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SEACAP 2
CAMBODIA TRANSPORT MAINSTREAMING PARTNERSHIP

Introduction to Rural Road Surfacing
ITC Rural Development Courses

This document supersedes the Lecture 13 of the ITC Development Engineering Courses, and is supported by a lecture presentation

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FOREWORD

This document has been prepared under the South East Asia Community Access Programme (SEACAP) project SEACAP 2 by Intech-TRL as a contribution to updating the ILO Upstream Project supported materials for ITC Development Engineering Courses prepared by John Tracey White in 2001. The document synthesizes the research and development knowledge accumulated by Intech-TRL in the recent rural road surfacing programmes in Cambodia and Vietnam. This document and the associated presentation supersede Lecture 13 (Case Study of low-cost road surfacing).

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ABBREVIATIONS & ACRONYMS

ADB	Asian Development Bank
AFEO	Asian Federation of Engineering Organisations
ASEAN	Association of Southeast Asian Nations
AusAID	Australian Agency for International Aid
CFRTD	Cambodia Forum for Rural Transport Development
CNCTP	Cambodia National Community of Transport Practitioners
CTMP	Cambodia Transport Mainstreaming Partnership
DFID	Department for International Development
DTW	A Mechanical Engineering NGO
EDC	Economically emerging and Developing Country
EIC	Engineering Institution of Cambodia
EU	European Union
FAO	Food and Agriculture Organisation
FFW	Food For Work
GMSARN	Greater Mekong Sub-region Academic & Research Network
GTZ	German Agency for Technical Co-operation
HQ	Head Quarters
HRD	Human Resources Development
IFG	International Focus Group (on Rural Road Engineering)
IFRTD	International Forum for Rural Transport Development
ILO	International Labour Organisation
IRAP	Integrated Rural Accessibility Planning
IRD	Integrated Rural Development
ITC	Institute of Technology of Cambodia
JFPR	Japanese Fund for Poverty Reduction
JICA	Japanese International Co-operation Agency
KaR	Knowledge and Research
km	kilometre
Koyun	Locally assembled light truck
LB	Labour Based
LBAT	Labour-Based Appropriate Technology
LBRIRMP	Labour-Based Rural Infrastructure Rehabilitation and Maintenance Project
LCS	Low Cost Surfacing
M	metre
MEF	Ministry Economic and Finance
MPW&T	Ministry of Public Works and Transport (Cambodia)
MRD	Ministry of Rural Development (Cambodia)
NCP	National Community of Practitioners
NFG	National Focus Group (for Rural Road Engineering)
NGOs	Non-Governmental Organisations
NRDP	North-Western Rural Development Project
PDP	Provincial Development Programme
PDRD	Provincial Department of Rural Development
PIARC	World Road Association
PIAS	Poverty Impact Audit System
PIP	Public Investment Programme

PLG	Partnership for Local Governance
PMU	Project Management Unit
PRDC	Provincial Rural Development Committee
PRIP	Provincial and Rural Infrastructure Project
RD&RP	Rural Development and Resettlement Project
RDS	Rural Development Structure
RGC	Royal Government of Cambodia
RIIP	Rural Infrastructure Improvement Project
RRGAP	The Rural Road Gravel Assessment Programme
RRSR	The Rural Road Surfacing Research
RRST	Rural Road Surfacing Trials
SEACAP	South East Asia Community Access Programme
SEDP I	First Five-Year Socio-Economic Development Plan, 1996-2000
SEDP II	Second Five-Year Socio-Economic Development Plan, 2001-2005
SEILA	Multilateral donors - Government Rural Infrastructure Development Programme
SIDA	Swedish International Development Agency
SWOT	Strengths, Weaknesses, Opportunities & Threats
TDSI	Transport Development Strategy Institute
TEDI	Transport Engineering Design Incorporation
TIM	Transport Infrastructure Management
TKP	Global Transport Knowledge Partnership
TMP	Transport Mainstreaming Partnership
ToR	Terms of Reference
TRIP	Tertiary Roads Improvement Project
TRL	Transport Research Laboratory
UK	United Kingdom
UN	United Nations
UNCDF	United Nations Capital Development Fund
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
VDC	Village Development Committee
WB	World Bank
WFP	World Food Programme
WSP	A firm of International Management Consultants
ZOPP	German acronym for Goal Orientated Project Planning

CONTENTS

ACKNOWLEDGEMENTS i
ABBREVIATIONS & ACRONYMS ii
Background 5
Scope of the Guidance 7
1 INTRODUCTION 8
1.1 RECENT RESEARCH IN VIETNAM 8
1.2 PREVIOUS 'RULES OF THUMB' 10
1.3 THE PROVEN ALTERNATIVES TO GRAVEL 10
1.4 SUITABILITY FOR SMALL & MEDIUM ENTERPRISES (SMEs) 12
1.5 REDUCING THE MAINTENANCE BURDEN 13
1.6 INITIAL OBSERVATIONS 14
2 SELECTION OF APPROPRIATE SURFACE TYPE 15
2.1 APPLICATION OF THESE GUIDELINES 15
2.2 TERMINOLOGY 15
2.3 BACKGROUND 15
2.4 RECOMMENDATIONS ON GRAVEL/LATERITE USE 18
2.5 SELECTION OF OTHER SURFACE TYPES 20
REFERENCES 25
FURTHER READING 26

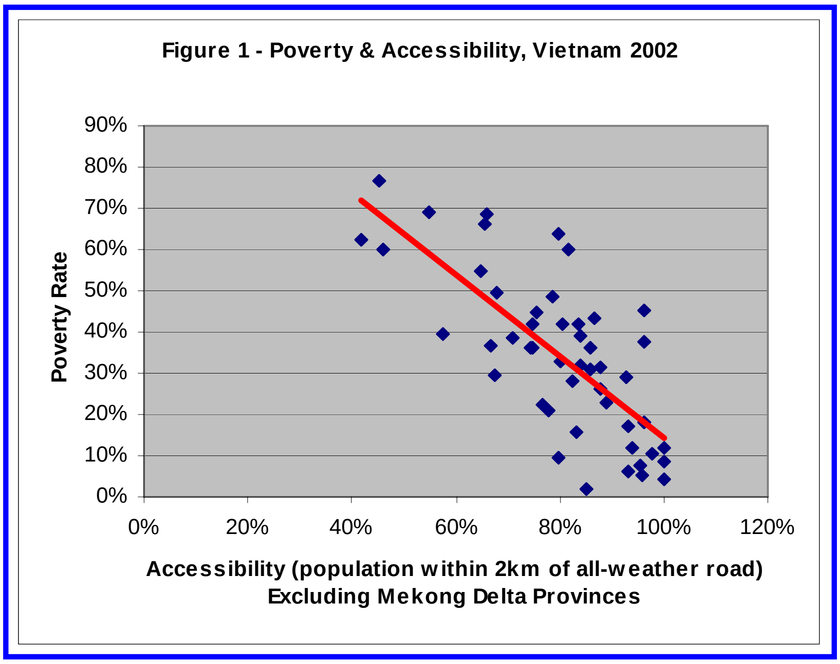
Background

The Institute of Technology Cambodia (ITC) has been developing courses for undergraduates on appropriate approaches to development and maintenance of rural infrastructure. Previously assistance for these initiatives has been provided by the ILO Upstream Project, under the management of Mr David Salter, and with the technical guidance of Mr John Tracey White and others.

