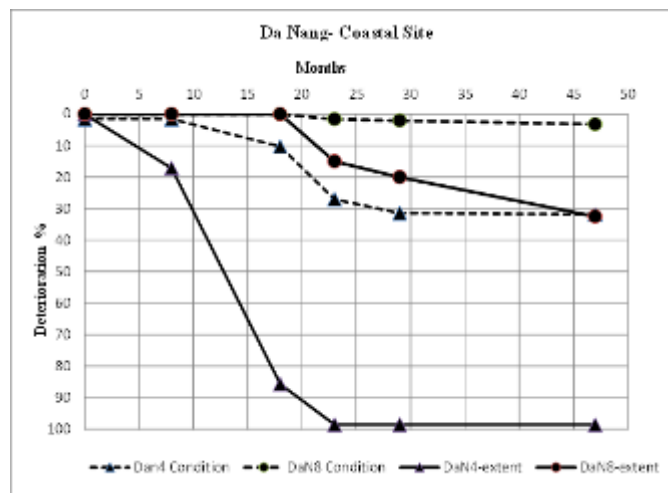
Individual Condition Deterioration Indices (CDIs) for individual factors can also be established. For example, in the case of the concrete slabs, assessing an individual CDI for slab seals has proved to be a necessary step.

The Road Condition Deterioration Index (RCDI) can be calculated for the series of condition surveys over a number of years and the comparative deterioration of pavements can be plotted versus time or traffic (esa^3). Individual Condition Deterioration Indices (CDIs) for separate factors can be examined to identify the most significant deterioration modes.

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

³ equivalent standard axle (80kN)

Figure 6.6 presents an example of plots of RCDI and DEI over time for one particular trial section in Da Nang Province.



In Laos, the surfacing trials monitoring exercise carried out in 2009 made the following conclusions regarding viable alternatives to natural gravel surfacing:

The interim survey of trial road conditions has raised some important issues regarding the selection and maintenance of LVRR pavement and surfacing options in Lao, namely:

1. The unsealed block option with sand joints is not likely to be a sustainable option unless regular maintenance is undertaken on the joints. Mortared joints or some form of water resistant bitumen-sand mix are likely to be more sustainable options. More stringent compliance with block strength specifications may be required in future use of this option;
2. The hand packed stone and mortared stone options have not been successful. Indications are that problems during construction may have contributed to their current deteriorating condition;
3. The sand sealed option is showing signs of serious deterioration and without immediate maintenance this could escalate rapidly;
4. The geocell options are performing well, although the deterioration of the surface screed and joint areas should be monitored for indication of any more serious consequential defects; and,
5. The concrete options require ongoing maintenance to the inter-slab seals, otherwise only occasion localised cracking is evident.

There is now a need for a final monitoring survey of these sites if any meaningful outcomes are to be achieved from the initial investments in this surfacing trials programme.

There have been no formal investigations of the performance of the Puok trials in Cambodia since the last Intech monitoring surveys under SEACAP 8 in 2006. However, the recent scoping study visit under this assignment found most of the trial sections to be in reasonable condition considering age since construction and lack of maintenance. Refer to Chapter 7 for a current assessment.

7 Scoping Study Country Investigations

7.1 Vietnam

The team leader visited Vietnam between 11 and 23 April 2016. Discussions were held with senior officials of Transport Development and Strategy Institute (TDSI) and Ministry of Transport (MoT).

TDSI was a partner in the original SEACAP initiative and is a research institution supporting policy development for the MoT.

With the cooperation of TDSI, visits were arranged to three of the RRSR trials provinces to inspect a selection of the trial roads that had been constructed in 2006: in Quang Binh, Ninh Binh and Hung Yen. Discussions were also arranged with the Provincial Department of Transport (PDoT) managers regarding the trials experiences. Some photographs of the trial sections are included in Annex D.

It was advised by the Provincial personnel, that since the RRSR trials and Gravel Performance Studies under SEACAP, the previously traditional rural road surfacing techniques of Gravel and Penetration Macadam have been discontinued by them; a very positive impact from the research generated knowledge. Currently, the preferred surface options were reported to be un-reinforced concrete slabs or double bituminous surface treatment (DBST) using either heated bitumen or bitumen emulsion. However, some SMEs are reported as not having DBST production equipment.

Quang Binh PDoT advised that they have some data on the maintenance carried out on some of the trial road sections; the necessary works were advised to be limited in extent. The site visits allowed some issues to be identified regarding design and construction precautions.

On-site concrete mixing without good water-cement ratio control and curing can have a detrimental effect on concrete durability. As identified in a number of trials, the initial slab on a section of concrete road can suffer from impact loading without the benefit of load transfer from the adjacent flexible or unpaved surface. These initial slabs can suffer consequential cracking and in future should require specific design considerations.

Streaking on bitumen seals was observed on some limited sections; which indicates poor control of bitumen application.

