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SEACAP 2
CAMBODIA TRANSPORT
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FINAL REPORT

APPENDICIES



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APPENDIX 1

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Policy for Rural Roads

Second Five-Year Socio-Economic Development Plan (2001-2005)
 Second Five-Year Socio-Economic Development Plan (2001-2005)
 A Sub- Sector Overview
 Transport Sector Strategy Study

Policy for Rural Roads 2002-a

MRD_5Plan_EH-s
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Providing Sustainable Access through road works techniques suitable for small & Medium Enterprises *LCS21-Text-Jan-2005*
 Rationale for the compilation of international Guidelines for Low-Cost Sustainable Road Surfacing *LCSWorkingPaper1_Eng*
 Gravel/ Laterite (Surface Option No.3) *RR SURFACE 3h*
 Gravel/ Laterite (Option No.3) *RR SURFACE 3h-francais*
 A Tractor and Labour Based Routine Maintenance System for Unpaved Rural Roads *Working Paper5*
 Paving the way for Rural Development & Poverty Reduction *Working Paper12-final*
 Grading Equipment for Earth & Gravel Roads *Working Paper14-Grading Equipment*
 Grading Equipment Development for Earth Roads *Working Paper15*
 Clay Brick Paving Investigations in Vietnam *Working Paper16a*
 Pouk Market Trial Road Investigation *Working Paper18a*
 Pouk Market Trial Road Investigation *Working Paper18a-PartA*
 Evaluation of Mark 2 Cambodia Light Grader *Working Paper19a*
 Pouk Market Trial Road Initial Pavement Monitoring April-May 2003 *Working Paper 17*
 Bamboo Reinforced Concrete Pavement Road Construction in Cambodia *WP7-BRCP - Final-aaa*

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Road Safety Report
Human Resources Development

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Working Paper 1draft-b-s

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Evaluation of Farm Level Impact of Barai Irrigation System	<i>Baray_Irrigation_Khmer-s</i>
Evaluation of Farm Level Impact of Barai Irrigation System	<i>Baray_Irrigation-s</i>
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A Survey of Transport Business in Rural Cambodia	<i>Rural_Transporters-s</i>
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Impact of Employment Generation in the ILO Supported Angkor Park Clearing and Cleaning Project (1992-1998)	<i>ses10_english-s</i>
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Report on Puok Trails Construction	<i>WP13 Puok Trials Report 1b</i>

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Rural Roads Capacity Building Initiative (RRCBI) Terminal Report	<i>RRCBI_Terminal_Report</i>
Rural Roads Maintenance Initiative (RRMI) Inception Report	<i>RRMI_INCEPTION_REPORT</i>
Main Technical Report	<i>PRIP_Main_Technical_Report 2003-s</i>
Rural Road Capacity Building Initiative (RRCBI) Inception Report	<i>RRCBI_Incep_Rep2nd_draft-s</i>
Rural Roads Maintenance Initiative (RRMI) Terminal Report	<i>RRMI_Terminal_Report-s</i>
Terminal Report	<i>Terminal_Report-s</i>

3.2-Road Safety-Cambodia

Access, Transport, and Local Economic Development	<i>AccessTransport_Economic_Development-s</i>
The Cambodian Road Safety Situation	<i>Cambodian_rural_road_safety-s</i>
Road Safety Action Plan	<i>CambodiaRSActionPlan_22 May 04_s</i>
Road Accident Cost in Cambodia	<i>CAM-RoadAccidentCostingReport-AC02-s</i>
Road Safety in Cambodia, Country Report-CR 02a	<i>Country Report- CR02a-s</i>
Road Safety in Cambodia, Country Report-CR 02	<i>Country Report- CR02-s</i>
Road Traffic Accident and victim Information System	<i>RTAVIS_Monthly_Report_February 2005_ENG-s</i>

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Proceedings of the National Workshop on Road Planning, Pavement Design & Overloading Prevention, 11 th -12 th November 05	
<i>AxleLoadingWS-MainReport-Eng-s</i>	
Proceedings of the Launch Workshop for the Cambodia National Community of the Transport Practitioners (CNCTP)	<i>CNCTP Launch</i>
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Thirty First Road Oversea	<i>ORN31_khmer-s</i>
International Road Maintenance Standard Vol.1	<i>PIARC Vol1_khmer-s</i>
International Road Maintenance Standard Vol.2	<i>PIARC Vol2_Khmer-s</i>
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International Road Maintenance Standard Vol.4	<i>PIARC Vol4_Khmer-s</i>
Save Your Countrys Roads	<i>SaveYourCountryRoad-s</i>



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**APPENDIX 2
MRD IRRS**

ROYAL GOVERNMENT OF CAMBODIA



MINISTRY OF RURAL DEVELOPMENT

INTERIM RURAL ROAD STANDARDS

Final Draft - January 2006

FOREWORD TO THE 2006 INTERIM RURAL ROAD STANDARDS

The Ministry of Rural Development (MRD) has formulated a policy document for rural roads which provides a framework for the sector activities (1999 and revised 2002).

These Interim Rural Road Standards (IRRS) interpret the MRD policy into practical and appropriate standards for the development and maintenance of the rural road network.

The IRRS have been developed by a Special Committee of MRD senior personnel with support from international and local advisers under the DFID funded SEACAP 2 project – Cambodia Transport Mainstreaming Partnership, under the Chairmanship of H.E. Suos Kong, Secretary of State.

The Committee also included the following members:

- H.E. Try Meng, Under Secretary of State.
- H.E. Kim Sour, Under Secretary of State.
- H.E. Cheam Nimol, Director General of Technical Affairs.
- Mour Kimsan, Deputy Director General of Technical Affairs.
- Yoeun Sophal, Director of Rural Road Department.
- Nguon Dara, Deputy Director of Rural Road Department.
- Noun Sokha, Deputy Director of Rural Road Department.
- Chhour Longsrin, Deputy Director of Rural Road Department.
- El Say, Director of PDRD Battambang Province.
- Moa So, Deputy Director of PDRD – Banteay Meanchay Province.
- Im Phoansopha, Deputy Director of PDRD – Siem Reap Province.
- Heng Kackada, Executive Secretary of CNCTP.
- David Salter, SEACAP Manager.
- Robert Petts, Regional Manager Intech-TRL & Director of SEACAP-2 project.

The document is divided into two parts. The first part contains the Interim Standards, whereas the second part contains background explanations or reasons for the choice of each standard. This will enable the standards to be more easily understood, and reviewed with full background knowledge at a later date, as circumstances on the rural road network or in Cambodian economy change.

POLICY OBJECTIVE

“The Ministry of Rural Development is responsible for facilitating improvement of rural social and economic conditions.”

Mission Statement

“The MRD Department of Rural Roads will contribute to this goal by increasing rural access through cost-effective investment in the maintenance and development of rural roads, routes and transport infrastructure.”

Source: Policy for Rural Roads

1 INTRODUCTION

1.1 *Setting & Updating Policy*

Ministry of Rural Development will be responsible for the development and implementation of policies for the rural roads and routes of Cambodia. It will also develop and monitor implementation strategies to achieve the policy objectives, review their impact and effectiveness and update the policies and strategies as necessary. Ministry of Rural Development will liaise with Ministry of Public Works & Transport (MPWT) and other partner organisations on all issues of common interest to ensure harmonisation with the National Transport Plans and other policies affecting the Transport sector.