Additional materials relating to the construction and maintenance of rural roads has been developed for use on these courses by the SEACAP 2 initiative: Cambodia Transport Mainstreaming Project, carried out by Intech Associates and TRL Ltd in 2004-5. These Guidelines contain the material developed by SEACAP 2 specifically for this purpose, based on the research into rural road surfaces in Cambodia and Vietnam in recent years. The recommendations on materials specifications refererred to in this document will be available for downloading in due course from: www.cnctp.info .

Context

In many developing countries, the main road network carries about 80 to 90 per cent of passenger and freight transport and it is, therefore, of key importance to the national economy. Main road networks are understandably given high priority in the allocation of investment and maintenance funds in recognition of their economic importance. Conversely, rural roads may make up over 80 per cent of the road network length, but are given lower priority in the allocation of funding because they carry much lower volumes of motorised traffic. Despite this, these rural roads are of vital importance to rural communities for their economic and social wellbeing and reduction of poverty. There is an established link between poverty and poor access (example Figure 1).



Source: Vietnam 2002 Living Standards Survey

The rural poor do not have motor cars. However they need reliable access for affordable transport or services (both motorised and non-motorised) such as bicycles, motorcycles, animal carts, minibuses, buses, whether owned or hired. Even if a vehicle ride is too expensive for them, they will still depend on the transporters that bring the medicine and teachers to the village, or carry crops. The essential challenge for engineers and road managers is therefore how to provide and maintain this rural access for the types of traffic currently in use, on a sustainable basis with the limited resources available.

Unsealed rural roads with earth and gravel/laterite surfaces comprise the greater proportion of the length of public roads in rural areas in developing regions[1]. Globally, they account for almost 60 per cent of the main road network, or about 1.2 million kilometres. In addition, there exists an estimated 5 to 6 million kilometres of designated minor roads and motorable tracks, and an extensive network of undesignated tracks and paths, probably several times the extent of the designated network[2].

Engineers have traditionally relied on the use of natural gravel/laterite as a rural road surface, due to its initial low costs and simplicity of use. However recent research[3] confirms the serious problems relating to maintenance and sustainability of such surfaces in many situations common in South East Asia. This experience is valid for certain combinations of conditions in other regions. There are also health and environmental concerns regarding the widespread use of gravel.

The Limitations of Gravel

The word gravel is used within this document to denote any naturally occurring granular material, including laterite gravel, used as a road surfacing material. The experiences also apply in many circumstances to (often more expensive) graded crushed rock aggregate. Gravel is a 'wasting' surface. Material is lost from the surface of the road due to the action of traffic and rainfall. Natural gravel should only be used for rural road surface applications in situations where certain conditions are fulfilled. Recent research by Intech-TRL shows that In general, **gravel may <u>not</u> be appropriate for use where any of the following conditions apply**:-

- **Gravel quality is poor** – Gravel should comply with grading and plasticity requirements, and not break down under traffic, otherwise it will be lost from the surface at a high rate. By its very nature, natural gravel quality varies substantially within each pit location and with depth. Great care is essential to ensure that only suitable material is selected, and that mixing of marginal/unsuitable material is avoided, unless the final product can consistently meet the specifications.
- **Compaction & thickness cannot be assured** – uncompacted surface gravel will be less durable. Supervision arrangements should ensure that the full specified compacted thickness is placed,
- **Haul distances are long** – if haul distances are longer than 10km, then other surface types may be cheaper in whole life cost terms. Hauling gravel for construction and periodic maintenance often causes damage or further maintenance liabilities to the haul routes,
- **Rainfall is very high** – Gravel loss is related to rainfall and may be excessive with intense storms or where annual precipitation is greater than 2,000mm,
- **There are dry season dust problems** – long dry seasons can allow the binding fines to be removed from the surface by traffic or wind. This is particularly problematic where communities live beside the road or their crops and property are regularly coated in dust. Inhalation of road dust is unhealthy and there are also visibility-safety issues,
- **Traffic levels are high** – gravel loss is related to traffic flows. It is unlikely that a gravel surface will be cost-effective at traffic flows of more than 200 motor (passenger car units) vehicles per day.
- **There are Longitudinal Gradients** – Gravel should not be used in low rainfall situations (< 1,000mm/year) on longitudinal road gradients of more than 6%. In medium rainfall

1 Vietnam has a road network of approximately 210,000 km, of which over 100,000 km are to earth standard.
2 Paving the way for rural development & poverty reduction, Gourley, Greening, Jones & Petts, CAFEO 20, 2002.
3 Rural Road Gravel Performance Assessment investigations in Vietnam, SEACAP 4, by Intech-TRL.

areas (1,000 – 2,000 mm/year) gravel loss by erosion will be high on gradients of more than 4%.

- **Adequate maintenance cannot be provided** – Gravel is a high maintenance surface requiring both routine reshaping/grading and expensive periodic re-gravelling to replace surface material losses. Neither are achieved to adequate levels in many Emerging and Developing nations due to funding and operational constraints [4, 5] .
- **Sub-grade is weak or soaked (flood risk) –** Weak subgrades (in-situ foundations) require additional thickness of residual gravel to prevent traffic 'punching through' to the subgrade. Flooding can seriously damage gravel surfaces,

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

Even in simple combinations of some of the above factors, gravel can be lost from the road surface at rates of more than 3cm per year, leading to the need to re-gravel at very frequent intervals[6]. The funding and resources are usually not available to achieve this and the surface will invariably deteriorate and revert to an earth surface.

These Guidelines provide information on the selection of suitable rural road surfacing materials, and the design, construction and maintenance of rural road surfaces.

Scope of the Guidance

Although local indigenous contractors, engineers and supervisors may have worked extensively in road construction, most of their experiences have probably been with gravel/laterite and (semi-) penetration macadam surfaces with heated bitumen, which for historical reasons, are also the techniques normally used in rural road techniques in Vietnam. The majority of pavement layer alternatives (sub-base, road-base and surfacing) being trialed in the Cambodian and Vietnam Rural Road Surfacing Research are likely to be new for them and road engineering students, especially the use of bitumen emulsion for surface treatments.

This technical material in this document is designed to be used as an introduction to and support documentation for provoking discussion and sharing experiences between engineers, contractors, supervisors, local and international consultants, and students during training for key issues of:

- "New" paving and surfacing techniques
- Consideration of suitability for the local technical/economical environment
- Advantages and disadvantages of each technique
- Important factors to consider
- Selection of appropriate surface types

Other relevant references are provided for complementary investigations, much of which is available on the www .

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

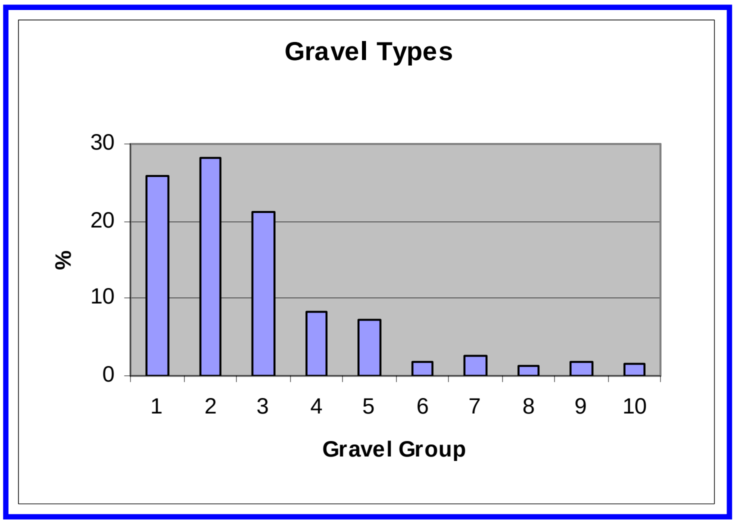
5 Roads 2000, a programme for labour and tractor based maintenance of the classified road network, paper for the RMI road maintenance policy seminar, Nairobi 2 – 5 June, Robert Petts 1992.