Settlement at some culverts suggest that particular attention needs to be paid to cut-off arrangements and avoidance of bedding leaching/piping.

On the Ninh Binh trial sections visited the initial concrete slab problem was again evident. Some of the bitumen seal sections have settled, possibly due to subgrade factors rather than issues with the seals themselves. The cobblestone paving was still in near perfect condition. However, it is evident that the motorcycle and bicycle users find the surface uncomfortable. The PDoT would welcome advice on overlaying such surfaces. For the small trucks using the route during rice harvest the surface roughness is not an issue.

Due to recently introduced improved rural road standards consideration is being given to widening some of the trial roads from 3.5m to 5.5m. This presents a challenge for 1m strip widening on either side of the existing concrete pavements, to key-in in such a way that minimises the risk of settlement and moisture entry at the interface of existing and new construction. The local authorities would also welcome advice on this issue.

Hung Yen PDoT managers advised that the concrete and bituminous seals surfacing solutions had been adopted by the province. The burnt clay brick option was however less popular. The site visits confirmed the generally good condition of the concrete and bituminous trials sections. The clay brick trial sections showed signs of significant distress in the form of pavement distortion. This may be attributable to subgrade issues. However, apart from small areas of brick element deterioration, the paving surface remained generally intact. Little or no maintenance had been carried out on the trial paving sections. The PDoTs would welcome advice on possible recycling or overlay options for the distorted brick paving.

If it is possible to summarise the impressions from the limited visual inspections of the trial sections in the three provinces in Vietnam, it is that they are generally in remarkably good condition 10 years after construction, in consideration of some possible subgrade issues, aggressive climate (annual rainfall typically more than 2,000mm) and low or zero maintenance regime.

The local road and bridge network in Vietnam comprises about 253,000 km, or about 85%, of Vietnam's total network of 295,000 km. Research carried out in Vietnam and neighbouring countries since 2000 under SEACAP and other initiatives has shown that investments in local roads and bridges has had a significant impact on poverty alleviation, social participation, school attendance and health services. Based on the results of this research, it has been estimated that an investment of 1% of GDP per year in rural transport has helped reduce the poverty rate by 1.5% per year, on average.

Vietnam has made impressive steps in substantially increasing the extent of the paved road network in a very short period of time (Table 7.1).

Table 7.1: Vietnam Road Length in km by category and pavement type (2014)

Category	Paved	Gravel	Earth	Total	% paved	
					2004	2012
National road	17,910	656	178	18,744	83.5	95.6
Provincial road	21,888	2,409	1,515	25,812	53.6	84.8
District road	25,326	9,326	8,664	43,316	20.2	58.5
Urban road	17,794	2,516	2,329	22,639	60.2	78.6
Commune road	67,273	36,203	81,624	185,100	2.2	36.3
Total	150,191	51,110	94,310	295,611	19.0	50.8

Source: DRVN

A meeting was held with World Bank representatives in Hanoi. They strongly support the logical follow up compilation and dissemination of the surfacing trials knowledge. World Bank has been an active supporter and facilitator of the original trials co-funded with finance arranged by them under the various Rural Transport Projects, and post-SEACAP monitoring of selected trial sections. The Bank would like to see the trials knowledge compiled and incorporated in revised national standards and specifications, and maintenance management guidance. They are willing to cooperate with any initiative supporting such an outcome.

At a meeting with a number of the Directors at the Directorate of Roads, Ministry of Transport, the appreciation for the SEACAP surfacing trials initiative was expressed. Further cooperation would be welcome in analysing the performance of the trials and facilitating the uptake of this knowledge.

7.2 Cambodia

The team leader visited Cambodia between 23 and 28 April 2016. Discussions were held with senior officials of the Ministry of Rural Development; the organisation responsible for policy and management of the rural road network. The Puok market surfacing and paving trials site was visited. The arrangements were facilitated by Engineer Heng Kackada; who was involved with the original surfacing trials initiative. Some photographs of the trial sections are included in Annex D.

The Puok trials are now up to 14 years old and with no maintenance having been carried out on most of the trial sections. However, some re-construction work was carried out as described hereinafter.

During the April 2016 site visit the original and rehabilitated trial sections were found to be in generally very good condition, despite their age and the absence of any maintenance work. Some surface defects are evident, as would be expected under the circumstances. However, there were no signs of pavement structural failure.

It is recommended that a further condition and traffic survey be arranged and the compiled knowledge from the original trials, the rehabilitated sections and the current conditions be used to contribute to the SEACAP surfacing data bank and outcomes.

The MRD senior management are enthusiastic regarding the possibility of compilation and dissemination of the Cambodia and Vietnam surfacing trials knowledge, and intend to incorporate any outcomes into the Cambodian National Standards and Specifications.