1.2 *Road Categorisation*

Public Roads in Cambodia are categorised as follows (source: MRD Policy 2002).

1.2.1 Non Urban Roads are currently categorised as:-

National (Ministry of Public Works & Transport)
Provincial (Ministry of Public Works & Transport)
 &
OTHER RURAL - which are the responsibility of Ministry of Rural Development.

1.2.2 The functional categorisation of the OTHER RURAL roads is necessary to enable ownership, responsibilities, resources and management to be assigned. The following criteria have been adopted for the general categorisation:-

TERTIARY -	District to District
SUB-TERTIARY 1 -	District to Commune
SUB-TERTIARY 2 -	Commune to Commune
SUB-TERTIARY 3 -	Commune to Village and Village to Village

1.3 *Application of these Interim Rural Road Standards*

The Interim Rural Road Standards should apply to 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.

Traffic volumes will vary considerably on rural roads depending on location, weather, seasonal factors, etc. Traffic composition will also vary substantially from road to road. There are currently no agreed arrangements or circumstances regarding when

roads should change from MRD to MPWT responsibility with growing traffic.

The Standards for Tertiary and Sub-Tertiary roads detailed by this document will accommodate motor traffic flows from Zero to more than 2,000 vehicles per day.

The Interim Rural Road Standards will apply to roads irrespective of their surface, be it earth, gravel/laterite or a more durable surface, however different requirements will apply to the various surface types.

1.4 Road Features

The various features of a typical rural road are shown in Figure 1.

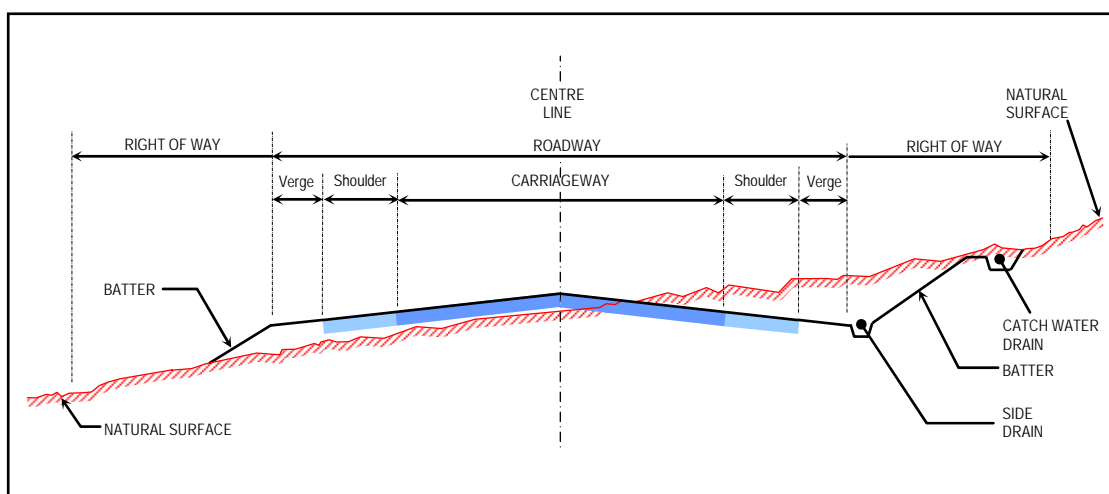


Figure 1 - ELEMENTS OF ROAD CROSS SECTION (Not To Scale)

Some of these features will not be required or be apparent, depending on location, circumstances and road category.

1.5 Determination of Future Traffic Flows

For the purposes of rural road design, the prediction of future traffic flows will be based on surveys of current traffic, and assessment of adjustments expected due to generated traffic, diverted traffic and future growth.

The standard for Traffic Flow measurement is Average Daily Traffic (ADT), based on the Passenger Car Unit (PCU).

The following table provides conversion factors for the various vehicle types.

Type of Vehicle	Equivalent Value in PCU's for Rural Traffic Flow Calculations
Passenger Car	1.0
Motorcycle	0.4
Motorcycle-trailer	0.6
Bicycle	0.3
Animal Cart	0.4
Light Vehicle / Van	1.0
Koyun	1.5
Medium Truck (6 tyres)	2.0
Heavy Truck (> 6 tyres)	2.5
Bus (> 4 tyres)	2.25
Mini-bus (4 tyres)	1.1

Figure 2 - Recommended PCU Conversion Factors for determination of road Type.

1.6 Topography

For interpretation of the standards and design purposes, topography is classified into **flat, rolling or mountainous** using the following definitions (Source: MPWT Road Design Standards):

Flat Terrain:

The topographical condition where road sight distances, as governed by both horizontal and vertical restrictions are generally long or could be made to be so without construction difficulty or expense. The natural ground, cross slopes (ie. perpendicular to natural ground contours) in a flat terrain are generally below 3 %

Rolling Terrain:

The topographical condition where the natural slopes consistently rise above and fall below the road or street grade and where occasional steep slopes offer some restrictions to normal horizontal and vertical roadway alignment. The natural ground cross slopes in rolling terrain is generally between 3 – 25 %.

Mountainous Terrain:

The topographical condition where longitudinal and transverse changes in the elevation of the ground with respect to the road or street are abrupt and where benching and side hill excavation are frequently required to obtain acceptable horizontal and vertical alignment. The natural ground cross slopes in mountainous terrain are generally above 25 %.