6 Required regravelling frequencies of 3 years or less are reported in some locations.

1 INTRODUCTION

1.1 RECENT RESEARCH IN VIETNAM

Intech-TRL have recently completed (2005), as part of SEACAP[7], a condition survey of a representative selection of unsealed and gravel rural roads in Vietnam. This Rural Road Gravel Assessment Programme (RRGAP) survey, which included in situ and laboratory testing of the road materials, has been conducted on 269 roads and 766 cross sections constructed with a variety of materials (Figure 1.1), in rainfall environments of between 850 and 3,000mm/year.



1	Laterite Gravel
2	Hill Gravel
3	Graded Crushed Rock
4	Non-Graded Crushed rock
5	Alluvial Gravel
6	Gravel + Soil Mix
7	Weathered Rock
8	Hand Packed stone
9	Quarry Waste
10	Other

Figure 1.1 – RRGAP Range of Materials Employed as Unsealed Road Surfaces

Analysis of the results has been finalised[8]. Issues identified relating to the general use of gravel materials on rural roads include the following:

1. Gravel material loss from the road surface is highly variable (Figure 1.2), with material type, drainage, sub-grade condition, gradient and rainfall being key factors. Many gravel roads have typically 80-90% of the road in fair to good condition after only a year or two of service, with some sections (10-20% of the length) in poor condition. This suggests a need to consider a spot improvement, or composite construction approach, in which at-risk or difficult sections are given a higher quality, more durable surface.
2. Many of the materials are not within widely accepted specification parameters. Hence a need to consider a design and quality assurance approach that specifies appropriate local materials rather than a blanket overall specification. Also a pragmatic approach is required to materials selection and approval, particularly in a remote location, constrained-resource environment, lacking good testing facilities and arrangements.
3. 75% of the surveyed roads have received no effective maintenance at all since construction. This emphasises the need either to construct road surfaces that are

7 SEACAP – South East Asia Community Access Programme, funded by DFID, World Bank and ADB.
8 Intech-TRL, Rural Road Gravel Assessment Programme (RRGAP), Vietnam, Module 4 Final Report, July 2005.

robust enough to withstand a low maintenance regime, or to put in place effective road maintenance arrangements that are not hampered by local funding or operational constraints, or skill and resource shortages. A coherent design and maintenance strategy is required, that recognises life cycle costs and the realities of maintenance capacity. It should be appreciated that effective maintenance regimes usually take decades, rather than years, to develop.

4. Two provinces outside of the RRGAP programme with very high rainfall (>3500mm/year) immediately overlaid the donor-sponsored gravel surfaces at their own cost, usually with concrete or bitumen penetration macadam. Besides the need for better surface selection procedures, this suggests the possibility of a staged construction approach to some rural roads, in which an initial unsealed surface may be overlain at a later date with an appropriate seal. However, indications are that a gravel wearing course would not usually be suitable for this approach unless sealing was guaranteed to be undertaken within a short period, or certainly before the onset of the first rainy season in high rainfall areas.

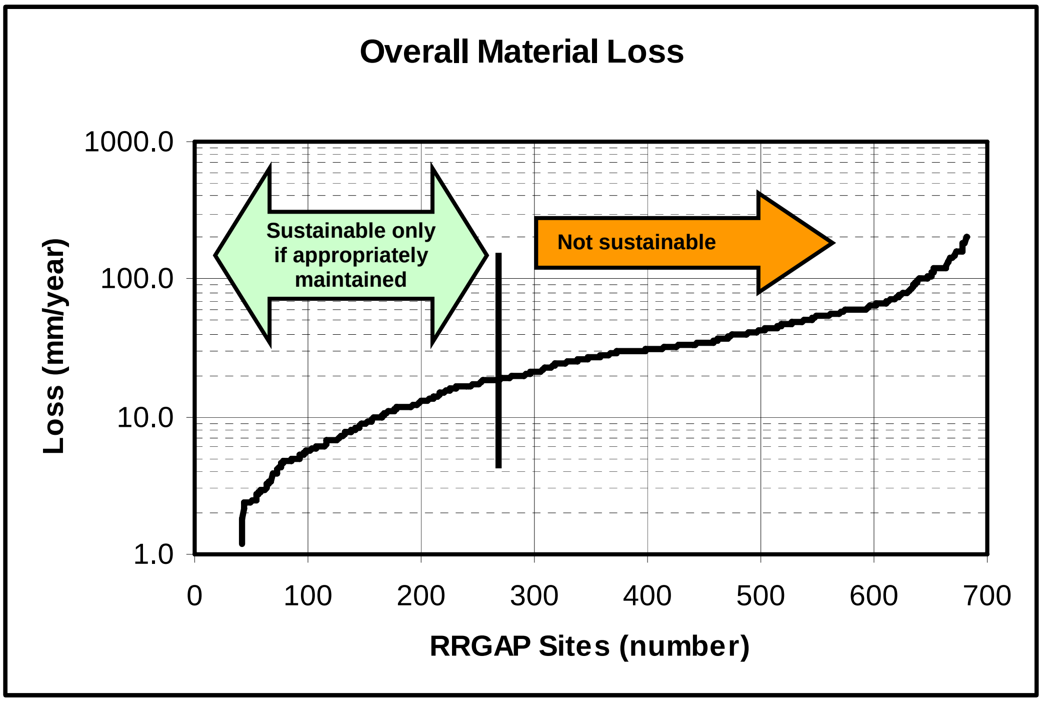


Figure 1.2 – Adjusted Apparent Material Loss Summary

Median	26 mm/yr
%>20mm/yr	58
%>40mm/yr	29

The results of the research have been published in July 2005. However it is clear that extensive awareness creation and training initiatives will be required to improve knowledge and decision making for policy makers, managers, engineers, contractors and communities regarding the challenges and constraints of the use of gravel and unsealed surfaces on rural roads. This document supports that strategy.

1.2 PREVIOUS 'RULES OF THUMB'

Previous sector 'Rules of Thumb' indicated that gravel could be suitable for roads with traffic flows of between 50 and 200 motor vehicles per day (vpd). These guidelines suggested that earth roads would be suitable for traffic flows up to 50 vpd. However, such guidelines are extremely misleading, as some soils are totally inappropriate to support any traffic flows whatsoever. Furthermore, the criteria listed previously demonstrate that even gravel should never be considered for some combinations of conditions. In fact, research in Southern Africa has shown that low cost bituminous seals can be justified at flows of only 70 motor vehicles per day[9,10]. It is likely that full whole life costing of surface options will show that natural gravel is **NOT** the most cost-effective surface in most situations. It is necessary to be more rigorous in evaluating the options for rural and access road surfacing. Long hauls, high rainfall, high traffic, poor material, steep gradients, flooding, poor construction practices, lack of maintenance capacity and other extremes of condition will exclude gravel from being the most appropriate surface in many circumstances.

Figure 2.4 shows the guidelines for gravel rural road surface selection produced for the Ministry of Transport, Vietnam, based on the gravel road performance research.