An ADB transport sector report (2011) noted that challenges on Cambodian rural roads included:

- Capacity of MRD weak and does not exist for paved road development
- Laterite roads not suitable in many cases for traffic and climate of Cambodia; material quality low and resources for materials being depleted
- Gravel roads not suitable from a health perspective for populated zones (dust); earth roads even less suitable for roadside communities because of very fine soils
- Rural road quality not adequate to meet requirements of agriculture and other sectors.

However, the ADB report does acknowledge the draft alternative paving designs and specifications developed under the SEACAP project.

7.3 Laos

7.4 AFCAP Back Analysis Project

TRL is undertaking a DFID funded research project for the Research for Community Access Partnership (ReCAP) to Develop Guidelines and Specifications for Low Volume Sealed Roads through Back Analysis: RAF2069A - Development of Guidelines and Specifications for Low Volume Sealed Roads through Back Analysis.

The aim of Phase 1 of the project is to provide a consolidated knowledge base related to the performance of LVSRs especially where non-conventional materials and designs have been used and to capture the data in a web based database. The database will provide a repository for information related to roads that have been 'back analysed' over the past four decades in Sub-Saharan Africa, and will provide:

1. A valuable source of information for use in current and future research projects involved in the development of guidelines and specifications for LVSRs,
2. The identification of gaps for further investigation in Phase 2 of the project,
3. An information management tool for consolidation of relevant LVSR performance data generated by emerging African research centres in future.

Phase 1 of Back Analysis runs until end Feb 2017, with an option for an additional 64 weeks for Phase 2 and 3.

It is understood that the intention is to develop an accessible database for researchers to lodge and analyse data on surfacing performance. There are obvious synergies between this project and the proposed follow up to this SEACAP Trials Scoping Study.

7.5 ASCAP Uptake Potential

The wide range of surfacing types and climatic environments encompassed by the Vietnam trials make the potential application of the derive knowledge applicable in many other regions. This report focusses on just a few of the potential ASCAP uptake possibilities.

Table 9.4 Summarises the national road network data for the ASCAP and SEACAP partner and potential countries, and the considerable scope for introducing affordable, local-resource-based surfacing and paving techniques on both the development of the unpaved networks and rehabilitation of paved roads.

Table 7.4: Road Network Data for selected AsCAP and SEACAP countries

Country	Paved Road Network (km)	Unpaved Road Network (km)	% Paved	Programme Partner	Data Source
Bangladesh (local roads only)	83,303	213,330	28	AsCAP	LGED website
Cambodia	3,500	41,300	8	SEACAP	ADB (2011)
Laos	6,500	37,100	15	SEACAP	MPWT (2012)
Myanmar	34,725	121,228	22	AsCAP	ADB 2015 (draft)
Nepal	8,145	56,000*	13	AsCAP	World Bank (2013)
Pakistan	185,063	78,879	70	AsCAP	CIA (2014)
Vietnam	150,191	145,420	51	SEACAP	DRVN (2014)

* Estimated

7.5.1 Bangladesh

Bangladesh shares a number of characteristics with the Mekong Delta region of Vietnam. Both are extensive deltaic regions with generally weak subgrades and almost total lack of hard stone resources suitable for road building.

The average annual rainfall in Bangladesh varies from about 1,000mm to over 5,000 mm per annum. This is compounded by substantial monsoon discharges into the country from the Brahmaputra, Ganges, and Meghna Rivers.

Bangladesh is situated in the tropics, the country is prone to cyclones associated with tidal surges, especially in the pre-monsoon and post-monsoon months. Because of high density of population in the flat deltaic coastal region, the loss of human lives in such cyclones can be substantial. Bangladesh is the nation most vulnerable to global climate change in the world, according to German Watch's Global Climate Risk Index (CRI) of 2011.

These issues represent a significant challenge to develop the national network of rural roads in an affordable and sustainable way. Lessons to be learnt from the SEACAP trials could make a significant positive impact on developing the Bangladesh strategy for sustainable rural access.➤

7.5.2 Myanmar

The ASCAP Scoping Study (Airey & Edmonds, 2015) advised that the nature of Myanmar's rural access needs means that ASCAP research has the potential to have a strong policy and programming impact in the targeting and implementation of current Government of Myanmar expenditure. ADB considers that the transport sector will play a critical role in facilitating economic and social development in the country. An important priority is improved domestic connectivity through more efficient transport linkages between rural areas, markets, and urban centres.

The report identified some of the relevant issues as:

- The long years of isolation have affected the rural road sector's ability to keep up with and adopt current developments and good practise.
- This "knowledge gap" begins with the need for the current relevant institutions to "know", manage and prioritise the upgrading of its network.
- There is a likely need to update the standards, materials and specifications being used to design and build rural roads and drainage structures (in conjunction with the move to Metric).
- There is the possibility of introducing low cost surfacing technologies that might supplement the current preference for macadam and bitumen surfaces

Myanmar experiences between 1,000 and 5,000mm of rainfall per year through its varied climatic zones. With only 22% of the current road network paved, there is a substantial need to introduce climate resilient and affordable paving techniques. The current KfW funded rural access programme in Shan State has included a limited number of trial sections. Knowledge on the SEACAP approach to monitoring and analysis could prove to be extremely useful in turning these construction trials into much more valuable performance trial .