PART A

**INTERIM
RURAL ROAD STANDARDS**

Interim Design Standards for Tertiary/Sub-Tertiary Rural Roads

Item	Designation	Type A	Type B	Notes
1	Composition of traffic (ADT)	201 ~ 2,000+	0 ~ 200	Design Period Max flow in PCU
2	Design Period	15 years	10 years	
3	Design speed (Km/hr)	70 / 60 / 50	60 / 50 / 40	Flat / Rolling / Mountainous
4	Assumed ESA of commercial vehicle (6 tyres or more)	1.0	0.4	If axle load surveys are not possible
5	Minimum radius of curvature (metres) Unpaved surface	190 / 125 / 80	125 / 80 / 40	Flat / Rolling / Mountainous
6	Minimum radius of curvature (metres) Paved surface	130 / 85 / 60	85 / 60 / 30	Flat / Rolling / Mountainous
7	Vertical alignment maximum (%) Earth Road	4%	6%	Steeper gradients should be spot improved
8	Vertical alignment maximum (%) Gravel Road	6%	6%	4% if rainfall 1,000–2,000mm/year. Gravel unsuitable > 2,000mm/year
9	Vertical alignment maximum (%) Paved Road	15%	20%	Maximum 10% for thin bitumen seals
10	Horizontal sight distance (metres) Flat / Rolling / Mountainous	85 / 65 / 50	65 / 50 / 35	
11	Maximum super elevation (%)	7%	7%	Normally 3 – 4% is appropriate
12	Extra widening / Increased width at curves (metres)	0.5m	0.5m	If radius of curvature <100m
13	Constructed Carriageway Camber / Cross fall (%): Unpaved / Paved	7% / 3%	7% / 3%	Concrete Slab may be 2%
14	Shoulder plus Verge Width each side of carriageway (minimum)	1.0 metre	1.0 metres	Can be reduced in mountainous areas with provision of passing bays on single lane roads. Minimum Type B roadway = 6.0m
15	Width of earth/gravel/laterite/paved surface carriageway (minimum)	5.0 metres	3.5 metres	These are minima. If resources allow, wider carriageway may be justified
16	Initial constructed thickness of laterite / gravel surface (mm)	200mm compacted	150 ~ 200 mm compacted	Use technical design guidelines, gravel may not be suitable
17	Paved road pavement thickness	depends on requirements	depends on requirements	Use technical design guidelines
18	Elevation of road formation (minimum)	500 mm above the HFWL	500 mm above the HFWL	Sub-grade formation level
19	Embankment construction Maximum layer thickness (compacted)	150mm (each) horizontal layer	150mm (each) horizontal layer	Depends on compaction equipment used. All earthworks must be compacted
20	Embankment side slope	1:2 ~ 1:3	1:2 ~ 1:3	(vertical:horizontal) Turfed finishing
21	Side drainage ditches	See technical guidelines	See technical guidelines	Trapezoidal shape, Turfed. Scour checks or lined if gradient >4%
22	Right of way (from Road Centre line to each Side) (metres)	15	15	Recommended
23	Unobstructed clearance between backs of culvert headwalls at road surface level (Minimum)	7.0 metres	6.0 metres	Headwalls extending above embankment finished level should be clearly marked
24	Unobstructed carriageway width at single lane drifts and structures with width restriction and warning signs (Minimum)	3.5 metres	3.0 metres	Suitable barriers and warning signing to be provided
25	Berm width at embankment toe	2.0 metre	2.0 metre	Recommended minimum

Note: Unpaved = Earth or Gravel/laterite

PART B

THE RATIONALE

B. THE RATIONALE

This **PART B** of the Interim Rural Road Standards sets out the rationale for determining values for the various items of the Interim Standards contained in **PART A** of this document.

Selection of which Standard (Type A or B) to use for a particular road should be based primarily on predicted traffic in the design period being considered (Item No. 1 of the Standards).

1. Composition of Traffic (ADT)

The traffic capacity assessments of Type A and B are based on international and local experience, with particular consideration of the current predominant nature of two wheel vehicles on Rural Roads. Refer to Figure 2 for PCU conversion factors to calculate the Average Daily Traffic (ADT).

2. Design Period

For most road projects in developing countries an economic analysis period of between 10 and 20 years is normally adopted. TRL Overseas Road Note 31 (ORN 31) recommends a pavement design life of 15 years to reduce the problem of forecasting uncertain traffic trends for long periods into the future.

In view of the current economic and social circumstances of Cambodia, with uncertainties of prediction and with national constraints on resource availability, it is appropriate to consider a shorter design period for some routes.

3. Design Speed

These standards are based on recommendations of TRL Overseas Road Note 6 (ORN6) and consideration of local physical and traffic characteristics in Cambodia.

4. Assumed ESA of Commercial Vehicle

It is not always possible to carry out axle load surveys for the design of Rural Roads. Therefore the Equivalent Standard Axle (ESA) values have been suggested for pavement design in these standards. However, if a particular route may be subject to unusual loading, such as haulage of timber or extraction of construction materials, then specific axle load surveys are strongly recommended.

5. Minimum Radius of Curvature, Unpaved Surface

These standards are based on recommendations of TRL Overseas Road Note 6 (ORN6) and consideration of local physical and traffic characteristics in Cambodia.

6. Minimum Radius of Curvature, Paved Surface

These standards are based on recommendations of TRL Overseas Road Note 6 (ORN6) and consideration of local physical and traffic characteristics in Cambodia.

7. Vertical Alignment Maximum, Earth Road

Earth roads are currently the predominant type of rural roads in Cambodia. They are low cost to construct, however often suffer from lack of maintenance and deterioration in the wet season. Particular attention should be given to minimizing the problems of earth roads by not using such a surface in conditions of steep gradient, where wet weather problems are particularly severe. Steep gradients are often limited in extent and consideration should be given to providing low cost, spot improvements to these sections by the provision of more durable surfaces.

8. Vertical Alignment Maximum, Gravel Road

Gravel road surfaces deteriorate more rapidly with increasing gradient and rainfall. Recent research in South East Asia (Intech-TRL - Rural Road Gravel Assessment Programme, Vietnam, 2005) recommends that restrictions should be placed on use of gravel as a road surface as indicated in the Interim Standards.

9. Vertical Alignment Maximum, Paved Road

Although paved surfaces are more durable than earth or gravel, limitations should be placed on longitudinal gradient due to the risk of deterioration of bituminous seals under repeated heavy braking, and the capacity and safety considerations for the types of vehicles in use.

10. Horizontal Sight Distance

These standards are based on recommendations of TRL Overseas Road Note 6 (ORN6) and consideration of local physical and traffic characteristics in Cambodia.

11. Maximum Super elevation

Determined based on factors of safety, speed and comfort in consideration of international standards and local physical and traffic conditions.

12. Extra widening / Increased width at curves

Determined based on factors of safety, speed and comfort in consideration of international standards and local physical and traffic conditions.

13. Constructed Carriageway Camber / Cross fall

Unpaved (Earth and Gravel/laterite) surfaces should be maintained at a cross fall of between 3% and 7% to shed rainwater effectively and provide a safe running surface. Therefore both types of surface should be constructed to an initial compacted straight cross fall of 7% away from the centre line of the road. Super elevation will be applied to curves/bends to vary the cross fall up to this maximum percentage.

14. Shoulder plus Verge Width each side of carriageway

Shoulders and verges are effectively merged on rural roads. Their functions include the need to:-

- Provide structural lateral support to the road surface or pavement,
- Provide for a safe margin between the carriageway and earthworks side slopes,
- Enhance visibility and safety,
- Provide space to stop in an emergency,
- Allow wide vehicles to pass safely on single lane roads.

The road shoulders should be completely free of any obstructions or obstacles such as culvert headwalls, sign post poles etc. and should be a continuous roadside refuge for any vehicle to pull up in an emergency.

In mountainous areas it is sensible to reduce or eliminate shoulders and verges in appropriate circumstances, so long as adequate drainage provisions are made and vehicle passing places are provided at regular intervals.

Minimum width of roadway is set so that two trucks may pass each other safely, even if they have to use the shoulders/verge to do so.

These standards are based on a review of international practice, practicalities of construction, and consideration of local experiences, physical and traffic characteristics in Cambodia.

15. Width of Carriageway

Standard has been determined based on factors of safety, economic, financial, speed and comfort in consideration of ORN6, international standards and local physical and traffic conditions. This includes consideration of the Puok surfacing trials and experiences with other rural road projects.

16. Initial constructed thickness of Gravel/Laterite Surface

Local Experience on gravel loss rates and the SEACAP 4 Rural Road Gravel Assessment Programme (2005), have demonstrated the very high rates of gravel loss experienced in Cambodia and South East Asia. Gravel must be properly compacted and meet the required technical specifications. Even then, surface loss rates of 2-5 cm per year will be common.