Figure 1.3 - ENGINEERED NATURAL SURFACES: Maintainable using simple locally made equipment

1.3 THE PROVEN ALTERNATIVES TO GRAVEL

Fortunately there is a range of proven alternatives to natural gravel. Some of these have similar initial construction costs to gravel in certain circumstances. Most have better whole life cost[11] attributes and lower maintenance liabilities.

Poor people often rely on non-motorised transport, motorcycles and simple trucks for their transport needs. On many soils, an engineered earth road is sufficient to provide basic access for these vehicle types, provided that specific, limited location constraints, such as watercourse crossings and steep gradients are adequately engineered with spot improvements. The camber and drainage must of course be maintained using appropriate, low cost techniques. Engineered Natural Surfaces therefore have enormous scope to improve access at very low costs for poor rural communities.

9 Performance of low-volume sealed roads: Results and recommendations from studies in southern Africa. TRL Project Report PR/OSC/167/99. Transport Research Laboratory, Crowthorne, Berkshire, UK, CS Gourley and PAK Greening, November 1999.

10 New approaches for the provision of low volume sealed roads. 20th Annual South African Transport Conference. Pretoria, South Africa, PAK Greening and CS Gourley, July 2001.

11 Whole Life Costs – discounted total construction and maintenance costs through the nominal life of the road.

Engineers need to give greater attention to improving these basic access routes which often constitute more than 50% of the rural networks in developing countries. Low cost construction and maintenance techniques using local labour and simple equipment have an important role to play. These techniques are particularly suitable for implementation by small enterprises or communities. They use the locally available labour and have negligible capital requirements. Such Engineered Natural Surfaces (ENS) can be provided for less than US$2,000 per km in many situations, including the necessary low cost drainage measures. Low cost grading of ENS can be achieved for as little as US$25 per km of grading using simple locally made equipment (Figure 1.3).

However in some circumstances the in-situ soils are just too weak to support any traffic in the wet, and must be covered. For these situations, there is a range of alternative surfacing and paving options already proven in various countries that could provide appropriate, economical and sustainable alternatives to natural gravel in developing countries. Suitability will depend on local circumstances. These alternatives, involving the appropriate use of locally available materials, may be cheaper in whole-life-cost terms. Many can be carried out by small and medium enterprises using low-capital, labour based and light equipment methods.

Communities themselves could use some of the techniques to improve their own access. The alternative surfaces should have lower (and more manageable) maintenance requirements than gravel, not only in terms of cost but also by reducing the need for (imported) heavy equipment to transport and compact. Their environmental impact could be substantially less.

There are many Proven Rural Road Surface Options using:

- **Stone**
- **Bitumen**
- **Concrete**
- **Brick**

They can have better Whole Life Cost & Local Resource Use attributes than gravel.

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Figure 1.4

The rural road surfacing options are summarised in Figure 2.5. These are all proven surfacing techniques. Guidelines on the use of these alternative surfaces and pavement layers have been compiled and successfully implemented in a number of countries. Similar documents are currently being compiled for South East Asia by Intech Associates-TRL, based on research work in Cambodia, Vietnam and elsewhere. These will be available shortly for downloading from www.cnctp.info .

1.4 SUITABILITY FOR SMALL & MEDIUM ENTERPRISES (SMEs)

The rural transport sector in many developing countries is characterized by the dominance of large construction enterprises using capital intensive methods for construction and maintenance works. These contractors have high overhead costs and their mobilization to the rural areas is expensive. Small and Medium Enterprises (SMEs) are generally poorly developed and have limited opportunities to penetrate the market.

However, if encouraged, SMEs would be particularly well suited to carrying out rural road construction of the alternative surfacing options due to:

- Possibility to be based in the rural areas with low mobilization costs,
- Low capital and set-up requirements,
- Inter-sector flexibility; possibility to provide services to a range of sectors and clients,
- Good market entry point for small entrepreneurs,
- Possibility to use affordable simple equipment, either owned or hired,
- Possibility to use local labour skills such as carpentry and masonry,
- Less pressures for corrupt practices, as they are part of the local community,
- Less opportunities for HIV-Aids infections due to less labour imported into the community,
- More of the costs recycled into the local community in employment of local labour, local tools production, local transport, local materials and profits,
- Construction skills developed in the local community which can be utilized for maintenance and other activities,
- Low overhead costs.

However, investigations have shown that these enterprises often suffer from a number of constraints that prevent them from establishing, surviving and delivering low cost infrastructure services to the rural communities. These constraints include:-

- Barriers, bureaucracy or costs of establishing SMEs,
- Inadequate Government policy framework to support the SME sector for rural roads,
- Insufficient public awareness of the potential benefits of SME rural roadworks implementation,
- Lack of appropriate contract documentation, pre-qualification & bidding procedures, standards and specifications, financial and performance audit, dispute resolution for small scale works, in place,
- Contract pre-qualification too demanding, for example 3 years previous experience of similar work,
- Contracting procedures and requirements usually (unnecessarily) demand heavy equipment holdings,
- Lack of access to capital or credit for equipment purchase or cashflow,

- Lack of opportunities to hire equipment,
- Poor contractors' capacity in costing and planning works,
- Inadequate access to low cost training, documentation and guidelines on small scale roadworks,
- Contract technical solutions are usually restricted to gravel and macadam surfaces,
- Lack of sustainable local funding for small rural road works contracts and maintenance,
- Lack of market and sustainable workload for SMEs,
- Lack of representation of SMEs (e.g. business association),
- Late and/or non-transparent payments for locally funded work,
- Corruption in award and payment for work.

The national sector stakeholders must cooperate to overcome or minimise these constraints, drawing where possible on the experiences and support of overseas partners and the knowledge and experiences of sector experts.

1.5 REDUCING THE MAINTENANCE BURDEN

Gravel road surfaces are justified in many developing countries using unrealistically low construction and maintenance cost norms that are inappropriate not only in terms of provision of an adequate quality initial surface, but also in the true cost of provision of the necessary maintenance environment to sustain a gravel surface. Routine maintenance is a fundamental and integral part of the yearly working life of these roads, much more so than for comparative sealed surfaces, and it is misleading to ignore the real cost of this work in budget assessments. These surfaces not only require the routine maintenance of other surfaces such as patching and off-road drainage clearing, but regular grading of the surface is necessary. This is required to reshape the surface to effectively shed the rainwater to the side of the road and prevent softening and defects formation caused by standing water. Normally, a camber of between 3% and 7% should be maintained. The grading activity is required to be carried out usually on a basis of 1 – 6 times a year depending on local conditions. This liability requires a well organised <u>and</u> funded routine maintenance organization. This is rarely found in a developing country.

Routine maintenance is a very challenging logistical requirement for gravel roads, however the periodic re-gravelling requirement is the specific burden that usually makes gravel roads an unaffordable and unsustainable surface option in many circumstances. The rates of gravel loss found in even many low rainfall environments cannot be replenished by the road authorities, due to lack of sufficient recurrent funding and resources (logistical and material). Inevitably many gravel roads revert to poor earth standard through lack of, or delayed, re-gravelling.

Whole life costing of the construction and maintenance of a gravel road and feasible alternatives will often show the gravel to be unsuitable in many circumstances. This will be particularly true where the capacity to provide effective and timely maintenance (or lack of it) is realistically evaluated and built into the costing process. The evident common cycle of constructing gravel roads and re-constructing them later through delayed or inadequate maintenance is a very high cost and unsustainable approach, and an irresponsible waste of scarce resources.

Whole life costing should be carried out based on local costing and surface performance evidence. Transferring experiences from other physical, climatic and operational environments needs to be carried out with care, making due adjustments for local conditions.