7.5.3 Nepal

Nepal's predominantly mountainous terrain and intense monsoonal climate have created substantial transport and access challenges. The ASCAP Scoping Report advised that Nepal's total road network is low in international terms and as a result less than half its population have access to all-weather roads.

DFID are funding Rural Access Programme Phase III and the Karnali Employment Programme (KEP). The former has a significant rural roads program strengthening capacity to improve and maintain the Local Road Network in 14 of the poorest districts of Nepal by labour intensive methods. The latter (KEP) is an important component of the Government of Nepal's social protection strategy in which, with RAP III and DoLIDAR support, local infrastructure is constructed by labour-intensive methods in the poorer communities of Karnali region. One of its objectives is to construct some 500 kilometres of rural roads and maintain a further 3,700 km of roads in the five districts of Karnali.

Project documents also stress poor and at times haphazard road construction techniques used on the less important Village and Agricultural roads. These often are not engineered and are not sustainable, inflicting significant environmental damage on unstable mountain slopes and valley bottoms.

With the wide variety of terrain and climatic zones the rainfall in Nepal varies between about 1,000mm and more than 3,000mm. With both an underdeveloped network and only 13% of the

estimated network being paved, there is a substantial need to introduce climate resilient and affordable paving techniques, building on the SEACAP experiences. There are clear SEACAP links with the proposed AsCAP dust suppressant project in Nepal

7.6 Africa Uptake Potential

The Southern Africa Development Community (SADC) road network of approximately 932,000 km (excluding the Democratic Republic of Congo and the Seychelles) is one of the Community's largest public sector assets with current replacement costs estimated at approximately US\$50 billion (Pinard, 2000). The World Bank estimates that only 15% of the networks in Africa were paved by 2005 (World Bank, 2008). There is therefore huge potential for adoption of affordable, local-resourced-based surfacing solutions and related benefits in this region.

8 SEACAP Trials Knowledge Base Structure and Status

8.1 Vietnam

The formal Vietnam RRSR database is made up of 3 principal components;

- The RRGAP unsealed rural road condition data
- The RRSR condition monitoring data and additional RRSR support data
- Supplementary data

The RRGAP component comprises two principal folders:

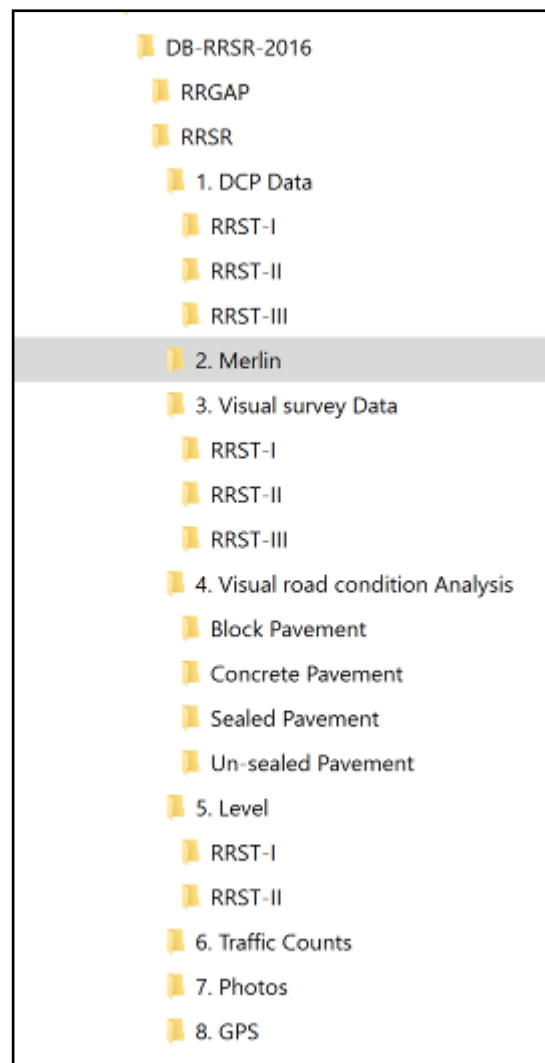
1. Grav: Gravel thickness data
2. Lab: Laboratory data and plots

The RRSR structure is essentially similar to that of the database handed over to the MoT in June 2009. The current structure is shown on Figure 8.1.