A “residual thickness” of gravel is required for the surface to continue to protect the underlying weaker subgrade from failure. This requirement is typically between 5 – 10 cm. Therefore initial constructed layer thicknesses should take account of the expected rates of loss and the maintenance arrangements for re-gravelling.

Gravel/laterite is not suitable for use in many locations and the Technical Guidelines should be used to evaluate suitability.

17. Paved Road Pavement Thickness

The choice of pavement type and layer thicknesses will depend on factors such as local conditions, available materials, traffic loading etc. The Technical Guidelines

should be used for pavement design.

18. Elevation of road formation

Excess moisture in the road pavement and subgrade will seriously reduce the bearing capacity of the pavement. Flooding of these layers with prolonged soaking should be avoided. The cost of increasing earthworks to raise the subgrade and pavement sufficiently above flood level invariably provides greater benefits of longer pavement life and reduced maintenance.

19. Embankment Construction Maximum Layer Thickness

Earthworks layer thickness should depend on the materials and compaction equipment and methods used. The contract specifications will provide requirements and guidance on compaction techniques and layer thicknesses.

20. Embankment Side Slope

These standards have been developed from experience of local materials and conditions. Due to the intense rainfall experienced, turfing is the preferred approach to counter erosion on newly constructed earthworks.

21. Side Drainage Ditches

Side drains should be constructed to a form that can be easily maintained. Protection against erosion is required in most locations through turfing to rapidly consolidate the drain surfaces. Where fast flows are expected on gradients, other forms of lining may be required.

22. Right of Way

These are recommended standards to prevent undesirable development at the roadside and allow for future widening.

23. Unobstructed Clearance between backs of Culvert Headwalls at Road Surface Level

The carriageway and shoulders of the roadway should be un-obstructed by any item or component of road furniture or structures. This is particularly important for night driving, when drivers can have their vision impaired by the lights of vehicles traveling in the opposite direction.

Culverts must be constructed so that any part of the headwall rising above the level of the road embankment or surface is outside of the shoulder margins.

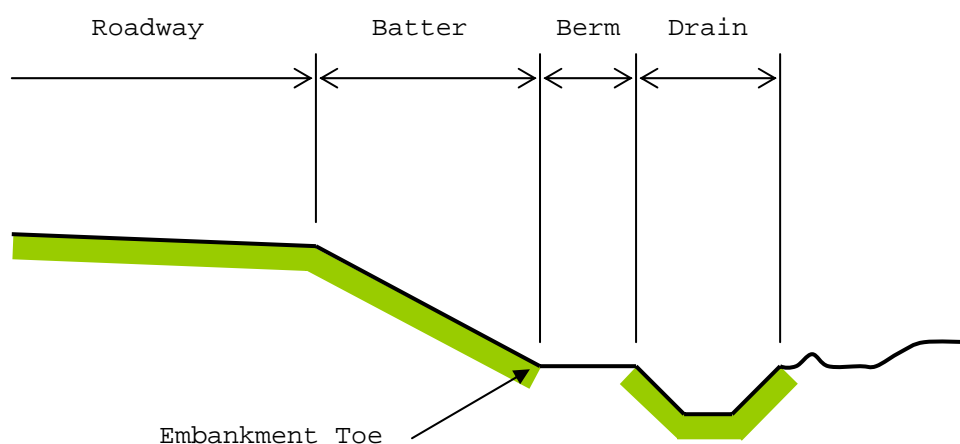
24. Unobstructed Carriageway Width at Single Lane Drifts and Structures with Width Restriction and Warning Signs

Because of the high cost of structures and drifts, it is sometimes not possible to justify two lane width construction on low traffic volume roads. In these circumstances a single lane structure may be justified. Adequate warning signs and safety features must be provided to provide advance information to drivers and safe

passage without risk of vehicle damage or injury to travellers. Adequate provision should be made for refuge and safety of pedestrians and other vehicle users where necessary.

25. Berm Width at Embankment Toe

This is the horizontal dimension between the toe of the embankment and the side drain. The standard dimension is recommended, however, this may have to be adjusted in consideration of local conditions, including land availability, whether there is significant animal cart traffic and whether the drain is lined.





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**SEACAP 2
CAMBODIA TRANSPORT
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FINAL REPORT

**APPENDIX 3
Technical Guideline No 1**

ROYAL GOVERNMENT OF CAMBODIA



MINISTRY OF RURAL DEVELOPMENT

Technical Guideline No 1
Rural Road Surfacing

Consultation Draft - January 2006

FOREWORD TO MRD TECHNICAL GUIDELINE NUMBER 1

This document provides guidance on the selection of an appropriate surface for rural roads.

The Ministry of Rural Development (MRD) has formulated a policy document for rural roads which provides a framework for the sector activities (1999 and revised 2002).

POLICY OBJECTIVE

“The Ministry of Rural Development is responsible for facilitating improvement of rural social and economic conditions.

Mission Statement

The MRD Department of Rural Roads will contribute to this goal by increasing rural access through cost-effective investment in the maintenance and development of rural roads, routes and transport infrastructure.”

Ministry of Rural Development is responsible for the development and implementation of policies for the rural roads and routes of Cambodia. It will also develop and monitor implementation strategies to achieve the policy objectives, review their impact and effectiveness and update the policies and strategies as necessary. Ministry of Rural Development will liaise with Ministry of Public Works & Transport and other partner organisations on all issues of common interest to ensure harmonisation with the National Transport Plans and other policies affecting the Transport sector.

One of MRD’s responsibilities is to provide Technical and Management guidance on aspects of Planning, Design, Construction, Rehabilitation and Maintenance of rural roads. This is the first of a series of Technical Guidelines intended to help fulfil that responsibility.

This document has been prepared with assistance provided by Intech-TRL, funded by the UK Department for International Development (DFID) under the SEACAP initiative.

1 INTRODUCTION

1.1 Application of this Guideline

The Technical Guideline No1 should apply to 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 will apply to roads irrespective of their current surface, be it earth, gravel/laterite or a more durable surface.

1.2 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 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.

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 intervals¹. The funding and resources are usually not available to achieve this and the surface will invariably deteriorate and revert to an earth surface.



Figure 1 Dust emissions from gravel road in the dry season

¹ 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 - 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 experiences² 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 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

² 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.

researched the viability of undertaking a national gravel surface performance study in 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 4).