1.6 INITIAL OBSERVATIONS

A range of **proven**, low-cost, rural road paving options exist as an alternative to the use of problematic natural gravel as a road surface. The low cost paving options usually have a number of economic, social, health and environmental advantages over gravel. These alternative paving techniques are suitable for construction and maintenance by Small and Medium Enterprises (SMEs). Most of these paving options require little capital investment, use local resource based techniques and can optimize the use of local materials.

The alternative surfaces often have lower maintenance requirements and lower whole life costs than gravel surfaces (depending on a range of local factors). Wider adoption of these alternative surfaces would reduce the overall network maintenance funding and works burden.

However there are a range of constraints that currently prevent these technical and operational approaches from being widely used in developing countries. Initiatives are required to be taken by governments, road authorities, contractors' associations and donor agencies to tackle these constraints to "mainstream" the rural road surface alternatives and to develop a vibrant market for rural infrastructure works. This will enable SMEs to establish and survive to deliver appropriate low cost road infrastructure solutions to the rural communities. This would provide an important improvement in the prospects for social and economic development, and rural poverty reduction.

2 SELECTION OF APPROPRIATE SURFACE TYPE

2.1 APPLICATION OF THESE GUIDELINES

These guidelines have been prepared for the Cambodian Ministry of Rural Development for the planning, design, construction or rehabilitation activities on any rural road that:-

i) MRD or a Provincial Department of Rural Development (PDRD) is the management or advisory agency for the construction or rehabilitation works,

ii) MRD or a PDRD is the management or advisory agency for the maintenance or spot improvement works.

The guideline should apply to roads irrespective of their current surface, be it earth, gravel/laterite or a more durable surface.

2.2 TERMINOLOGY

The word gravel is used within this guideline to denote any naturally occurring granular material, including laterite gravel, used as a road surfacing material. Also included within this definition is the material sometimes used as a gravel surfacing that is usually more expensive and termed graded crushed rock aggregate.

2.3 BACKGROUND

Although most rural roads in Cambodia are currently only to an earth standard, gravel or laterite has traditionally been used as the surface to be applied to many new or rehabilitated routes to provide "all-weather" passage for vehicles.

However, gravel is a 'wasting' surface. Material is lost from the surface of the road due to the combined action of traffic, rainfall, flooding and wind.

Figure 2.1 Dust emissions from gravel road in the dry season

Even in simple combinations of some of the above constraining factors, gravel can be lost from the road surface at rates of more than 30 mm per year, leading to the need to re-gravel at very frequent intervals[12]. The funding and resources are usually not available to achieve this and the surface will invariably deteriorate and revert to an earth surface.

12 Required regravelling frequencies of 3 years or less are reported in many locations.

Gravel is a natural and finite resource that may occur in limited quantities. It also tends to occur in relatively thin layers (1-1.5m), hence development of borrow areas inevitably carries with it “green environment” penalties. For example, each kilometre of a 3.5m wide gravel surfaced rural road will require the opening up and excavation of approximately a 30mx30m borrow area (assuming a 1m thick deposit layer) as well as attendant overburden dumps and access roads. In addition, once deposits are used up, subsequent periodic re-gravelling will involve longer hauls and higher maintenance costs.

Figure 2.2 – Hill Gravel deposit

Engineers, planners and decision makers involved with rural road investment often fail to adequately advise and consult with the target beneficiaries regarding surface options, or respond appropriately to the beneficiaries’ views. The accommodation of survey responses such as that shown in the box below should have a greater bearing on rural road decision making processes.

Example survey responses on the provision of gravel roads

“Dust on the roads stemming from the gravel top-layer causes dust clouds on the rehabilitated roads, which is mentioned as a serious problem. All ILO villages (and about 40 per cent of the control villages) report a negative impact. Some villages clarify that families whose property directly borders to the road, complain about health problems. Where dust clouds are a serious problem, communities face the dilemma: dust clouds or no road.”

Source: Reference 4, ILO.

A particular problem that should be recognised with gravel is the rapid deterioration when layer thickness falls below a “residual” amount necessary for the surface to continue to perform. There is often insufficient warning of this occurrence to allow regravelling resources to be mobilised before the gravel surface deteriorates to a condition requiring rehabilitation.

One further consideration is that, by its very nature as a “wasting surface”, the use of gravel surfacing can encourage corrupt practices, as the evidence of thin layer applications and use of sub-standard quality materials can be lost from the road site within months, whereas the specification compliance of more durable surfaces can be checked years after construction.

There have been concerns regarding the sustainability of gravel/laterite roads in many locations in Cambodia in recent years, however quantification of the problem was not previously available to support appropriate action. ILO Upstream Project experiences[13] of gravel loss and maintenance in Battambang Province, Cambodia were documented in 2001. This highlighted the serious environmental and social consequences of the use of gravel as a surfacing, the very high overall cost and the lack of sustainability of the approach.

Figure 2.3 – A donor funded project gravel road within 2 years of maintenance cessation (dry season and impassable by motor car!)

Recent research on rural road gravel performance in Vietnam is particularly relevant to Cambodia. Both countries suffer similar problems regarding the use of gravel/laterite as a road surfacing material.

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

The Rural Road Surfacing Trials (RRST) were planned and are currently being implemented. Subsequently, DFID agreed to fund a scoping study by Intech-TRL within the existing Rural Road Surfacing Research Programme. This sub-study researched the viability of undertaking a national gravel surface performance study in

13 Rural Road Investment, Maintenance and Sustainability, A Case Study on the Experience in the Cambodian Province of Battambang, Dara Johnstone and David Salter, May 2001.

Vietnam; developed appropriate methodologies for the work and proposed a general framework for the Rural Road Gravel Assessment Programme (RRGAP).

The RRGAP Scoping Study revealed that although gravel has been the commonly recommended surfacing in recent rural road rehabilitation programmes, there is little available data on its engineering performance and deterioration. It is evident that Vietnam (and Cambodia) experiences conditions outside of the envelope of researched knowledge with regard to factors influencing gravel surface performance, compared to most developing countries. In the light of increasing speculation as to the long term cost-effectiveness of gravel surfacing in many locations in Vietnam, this knowledge gap is one that required urgent attention and which has been addressed by the main RRGAP research.

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 (of more than 20mm/year), while 28% are losing material at twice the sustainable rate (Figure 1.2).

2.4 RECOMMENDATIONS ON GRAVEL/LATERITE USE

From the RRGAP investigations, and consideration of other complementary research and knowledge of the performance of gravel roads elsewhere, the following guidelines are proposed for the restriction and use of gravel as a rural road surfacing in the range of conditions experienced in Cambodia.

It is recommended that the use of gravel as a rural road surface be restricted as follows:-

1. Rainfall and longitudinal gradient:

Rainfall < 1,000mm/year : restrict use of gravel to road gradients < 6%

Rainfall 1,000 – 2,000mm/year : restrict use of gravel to road gradients < 4%

Rainfall > 2,000mm/year : do not use gravel – material loss and erosion are likely to be unsustainable.

2. Materials Haulage

If the materials haulage distance from source to road site is more than 10km, a detailed infrastructure initial and maintenance cost (whole life cost) comparison of gravel and other technically feasible surface options should be carried out. Furthermore, road user costs, and socio-economic consequences that are currently more difficult to measure, such as dry weather dust emissions, local resource use relating to community benefits (employment etc.) and environmental resource consumption factors, should be included in the surface consideration and decision process.