The 8 principal folders are as follows:

1. DCP data: holds raw and processed DCP data from as built and condition surveys.
2. MERLIN: hold all roughness data from the trial sections. These data still require some more analysis to remove anomalous data sets.
3. Visual Survey Data: contains all raw visual un-analysed data on XLS sheets from the 16 provinces of RRSR I, II, III. RRSR III data comprises on as-built information.
4. Visual Road Condition Analysis: contains analysed data on XLS sheets from the 12 provinces of RRSR I and II collated under surfacing group: Seals; blocks; concrete, unsealed. RRSR III data from the single as-built survey is not included.
5. Level: Contains level data on all unsealed monitoring sections from RRSR I and II.
6. Traffic counts: Contains traffic count data for

Figure 8. Structure



RRST I and II roads up to 2009.

7. Photos. Contains relevant condition photographs from RRST I and II and construction photographs from RRST III.
8. GPS. Contains gps location data for trial section in “gdb” format.

The supplementary data sections comprise a number of folders that include such relevant information as:

- Pavement designs
- Construction costs
- Trial and monitoring lengths
- Construction quality assessments
- Laboratory results
- Historic rainfall

The RRSR database (2009) was handed over to the Ministry of Transport, Government of Vietnam. Copies of this database and the subsequent additions and upgrades under World Bank funding are held by OTB Engineering Ltd.

8.2 Laos

The less comprehensive and less structured database on the Laos trials and their performance comprises three main elements.

- Phase 1- A built; Contains data from surveys undertaken following completion of construction of the trials (Figure 8.2)
- Phase 2- Survey 2009: Contains data from survey a SEACAP undertaken by OTB Engineering - LTEC in 2009 with surveys of additional unsealed roads. Visual data analysed following the Vietnam RRSR procedures (Figure 8.3).
- Phase 3- Survey 2012. Additional survey undertaken in 2012 under AfCAP I funding by Roughtons-LTEC. Information on comparison with 2007 and 2009 surveys held with Technical Report.

Figure 8.2. Phased1 Data Files

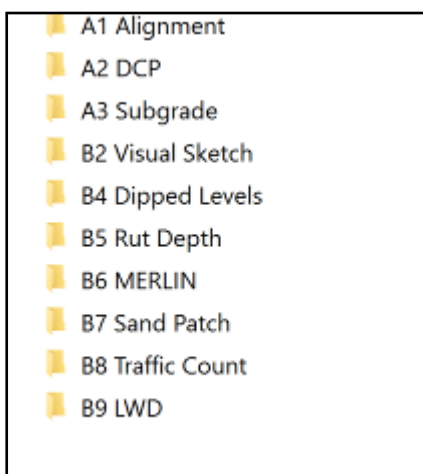
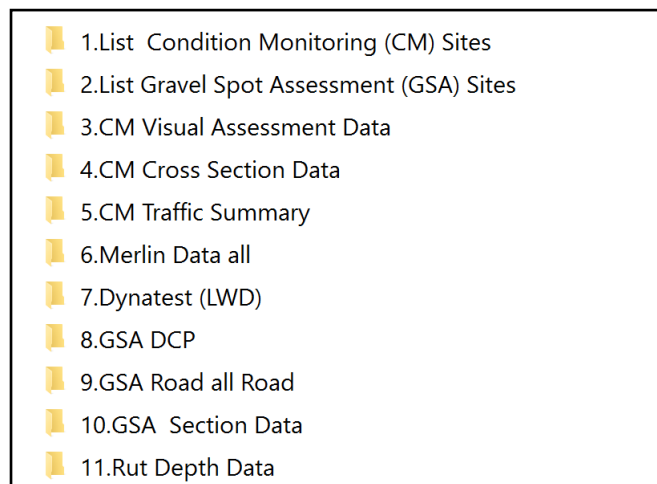


Figure 8.3. Phase 2 Data Files



The differing Lao database files require collation into a single database and consequent re-analysis.

8.3 Cambodia

No overall formal database was set-up for the Cambodia surfacing trials and other relevant data sets such as those from the Engineered Natural Surface (ENS) trials (SEACAP 19). Relevant Cambodian Rural Road Performance Data (RRPD) has been gathered into one main folder with sub-folders as follows.