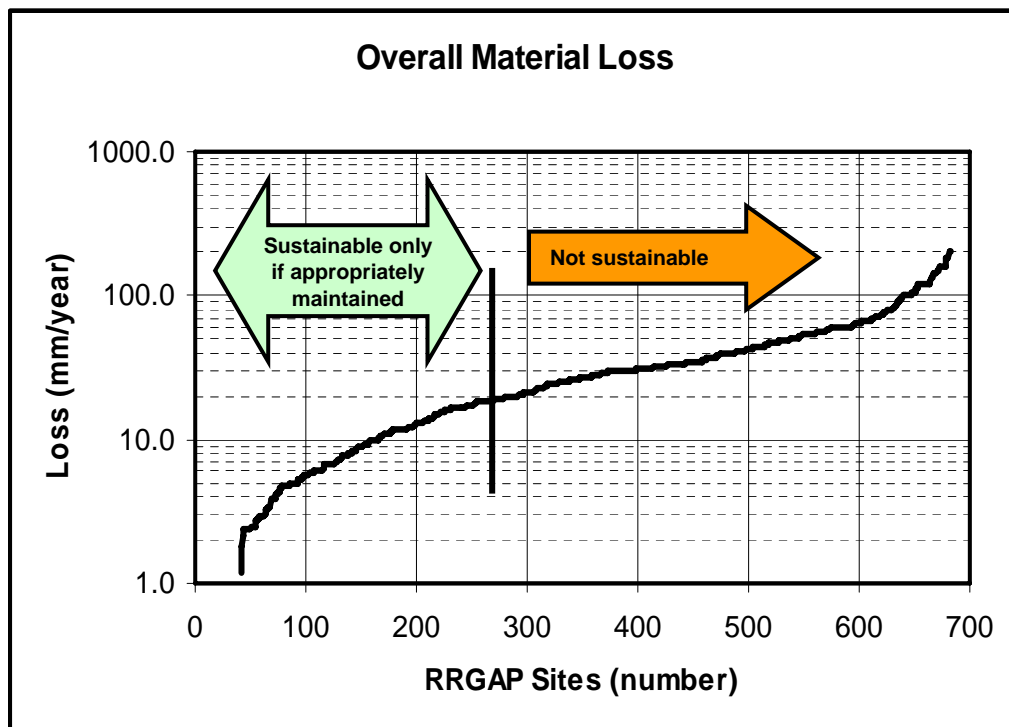


Figure 4 - RRGAP investigations of Annual Gravel Loss on over 700 roads sections

3 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)³, 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.

³ ADT = Average Daily Traffic. PCU = Passenger Car Units (See MRD Interim Rural Road Standards for conversion factors).

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.

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 **Appendix 1** of this document.

4 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 **Appendix 2** provides the preliminary listing of the various rural road surface options.

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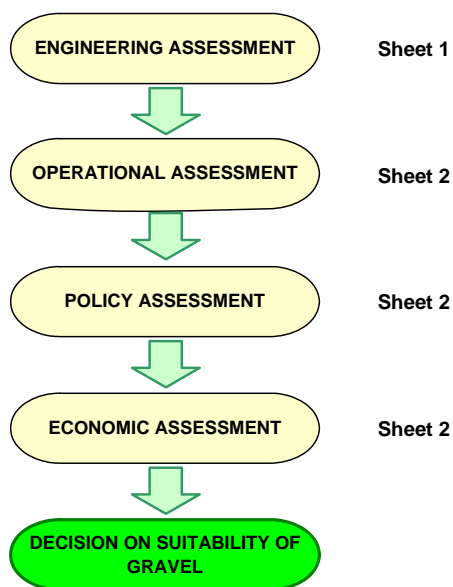
APPENDIX 1

APPROPRIATE RURAL ROAD SURFACE SELECTION

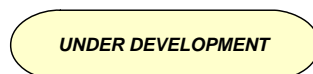
A Decision Management System for the Assessment of Gravel as a Paving Option