3. Traffic

Gravel should not be used for roads with traffic expected to be higher than ADT 200 (equivalent PCU)[14], except as part of a planned and funded “stage construction” strategy. For expected motor traffic levels of more than the equivalent of ADT 100, it is recommended that a whole life cost evaluation of gravel and other technically feasible surface options should be carried out.

4. Flooding

Gravel should not be used on roads liable to regular or occasional flooding.

The following arrangements should be assured to allow any justifiable use of gravel to be cost affective and sustainable:-

5. Quality Control

There should be improved and adequate testing and quality control arrangements and funding in place to approve gravel material sources, and confirm availability of the necessary quantities for both construction and maintenance needs. Furthermore sufficient material testing must be arranged to ensure that the material placed on site conforms to the specifications and contract requirements, and will not break down or deteriorate under traffic.

6. Drainage

There must be adequate provision in the construction and maintenance of the gravel surface to keep the surface crossfall within the serviceable range of 3 – 7 % to ensure drainage of the rainfall from the road surface. This can be achieved either by mechanical grading or manual reshaping. Soil surfaced shoulders should not be constructed for gravel roads as this risks contamination of the gravel road surface during grading operations, or the trapping of surface water on the road surface as the gravel surface wears down. Shoulders must freely drain away from the road surface, and effective side and turn out drainage must be provided throughout the length of gravel surfaced road, and be maintainable.

7. Maintenance

There should be adequate arrangements in place to fund and organise the ongoing routine maintenance of the road, particularly the gravel surface, and the periodic maintenance regravelling to restore the material lost due to traffic and rainfall effects. Discussions of all of these issues are contained in the study final document (Reference 2).

Application of the RRGAP recommended guidelines will substantially reduce the future use of gravel rural road surfacing in Cambodia, in favour of increased and more sustainable use of other surface types.

14 ADT = Average Daily Traffic. PCU = Passenger Car Units (See MRD Interim Rural Road Standards for conversion factors).

The outcomes of the complementary Rural Road Surfacing Trials (RRST) will allow detailed recommendations to be made on the selection, design and use of a range of surfaces, including gravel, and possible stage and composite (variable surface) construction strategies.

Further research, particularly on the relationship between rainfall and gravel loss, could allow these RRGAP guidelines to be refined, suitable for the range of unsealed road surface materials, terrain and climate experienced throughout Cambodia, and for detailed whole life costing relationships to be developed. The database assembled under RRGAP will allow further investigation of factors affecting gravel road performance that were not possible due to the limited resources available for analysis under the SEACAP 4 study.

The results of the RRGAP and rural road surfacing research have already been incorporated in the latest World Bank Guidelines on upgrading unsealed roads (Reference 3).

A Decision Framework for the selection of appropriate rural road surfacing is provided in Figure 2.4 of this document.

2.5 SELECTION OF OTHER SURFACE TYPES

Research work based on the Puok Market and other trials in Cambodia, and the Vietnam surfacing trials, is currently being finalized. This will allow detailed recommendations of the various surface options to be made in the near future. The table in Figure 2.5 provides the preliminary listing of the various rural road surface options.

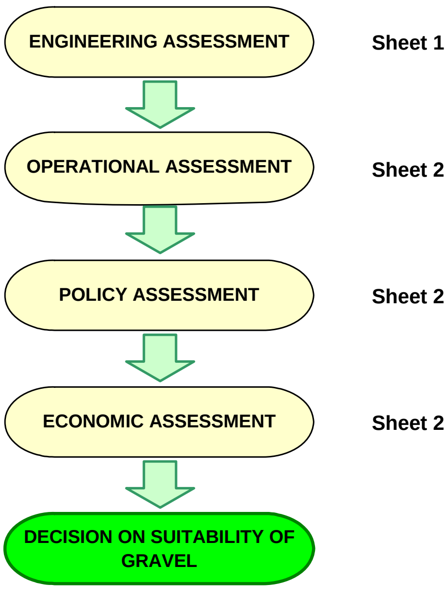
Figure 2.4 (3 pages)

APPROPRIATE RURAL ROAD SURFACE SELECTION

A Decision Management System for the Assessment of Gravel as a Paving Option

OVERVIEW OF SURFACE OPTION SELECTION
FOR A RURAL ROAD OR ROAD SECTION

STEP 1 - Consideration of Natural Gravel as a Rural Road Surface Option

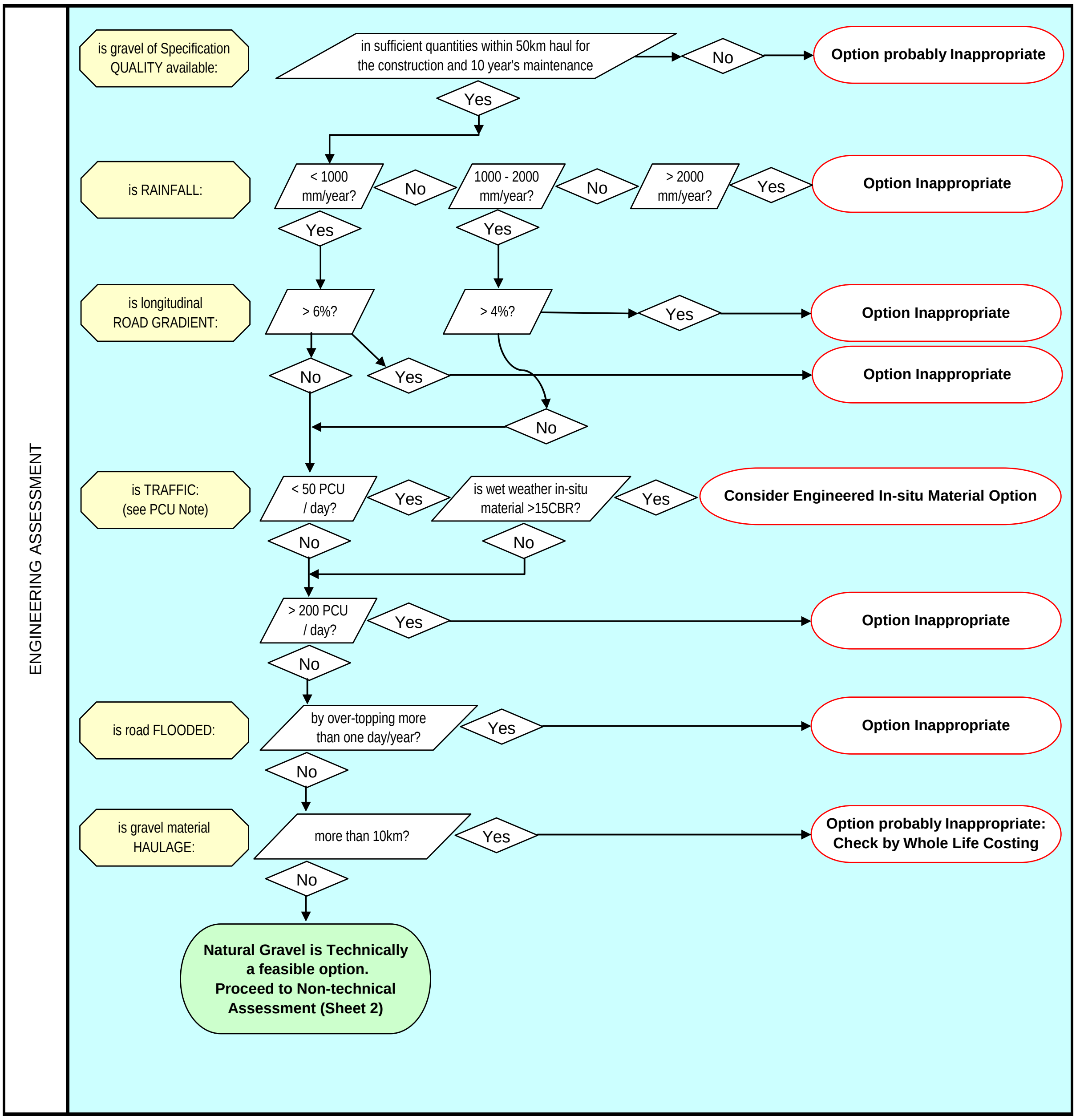


STEP 2 - If Gravel is not suitable, Selection of Appropriate Surface Option

UNDER DEVELOPMENT

Decision Flow Chart for the Consideration of Natural Gravel as a Rural Road Surface Option