Main Folder: Cambodia RRPD

Sub-Folders

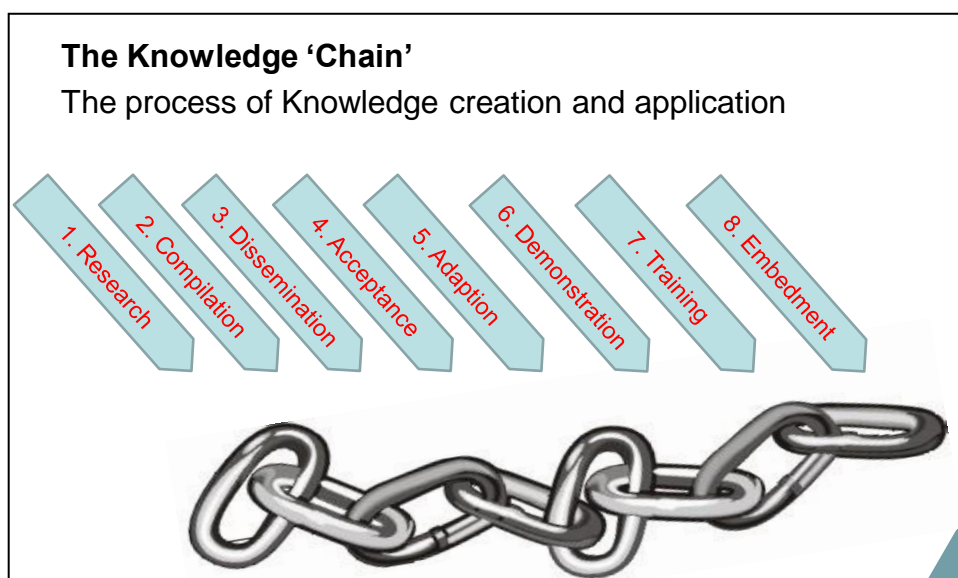
1. Puok: reports relating to the various construction, deterioration, repair and assessment of the Puok surfacing trials in Sim Reap Province. Data is contained within tables in the reports' text or Appendices/Annexes.
2. ENS: Reports and associated databases (Microsoft Access) relating to the SEACAP 19 (Task 2) research into performance ENS roads in Cambodia.

The Cambodian data is currently held by one or more of: Intech Associates; TRL Ltd or OTB Engineering Ltd with copies of all final reports held by the Ministry of Rural Development, Royal Government of Cambodia. As with the Lao data this information requires collation into a structured format.

9 Proposed Strategy for Consolidation and Uptake of the SEACAP Trials Knowledge Base

The process of developing knowledge and mainstreaming the results is represented in Figure 9.1

Figure 9.1 – The Knowledge Chain Concept (Source: Intech Associates)



Many past sector research initiatives have not realised the potential economic and social benefits due to the 'Knowledge Chain' not being carried through to its final 'embedment' stage.

It is clear that the very valuable research generated by the SECAP trials has brought some benefits already. However, a planned programme of analysis, dissemination and uptake is required to realise the considerable potential additional benefits.

The following coordinated programme of initiatives and task groups is proposed to achieve this objective.

TASK GROUP 1 – Trials Research Consolidation and Data Analysis

- Carry out Final Round of Condition Surveys on all Vietnam monitoring, Puok and Laos Trial Sections
- Carry out traffic surveys on Trial Sections
- Develop criteria for acceptable serviceability for each LVR paving type
- Identify Surface/Sub-base/Base types with useful data sets
- Carry out consolidated data analysis and develop amalgamated SEACAP research findings and recommendations
- Consolidate and assess the cost data available, particularly from Vietnam, for immediate application related to ongoing ReCAP work on cost-benefit analyses of LVRR research and its uptake.

TASK GROUP 2 – Investigate Regional, AsCAP and AfCAP Synergies and Application Potential

- Review Vietnam RRSR trials, Cambodia and Laos data for usefulness in other Asian and African environments
- Identify influential/limiting factors: e.g. traffic, maintenance regime, climate, axle loading regime etc.
- Confer with AsCAP and AfCAP partners regarding uptake potential
- Confer with RAF2069A Sealed LVR Back Analysis Project on potential common knowledge applications
- Review other AfCAP Surfacing Research Outcomes

TASK GROUP 3 – Dissemination

- Develop 2-3 page Technical Information Notes (TINs) for each surfacing and paving option for general knowledge dissemination
- Update the AFCAP Low Volume Rural Road Surfacing and Pavements - A Guide to Good Practice (LVRRSPG), and rebrand as a ReCAP document
- Seek endorsements for TINs & LVRRSPG from key institutions (e.g. ADB & WB)
- Programme of dissemination through key conference events, professional papers, and knowledge, professional and training fora (e.g. Birmingham University in-career training courses)

TASK GROUP 4 – Technology Transfer & Uptake

These tasks will require the support and involvement of a range of partners for local technology transfer and uptake of the knowledge. The TINs should be used as the basic tool for facilitating discussion, adaption/adoption, acceptance and mainstreaming of the surfacing trials knowledge.

- Develop the Standards and Specifications for the different Surface types (could initially be on a provisional basis)

- Develop the Maintenance standards and Specifications for the different Surface types
- Develop training dissemination and uptake strategy for national application
- Media and public awareness campaign
- Carry out training and dissemination. Embed in local university and technical college courses
- Agree further research and seek funding – e.g. Cement & Soil Stabilisation of sub-base and road base, Continuous un-reinforced concrete pavement, axle loading for minor roads, stage construction and upgrade strategies.