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

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

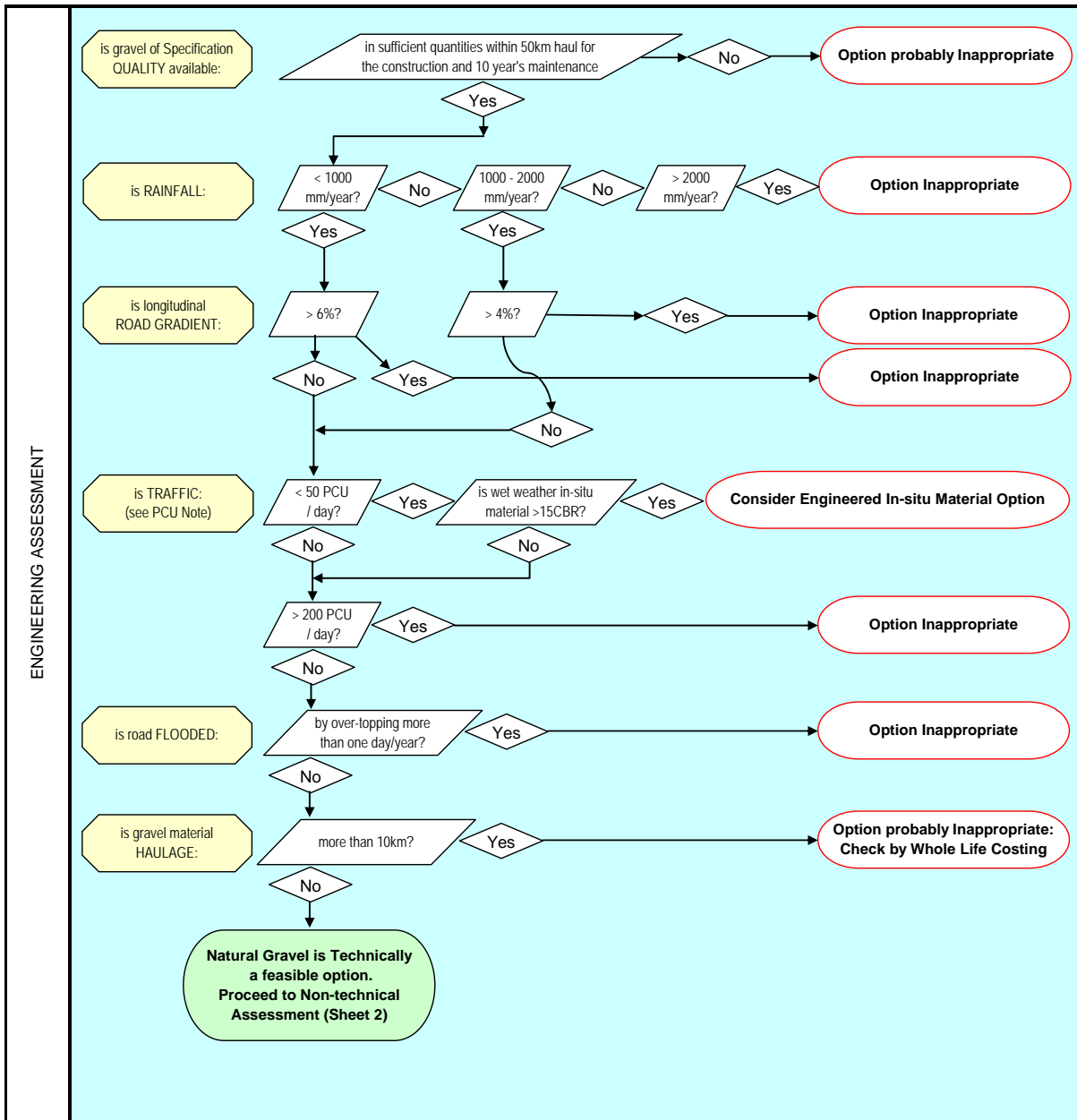


STEP 2 - If Gravel is not suitable, Selection of Appropriate Surface Option



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

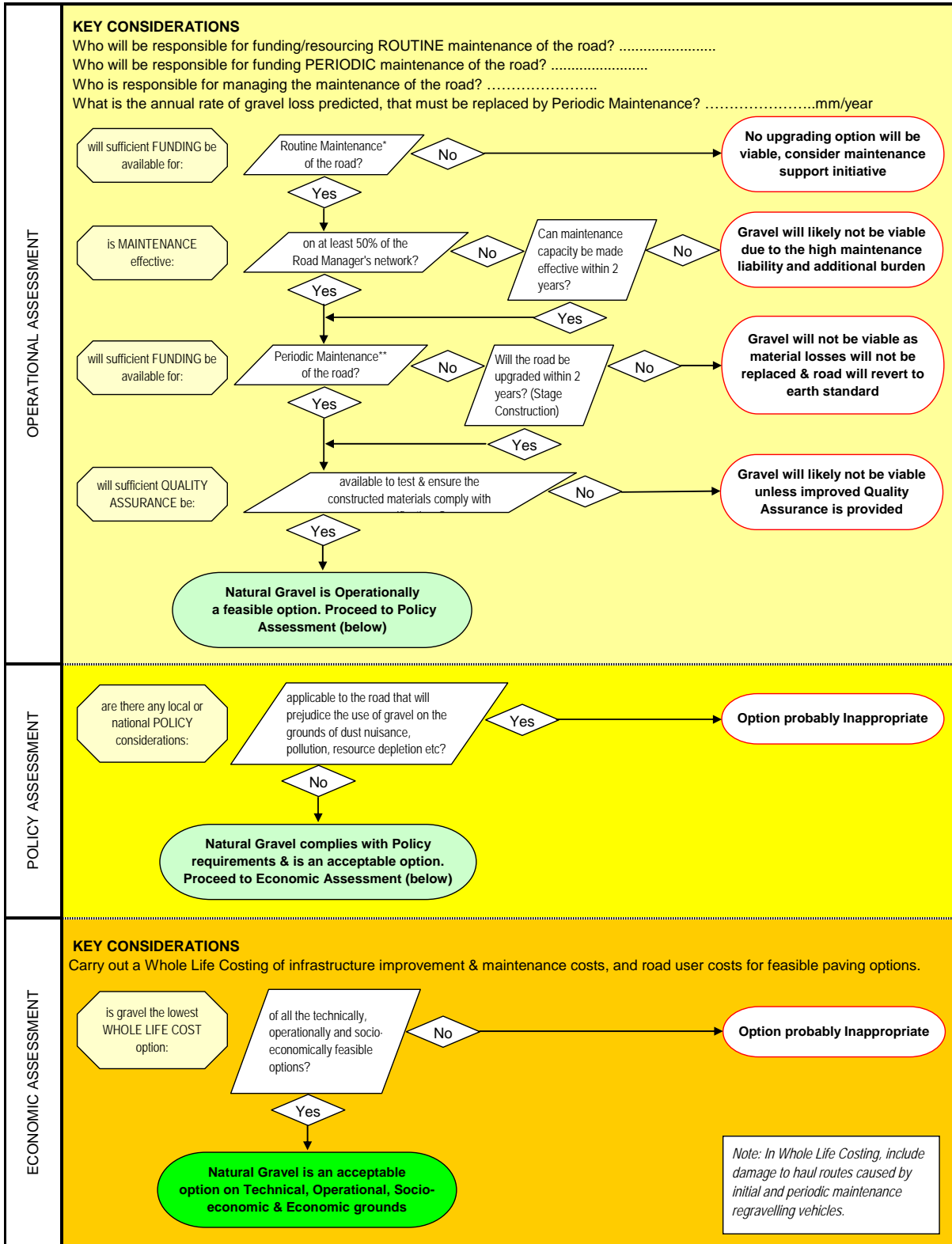
SHEET 1 - Engineering Assessment



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

APPENDIX 2

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

Type of Roadbase or Subbase

Application suitability depends on various factors.

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

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



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FINAL REPORT

**APPENDIX 4
Road Safety Recommendations**

SEACAP 2 – Final Report

APPENDIX 4 – SEACAP 2 Road Safety Recommendations

INTRODUCTION

The contents of the current draft Cambodian National Road Safety Action Plan are generally sound and relatively comprehensive covering a total of 15 different sectors or subject areas, each having its own series of Actions. These summary tables of Actions are reproduced in the main body of SEACAP 2 Road Safety report and the sectors' weaknesses and strengths are each discussed. Thus, only the additional recommendations of the SEACAP 2 study (in brief) for each of the 15 sector Action Plans are included in the following sections of this Appendix. For full details refer to:-

SEACAP 2 - WORKING PAPER 3, Improving Road Safety, May 2005, available on www.cnctp.info

RECOMMENDATIONS

Action Plan 1: Establishing a NRTSC for Coordination and Management of Road Safety

- 1.1 The NRTSC should revise the draft Action Plan after carefully deciding on a more accurate budget allocation based on a detailed costing of actions required over the next 5 years.
- 1.2 Many stated dates in the Plan have already passed without the particular action having been completed. All actions need to be thoroughly investigated and a new timetable set, otherwise it is likely that confidence and momentum will be lost.
- 1.3 Agree a timetable for regular meetings of the NRTSC (for example, quarterly) to ensure members are kept up-to-date with progress around the country on road safety and to serve as an incentive to report back actions taken.
- 1.4 The NRTSC should disaggregate the target casualty reductions proportionately to the Municipality and Provincial Regions on an annual basis in terms of actual number to be achieved.
- 1.5 The NRTSC should produce and require Municipal and Provincial Committees to issue detailed plans on an annual basis, stating exactly how their budgets will be spent to achieve their individual targets.
- 1.6 It is important that the strategy is monitored at various stages throughout its implementation to help keep it on course, and ultimately a full evaluation of its effectiveness should be carried out.

Action Plan 2: Road Accident Data System

2.1 Incorporate additional fields on the new accident report forms, as detailed in Appendix A.

2.2 Consider introduction of an easy-to-use computer accident database and analysis system (such as TRL's MAAP). The package should require minimal training yet provide reliable cross tabulations and other analyses, including GIS mapping analyses. It should help to ensure more widespread utilisation of the database across the country.

2.3 Greater funding will be required for the system, hardware and comprehensive training for the accident database than is currently given in the National Action Plan. Indeed the Plan for the accident database should be more detailed showing planned phases of extension to other hospitals around the country by set dates, to assist gradual national coverage.

Action Plan 3: Road Safety Funding

3.1 All items in the National Road Safety Plan should be carefully costed in the submission for ministerial approval.

3.2 Consider setting up a road fund, for example, from a fuel levy and/or special tax from the vehicle insurance industry.

3.3 Consider making 3rd party vehicle insurance compulsory, with appropriate controls set on the insurance companies to maintain realistic, affordable maximum premiums.

Action Plan 4: Road Safety Audit – Hazardous Locations

4.1 The persons carrying out road safety audits or AIP work need to possess considerable experience in recognising potential safety problems. Thus initially there will be a need to commission audit experts to help decide on the necessary types of audit, conduct audits and provide long-term training. This is essential in order to build up the very necessary knowledge and perceptual skills required by the relevant local engineers. .

4.2 Define current blackspot levels including highway units. This is important in order to make legitimate comparisons and to set priorities for treatment.

4.3 Ensure that highway engineers monitor and carry out evaluations of effectiveness of implemented safety schemes, and record the results in their annual plan.