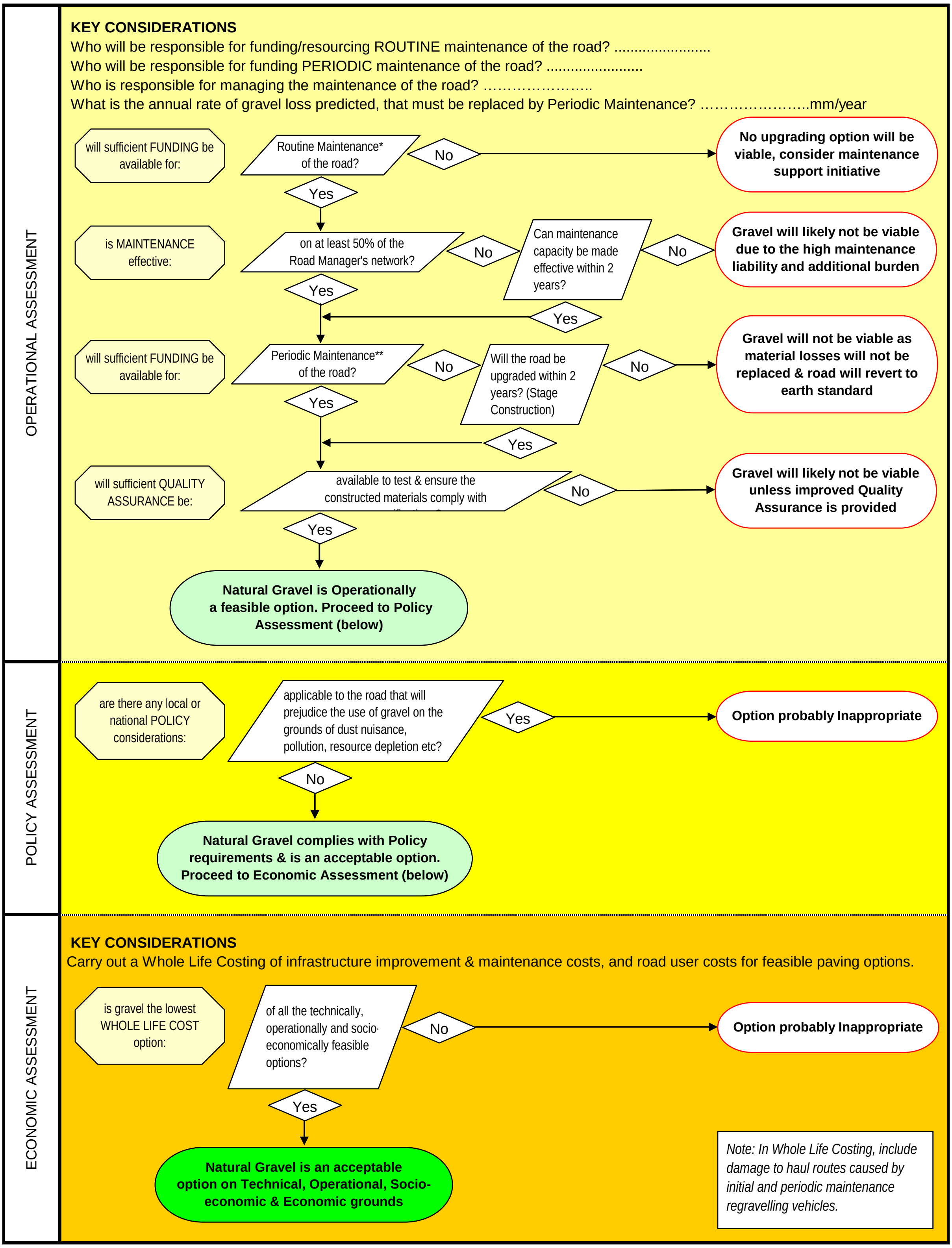
SHEET 1 - Engineering Assessment



NOTES: PCU = Passenger Car Unit (other vehicle types to be converted from traffic surveys and maximum predicted daily flows for next 3 years).
CBR = California Bearing Ratio - Strength in situ measured by DCP, or to be decided by visual assessment
DCP = Dynamic Cone Penetrometer
Engineered Insitu Material = Earth Road Standard with maintained camber and effective drainage system

Decision Flow Chart for the Consideration of Natural Gravel as a Rural Road Surface Option

SHEET 2 - Operational, Socio-economic and Economic Assessment



NOTES: * Routine Maintenance funding includes voluntary labour contributions by the community
** Periodic Maintenance includes the regular and timely re-gravelling to replace the predicted gravel losses

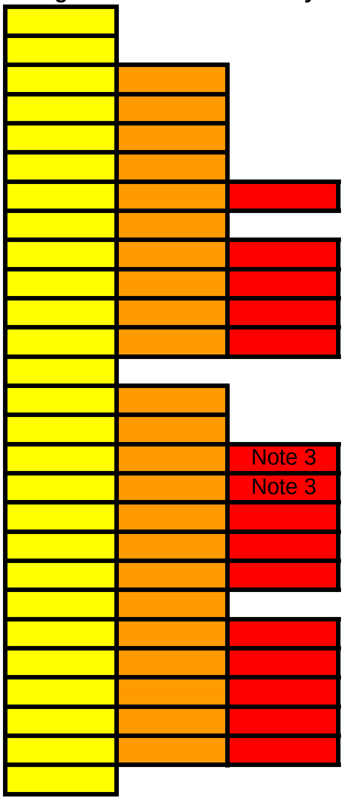
Figure 2.5

RURAL ROAD SURFACING GUIDELINES

Using Local Resource Based Methods
Focusing on the use of local labour, materials, enterprises and the community themselves.
Broad suitability guidelines are indicative only - dependant on site conditions and environment.