Annex A: Updated Workplan

	Week No.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PHASE	Mobilisation/Inception			ReCAP Response	In country visits and evaluations							Scoping Study Report		Output Materials	
Prime Location	UK				Vietnam		Cambodia	UK							
Milestones ◊		Inception Report ◊									Draft Scoping Report ◊		Paper + PPT ◊		
Date	Started 14 March		Submitted 31 March		Started 11 April		Started 23 April	Started 2 May					Submit 10 June		Submit 24 June

Annex B: Results Achieved

Table to be completed based on the guidance provided in the “Notes on Logframe Indicator Calculation Notes”

Intervention Logic	Indicator	Baseline (Date)	Progress against Milestone 1 (Date)	Progress Against Milestone 2 (Date)	Progress Against Milestone 3 (Date)	Achieved
Outcome: Sustained increase in evidence base for more cost effective and reliable low volume rural road and transport services, promoted and influencing policy and practice in Africa and Asia	Select Outcome Indicator 1					
	Select Outcome Indicator 2					
Output 1: RESEARCH and UPTAKE: Generation, validation and updating of evidence for effective policies and practices to achieve safe, all-season, climate-resilient, equitable and affordable LVRR and transport services in African and Asian countries. (Low Volume Rural Roads : LVRR)	Select Output Indicator 1.1.					
	Select Output Indicator 1.2.					
Output 2: CAPACITY BUILDING: The building of sustainable capacity to carry out research on low volume rural roads, and rural transport services in	Select Output Indicator 2.1.					
	Select Output Indicator 2.2.					

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Intervention Logic	Indicator	Baseline (Date)	Progress against Milestone 1 (Date)	Progress Against Milestone 2 (Date)	Progress Against Milestone 3 (Date)	Achieved
African and Asian countries.						
Output 3: KNOWLEDGE: Generated evidence base of LVRR and transport services knowledge is widely disseminated and easily accessible by policy makers and practitioners (including education and training institutions).	Select Output Indicator 3.1.					
	Select Output Indicator 3.2.					

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Annex D: Persons Consulted

1. Quang Binh PDoT:

Mr. Chien - Deputy Director of Rural Road Project Management Unit;

Mr. Tan - Head of Supervision Department;

Ms. Quyen - Deputy Head of Planning Division;

2. Ninh Binh PDoT:

Mr. Soa - Director of ODA Transport Construction Project Management Unit;

Mr. Thang - Deputy Director

Mr. Truong - Deputy Director of Projects Management Unit.

3. Hung Yen PDoT:

Mr. Huy - Deputy Director of Transport Infrastructure Construction Investment Project Management Unit.

Mr. Son - Deputy Director of Transport Infrastructure Construction Investment Project Management Unit.

4. World Bank, Hanoi:

Ms. Phuong - Task Team Leader;

Ms. Hoa - Senior Project Officer;

Mr. Kien - Transport Project Officer;

5. Ministry of Transport/ Directorate of Roads of Viet Nam :

Mr. Toan - Director of Science, Technology and International Cooperation Department;

Mr. Diep - Director of Maintenance Department;

Mr. Sy - Director of Construction Management Bureau.

6. Ministry of Rural Development, Cambodia

Excellency Suos Kong, Secretary of State

Excellency Dr Chan Darong, Under Secretary of State

Annex E: Examples of Network Re-Gravelling Performance

There is little documented evidence of re-gravelling performance of unpaved road networks in developing and emerging economies. However, the following records indicate the extent of the challenges to effectively maintaining a gravel surfaced network in a limited resource environment and with steadily depleting natural gravel resources.

A study of the **Kenya** Classified Road network by Intech Associates (1993) found that over the period 1984 to 1990, re-gravelling averaged only 360km per year on the 19,397km of non-project gravel category classified roads. This represented a re-gravelling cycle of 54 years. Furthermore, resource inventory surveys found that exploitable natural gravel resources were very limited in many districts; placing the sustainability of natural gravel surfacing on a network basis in serious doubt.

In **Zimbabwe**, the parastatal organisation District Development Fund (DDF) was responsible for the development and maintenance of the major LVR network in the country. As Table E.1 shows, the periodic maintenance re-gravelling performance reached an output peak of a 22 year cycle in 1995/6, but declined rapidly thereafter. The economic and planned cycle for re-gravelling was 5 – 7 years.

Table E.1 – Zimbabwe LVR network Development and Maintenance 1993-9

FINANCIAL YEAR	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99
TOTAL NETWORK (km) COMPLETED BY END OF FY	13,910	14,974	15,644	16,654	19,077	21,500
PLANNED (km)	1,550	1,550	1,100	1,010	2,423	2,423
ACHIEVED (km)	1,700	1,064	670	-	-	-
OUTSTANDING (km)	7,590	6,526	5,856	4,848	2,423	0
TARGET (km)	21,500	21,500	21,500	21,500	21,500	21,500
ROUTINE MAINTENANCE (km)	14,500	16,789	19,500	20,800	20,800	23,484
PERIODIC MAINTENANCE (km)	148	350	700	140	21	-
EFFECTIVE RE-GRAVELLING CYCLE	94 years	43 years	22 years	119 years	908 years	∞