4.4 In the current draft of the Action Plan, a considerable increase in the budget specified for treatments will probably be required to meet casualty reduction targets.

Action Plan 5: Roads Environment and Road Design

5.1 The roads standards, particularly with regard to safety features, need to be followed much more consistently and good records kept centrally of justifications for any departures from standards.

5.2 There needs to be clear unambiguous priority indicated at each intersection (signs and stop lines), so that traffic on the higher status road is always given precedence over that from the less important road.

5.3 It is essential that land-use planners understand the traffic and safety implications of their proposals before schemes are finalised. This should be done by circulating the plans for comment to fellow professionals responsible for traffic and road safety (part of the safety audit process).

5.4 Carry out research into the possibility of using local (waste or by-product) materials as dust inhibiting agents to spray/spread on rural roads in the dry season.

Action Plan 6: Road Safety Education for Children

6.1 The cost of the road safety training materials should be included in the MOEYS's current 5-year action plan (currently in draft).

6.2 The MPWT need to inform MOEYS when they install new road features with which road users may not be familiar (eg. the diagonal line-marked pedestrian crossing, and the concrete median dividers), so that children can be informed at school, and the course material changed as necessary.

6.3 The budget currently stated in the NRTSC Action Plan for printed material will only provide, on average, about US\$20 per school. It is suggested therefore that this be increased significantly.

6.4 It is suggested that separate practical lessons in the playground on safe cycling would also provide very worthwhile training.

Action Plan 7: Traffic Law and Regulations

7.1 The new draft Traffic Law needs to be finalised and introduced as soon as possible.

7.2 All the suggestions made by Handicap International on this draft should be incorporated (Appendix B), with the minor exception to Article 17 which it is recommended should that there should be no differentiation in maximum speed limit for different vehicles in both urban and rural areas. However, for heavy vehicles

greater than 3.5 tons, it is felt that there should be a limit of 70km/h on rural highways.

7.3 A number of further minor amendments to the HI comments are listed in Appendix B of this report. These include the following:-

- i) That the section on law infringement penalty details for each offence, i.e. fines, licence bans and prison sentences, should be moved to a separate set of Regulations or sub-decree in order to make them more easily updated without another full set of Land Traffic Laws having to be approved.
- ii) The rule pertaining to wearing of helmets should also have a note about proper wearing of the chinstrap.
- ii) The need for child seats and restraints in cars.
- iii) Consideration of effectively banning remorques by limiting by law the number of passengers they may carry.
- iv) Bicycles or tricycles should show a white light to the front and red light to the rear if ridden during the hours of darkness.

Action Plan 8: Law Enforcement

8.1 An expert police advisor is recommended to review operations and draw up a policing plan, including equipment and training needs. The Traffic Police strongly support this recommendation.

8.2 There appears to be a clear need and justification for acquiring appropriate equipment for enforcing speed limits and drunk driving.

8.3 Improve safety of pedestrians by helping to enforce give way rules at zebra crossings and keeping footways clear.

8.4 Reducing the number of unregistered vehicles by increased vigilance and eventual use of vehicle registration database to subsequently follow up vehicle owners that have committed traffic infringements.

Action Plan 9: Technical Inspection (of vehicles)

9.1 Consideration should be given to making it a requirement to show a valid inspection certificate when road tax is renewed.

9.2 Assign realistic estimates for the opening of more test centres in the provinces as noted in the Action Plan.

9.3 Encourage proper completion of the visual part of the vehicle inspection procedure carried out manually, as specified.

Action Plan No. 10: Driver training (and testing)

10.1 Provision should be made now to be able to cope with the expected high demand for motorcycle tests when the new Traffic Law comes into force.

10.2 It is suggested that examiner's increase the standard required to pass the driving test, e.g. the pass rate should be reduced from 80% to about 50%, in common with many other countries.

10.3 Increase enforcement of the need to produce a medical certificate assuring of fitness to drive before taking the test, and also include a simple eyesight test (eg. reading a registration plate at a set distance).

10.4 The candidate's ability to stop the vehicle in a controlled manner in an emergency should be tested. Again this can be done simply by the examiner sitting in the car, instructing the candidate to imagine a child has run into the road when he taps the dashboard.

10.5 Consideration should be given to including a second part of the test after successful completion of the test track, when the examiner accompanies the candidate on a given route along public roads.

Action Plan 11: Emergency Assistance to Traffic Accident Victims

11.1 Given the very high cost of procuring ambulances in Cambodia, the current amounts stated in the Safety Plan will be grossly inadequate to meet the stated demand, and should therefore be revised.

11.2 A more detailed needs assessment should be carried out that gives greater attention to where ambulances are needed in relation to the response times that can be assumed for all locations in the country. This plan should also include costs of running the ambulances (ie. crew, spares, fuel etc) and purchase of the right sort of vehicles (e.g. adapted 4-wheel drive vehicles will be needed in most rural areas).

11.3 The equipment carried on board ambulances is rather limited and a review of this together with extraction equipment for fire tenders should be made and separate budget allocation made in the Plan.

Action Plan 12: Road Safety Publicity Campaigns

12.1 Design publicity campaigns drawing on the theme of personal responsibility. This has been the mark of effective campaigns in many countries.

12.2 Safety publicity activities in Cambodia have made good progress towards the general goal of raising the level of safety consciousness. The objectives now must be:

- to ensure continuity in publicity activities
- to improve the techniques employed
- to move towards a more focused and integrated approach
- to introduce structured evaluation of safety activities.

12.3 When the new Law on Land Traffic is given ministerial approval the radio and television services should be utilised fully to convey the important changes in the laws to all road users. Preparation of these bulletins should begin well in advance of the law ratification.

12.4 Campaigns on speeding and drinking and driving should be planned, perhaps also focussing on the young males.

Action Plan 13: Partnerships with Private and NGO's

13.1 As a means of boosting the funds that central government will need to achieve the casualty reduction targets, the NRTSC should seek discussions with the oil industry, tyre companies, insurance companies, motor suppliers etc. to see if they are prepared to contribute resources for either campaigns, other road safety publications or even road infrastructure improvements.

Action Plan 14: Road Accident Costing

14.1 Use the accident costings currently available from the ADB study, but conduct a full in-depth study every 5 years, applying multipliers for national annual inflation in the intervening years.

14.2 Ensure that these figures are used effectively throughout the country to justify expenditure on accident remedial work and also used in the eventual evaluation.

Action Plan 15: Road Safety Research Institution

15.1 Conduct a series of roadside surveys to determine the incidence of drink and drug usage by drivers. Continuing surveys would allow for effective evaluation of the measures that are taken to combat the problem, and ensure that future efforts are properly directed.

15.2 A series of vehicle speed surveys should be conducted to determine the level of speed limit infringement.

15.3 Cooperate with UPM of Malaysia in joint studies to research effective ways of coping with safety problems associated with high volumes of motorcycle traffic.

THE WAY FORWARD

The improvement in road environment and driver and other road user behaviour in Cambodia will necessarily take a long period of time to bring about. However, the 'do-nothing' option will result in extremely high numbers of deaths and seriously injured people on the nation's roads by 2015.