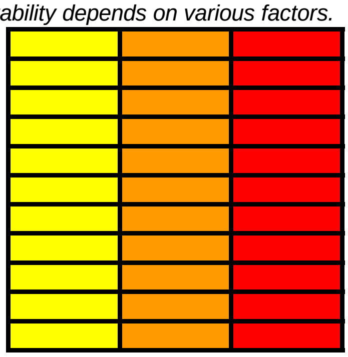
Number	Type of Surface
1	Engineered Natural Surface
2	Soil Stabilisation
3	Natural Gravel / Laterite
4	Water Bound Macadam
5	Dry Bound Macadam
6	Crushed Stone Macadam
7	Hand Packed Stone
8	Telford Paving
9	Cobble Stones
10	Stone Setts or Pavé
11	Dressed Stone
12	Mortared Stone
13	Stone Chippings
14	Slurry Bound Macadam
15	Bituminous Sand Seal
16	Bituminous Chip Seal
17	Slurry Seal
18	Ottaseal
19	Penetration Macadam (Bitumen)
20	Pre-Mix Macadam (Bitumen)
21	Burnt Clay Brick
22	Concrete Brick
23	Un-reinforced Concrete
24	Steel Reinforced Concrete
25	Bamboo Reinforced Concrete
26	Geo-cell Paving
27	Stone Chipping Blinding

SUITABILITY FOR TRAFFIC
As a Road Surface
Light Medium Heavy



	Type of Roadbase or Subbase
1	Soil Stabilisation
2	Natural Gravel / Laterite
3	Water Bound Macadam
4	Dry Bound Macadam
5	Crushed Stone Macadam
6	Hand Packed Stone
7	Telford Paving
8	Slurry Bound Macadam
9	Sand Aggregate
10	Armoured Laterite
11	Pulverised Fuel Ash

Application suitability depends on various factors.



Traffic

Light: Mainly non-motorised, motorbikes & less than 25 motor vehicles per day, with few medium/heavy vehicles
Medium: Up to 100 motor vehicles per day including up to 20 medium (10t) goods vehicles
Heavy: Accessible by all vehicle types including heavy and overloaded trucks

Notes

1. Assumes that adequate specifications, thickness & foundations are provided for each surface type.
2. Engineered Natural Surface suitability depends on soil type and environment
3. Suitable for Heavy Traffic in Multiple Seal applications

REFERENCES

1. Johnstone D., and Salter D., Rural Road Investment, Maintenance and Sustainability, A Case Study on the Experience in the Cambodian Province of Battambang, May 2001.
2. Cook J. R., and Petts R. C., Intech Associates -TRL, Rural Road Gravel Assessment Programme (RRGAP), Vietnam, Module 4 Final Report, July 2005.
3. World Bank, Surfacing Alternatives for Unsealed Rural Roads, prepared by MWH, September 2005.
4. Sakko C.J., Access, Transport and Local Economic Development: The socio-economic impact of Labour-based rural infrastructure rehabilitation and maintenance in Siem Reap Province, Cambodia, ILO, 1999.
5. Cook J. R., and Gourley C.S., 2002. A framework for the appropriate use of marginal materials. World Road Association (PIARC). Technical Committee C12 Seminar, Mongolia.
6. Geological Survey of Vietnam, 1991. Geological map of Cambodia, Laos and Vietnam at 1: 1,000,000. and Explanatory Note.
7. Intech-TRL, 2003. RRGAP Scoping Study. DFID funded South East Asian Community Access Programme
8. Nguyen Quang My et al, 1990, Geomorphology of Cambodia, Laos and Vietnam. 2nd Conference on Geology of Indochina, Hanoi.
9. Ministry of Rural Development, Policy for Rural Roads, Cambodia, 2nd edition 2002.
10. Petts R. C., Low Cost Surfacing, Working Paper No 1 - Rationale for the compilation of international guidelines on low-cost, labour-based, alternative & sustainable road surfacings, March 2002.
11. Lebo J and Schelling D, Design and Appraisal of Rural Transport Infrastructure. Ensuring basic access for rural communities. World Bank Technical Paper No. 496, 2001.
12. Intech Associates – TRL, Rural Road Surfacing Research, Vietnam, 2002 – 2005.
13. Intech Associates, Low cost surfacing research, KaR 7782, 2000 – 2004.
14. Greening P. A. K.and Gourley, G. S.,New approaches for the provision of low volume sealed roads. 20th Annual South African Transport Conference. Pretoria, South Africa, July 2001.
15. Gleeson F., Low Cost Surface (LCS) Options Trials, Conclusion of Construction Phase, Intech Associates, 2002.
16. Gourley, G. S. and Greening, P.A. K.,Performance of low-volume sealed roads: Results and recommendations from studies in southern Africa. TRL Project Report PR/OSC/167/99. Transport Research Laboratory, Crowthorne, Berkshire, UK, November 1999.
17. Gourley, Greening, Jones & Petts, Paving the way for rural development & poverty reduction, CAFEO 20, 2002.

FURTHER READING

A. SPECIFICATIONS

The RRST-I project in Vietnam will shortly be publishing recommendations on specifications for a wide range of surfacing options. These will be available to download from the websites: www.cnctp.info and www.mt.gov.vn/ruraltransport/rrsr/ .

B. ROAD POLICY

MRD has developed a road policy which provides a framework for strategy, operations and initiatives in the Road Sector. For further details refer to “Policy for Rural Roads” on www.cnctp.info .

C. RURAL ROAD STANDARDS

There MRD has developed Interim Rural Road Standards (IRRS) based on the particular needs of the rural road sector in Cambodia and the recognition of the shortage of resources that will be available in the medium term future for construction and maintenance of the road network asset. These IRRS are available for downloading from www.cnctp.info .

D. ROAD MAINTENANCE

Road maintenance continues to be a major challenge for the RGC on both the main and minor roads in Cambodia. The document “Rural Road Maintenance & Surfacing Discussion Paper” by the SEACAP 2 project provides a recent assessment of the situation in Cambodia and is available from www.cnctp.info .

E. OVERLOADING

The vehicle overloading situation in Cambodia is serious, and affects the performance of investments in rural roads. The document “Proceedings of Workshop on Road Planning, Pavement Design & Axle Loading Strategy” provides a recent assessment of the situation in Cambodia and is available from www.cnctp.info .

F. LOCAL RESOURCE BASED ROADWORKS METHODS

Economically emerging and developing countries (EDCs) vary enormously in their economic, resource, industrial, service sector and social circumstances. This suggests that the technologies and methods used for road construction, rehabilitation and maintenance should also vary and be appropriate for their individual circumstances. Unfortunately it is not always immediately obvious that the “state-of-the-art” technologies used and taught in developed country organisations and institutions are often not appropriate, economic nor sustainable in ***most*** situations in many other countries. What is required is an ***Appropriate Technology and Management*** approach.

Economically emerging and developing countries (EDCs) are usually characterised by a resource base that is very different from that found in economically developed countries. For example in developed countries labour wage rates are typically in the range of US$40 to 200 or more per day equivalent. In comparison, EDCs may have abundant low cost and under-utilised labour (wages often less than US$5/day equivalent), particularly in the rural areas. Furthermore they have local traditions and procedures, and a fledgling or intermediate-technology industrial and service sector base which are substantially different from the industrialised countries. It makes economic, social and management sense to seek an optimal use of these lower cost, locally available resources, including local skills and traditions before resorting to importing expensive (and often problematic) heavy equipment and expertise on a large scale.

In the road sector, heavy construction plant will still continue to be justifiable on many large, paved main road, reconstruction and rehabilitation projects. This is because the factors of high road traffic, high technical specifications, high guaranteed plant utilisation, economies of scale, intensive management, rapid implementation and relatively simple logistics can support a large-contractor, capital-intensive approach. However for most other roadworks the use of an appropriate combination of intermediate equipment and labour is often cheaper and more appropriate. There are also strong political and social arguments for adopting a more ***local-resource orientated*** approach.

Many important documents concerning local resource based roadworks, developed by the ILO in connection with the Cambodian Upstream Project and other initiatives are available from www.cnctp.info .

G. GENERAL TRANSPORT KNOWLEDGE

The global Transport Knowledge Partnership (gTKP) is a web based portal for documentation on many aspects of the transport sector in developing countries. The portal provides direct access to a number of other knowledge and organisations' websites: www.gtkp.org .

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