Source: DDF

Annex F: Summary of Road Condition & Rehabilitation Works for each Puok Trials Section

SECTION	DESCRIPTION OF ORIGINAL DESIGN	CONDITION SUMMARY	ACTION (REPAIR AND MAINTENANCE OPTIONS)	ASSOCIATED RISKS OR COMMENTS
ILO	Bamboo Reinforced Concrete Pavement	No deterioration apart from cracking at the end of the last (transition) slab (Figure 6.1) and one other slab with a minor crack Minor cracking of bitumen seal joints	Reconstruction of last slab with un-reinforced concrete pavement (4m long).	None anticipated
Transition gap	10.1 metres long gap of Laterite surfacing between ILO-built BRCP and the start of the LCS Trials	Laterite surfacing level is below adjacent sections. Some surface erosion	Excavate approx 150-200mm existing laterite and reconstruct with 150mm thick of un-reinforced concrete pavement.	None anticipated
Trial Section No 1	Bamboo Reinforced Concrete Pavement (BRCP)	No deterioration apart from minor cracking of bitumen seal joints	Monitoring of construction joints Clearing grass and material accumulated on shoulders.	None anticipated
Trial Section No 2	Sand-Aggregate Roadbase & Single Bitumen Stone Chip Seal	Edge broken at access points to people's houses	General overlay with bitumen emulsion sand seal. Small areas of patching along the edge of surfacing and install concrete kerb at those problematic locations to prevent future edge failure (access to houses along this section).	None anticipated
Trial Section No 3	Dressed Stone with Bitumen-Sand Sealed Joint	No significant deterioration. Localised shallow depressions	Provide diluted emulsion tack coat, overlaid with thin layer of well graded crushed aggregate as regulating layer. The surface is then to be primed and paved with DBST (14mm and 8mm stone chipping). Clearing grass and material accumulated on laterite shoulder.	Peeling of regulating overlaid layer if poor adhesion with existing dressed-stone road surface
Trial Section No 4	Armoured Laterite Roadbase & Single Bitumen Stone Chip Seal	Severe rutting and 80% of the Section had failed Erosion occurred on the slope of the embankment.	Excavation and reconstruction of whole section with 150mm of hand packed stone blinded with sand/fine aggregate, primed with diluted emulsion prime coat and sealed with double treatment of SBST (14mm stone chipping) and sand seal. Install concrete kerbs at accesses to houses along this section (64.5 linear m.). Repair embankment slope erosion. and Turfing	Cracking if individual stone pieces are not well packed, blinded and compacted properly.
Trial Section No 5	Dressed Stone Pavement & Bitumen-Sand Seal Joint	No significant deterioration. Some shallow localised rutting	Provide diluted emulsion tack coat followed by an overlaying of thin layer of well graded crushed aggregate as a regulating layer. The surface is then to be primed and paved with double treatment	Peeling of regulating overlaid layer if poor adhesion with dressed-

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			of SBST(14mm stone chipping) and sand-seal.	stone road-base.
Trial Section No 6	Sand-Aggregate Roadbase & Single Bitumen Stone Chip Seal	Potholes. Minor pavement edge erosion Shallow rutting not impacting on the integrity of the seal.	Repair 2 No. potholes. Minor edge repairs and install concrete kerb at those problematic locations (22.5 linear m.).	None anticipated
Trial Section No 7	Telford Water Bound Macadam & Single Bitumen Stone Chip Seal	Minor pavement edge erosion, shallow rutting not impacting on the integrity of the seal. Standing water on deck of concrete box-culvert in the middle of Section 7.	Levelling decks of box-culvert with un-reinforced concrete overlay, the surface is to be primed with bitumen emulsion and paved with SBST to provide bituminous surfacing continuity for trial section No 7. Minor edge repairs and install concrete kerb at those problematic locations (27.6 linear m.)	None anticipated
Trial Section No 8	Water Bound Macadam & Double Bitumen Stone Chip Seal	Minor pavement edge erosion, shallow rutting not impacting on the integrity of the seal.	Minor edge repairs and install concrete kerb at those problematic locations (10m long).	None anticipated
Trial Section No 9	Armoured Laterite Roadbase & Sand Seal	Severe rutting and break-up of surface affecting 20% of this section. Significant rutting in one wheel track.	Excavation and reconstruction of whole section with 150mm of hand packed stone blinded with sand/fine aggregate, prime with diluted emulsion prime coat and sealed with DBST (14mm and 8mm stone chippings) Install concrete kerb at access point to houses (40 linear m.)	Cracking if individual stone blocks are not well packed, blinded and compacted properly.
Trial Section No 10	Hand-Packed Stone with Laterite Wearing Course	Severe loss of laterite wearing course	Replacement of wearing course with 100mm of specification compliant laterite gravel from Phnom Dey. Install level bench-mark for reference of gravel loss monitoring.	Monitors loss of gravel wearing course every 2 months with auto-level.

Annex G: Photographic Images

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