If the Road Safety Action Plan together with further recommendations made in this report are followed then the targets set for the next 5 and 10 years should be achievable. If they are achieved, then over the 10-year period to 2015 this will result in a total of 8500 lives having been saved. Using the latest approximate costing produced for Cambodia, a total of about US\$174million will be saved over this 10-year period in fatality accidents alone. This would justify a doubling in the current estimated budget for the Plan which would still result in a saving of US\$20million to the nation. It should be noted that this is also a conservative figure because with the remedial work that will have been put in place to achieve this saving in fatalities, it is certain that many other serious injury accidents will be saved, thereby wasting less of the nation's resources and saving a great deal of human suffering.



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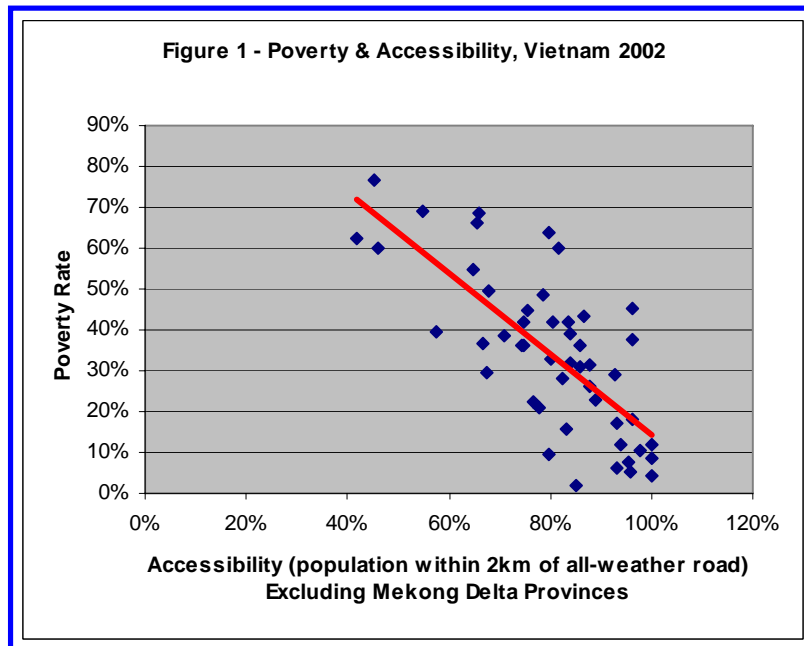
**APPENDIX 5
BBC Earth Report Bulletin**



Series 7: Programme 5 (of 8) - 'Taking Off'

Cross-country Traffic - Cambodia

Good roads provide an economic lifeline for remote areas, allowing the transportation of goods and also enabling people to access services such as education and health. The clear link between poor access and poverty is established: see example Figure 1.



Source: Vietnam 2002 Living Standards Survey

In rural parts of Cambodia and Vietnam road conditions are generally poor, with ruts and gaping potholes slowing down and damaging vehicles, and raising transport costs. New ways of using cheap local materials are smoothing out these roads allowing access for South East Asia's cross-country traffic.

Road Construction

Laterite, and other forms of naturally occurring gravel, has been widely adopted as a surfacing material for low cost rural roads as it has been relatively cheap and until recently reasonably available in many locations. This is an intermediate initial cost solution between a basic earth road construction and the more sturdy, but costly, bituminous or other types of paving. However laterite/gravel material has its limitations – traffic loads and levels must not be too high, gradients not too steep and it is also affected by extreme weather such as tropical monsoons, which wash away the gravel, and in the dry season dust is a significant hazard and further loss of the surface materials. These roads need regular maintenance

as once the surfaces become eroded rural communities become cut off, slowing down their economic and social development. Proper maintenance in developing countries is unfortunately difficult to achieve for a range of reasons.



Photo 1
Eroded Gravel Road

The scale of this problem is huge, for instance in Cambodia it is estimated that there are 28,000 kilometres (km) of rural roads, most of which are unsurfaced. In Vietnam the total road network is approximately 210,000km, but only about 15 percent is considered to be in good condition. The cost of fully rehabilitating and maintaining these roads to gravel standard would be prohibitive, especially as natural gravel is becoming an increasingly scarce resource. Indeed the transportation of gravel in heavy trucks itself is a factor in the deterioration of roads.

A project run by Intech Associates and supported by TRL Ltd, with financial support from the UK Department for International Development (DFID) and the World Bank, is looking at the effectiveness of alternative materials in an appropriate way, such as bamboo, stone, cement and brick to make roads in Cambodia and Vietnam. Using local resources and machinery means the roads would be more affordable, and it would provide a useful income for local enterprises and communities.

Innovative Approach

The project takes a more realistic approach to road design taking into account local conditions and the road environment, traffic characteristics and loading, maintenance, resources, technical and implementation options, environmental and whole life cost considerations.

“In essence what we are trying to do is develop road construction and surfacing techniques that governments and communities can afford, have low maintenance so that they will be possible to maintain and also to create local job opportunities” says Rob Petts, from Intech Associates.

It was decided to assess the effectiveness of other surfacing materials, which although they may have a higher initial cost, over the whole life cycle of the road would prove more durable and therefore more cost effective. Improvement options ranged from the low cost 'hardening' of earth roads where these were only used by non-motorised transport or motorcycles, up to paving which could cope with heavily loaded trucks. A range of alternative materials were explored, including bamboo, stone and brick.

Bamboo can be used to reinforce a concrete road surface. It is a native plant in many parts of Asia and in splint form, laid as a lattice within the concrete, has proved as effective as imported steel in reinforcing these roads. The strong straight structure of mature bamboo splints acts like thin binding steel rods preventing shrinkage cracks as the concrete road surface dries out after casting.



Photos 2 and 3 – Bamboo Reinforced Concrete road

The bamboo should be mature, about four years old, with straight, thick stems. It should be cut and allowed to dry and season for up to six weeks before use. Then the bamboo should be split into splints, no more than 25mm wide. The cured splints are placed in a reinforcing lattice framework within the concrete. The road itself should have well designed drainage, with a slight surface camber (1cm drop in every 50cm) to shed rainwater to the side, to ensure longevity. The concrete when mixed must not be too wet (like soup) as this inevitably causes cracking as it dries out. This is a common fault with concrete roads built by communities or inexperienced contractors.

Although using bamboo reinforced concrete means construction takes longer and has higher initial costs, the advantages are considerable:

- it has an estimated life span of 40 years or more
- there is minimum maintenance
- it only requires simple equipment to use - a small roller, concrete mixer and vibrator

- it is a good use of local resources, especially labour and materials
- it is dust-free, easy to clean surface
- it has tolerance to flooding

Using local materials for the road base means women can regularly earn cash by hand-breaking stone. Depending on the quantity of stone they break, these women earn on average £28 (\$50) a month - around 85p (\$1.50) per day. Depending on the size of the stone a layer is bedded on a thin layer of sand and gravel, for example 10-15cm stones are hand packed and placed in a 2-3 cm thick sand/gravel layer, then tightly packed and wedged into place, smaller stone chippings are then hand rammed into the joints and remaining gaps filled with sand.



Photos 4 and 5 – Hand quarried stone and Cobble Stone Paving

“In this country where labour is abundant and cheap you know that US\$1 a day wage is attractive for many rural people. This is an ideal local resource. Most of the investment will go to the local economy and generate direct employment as well as indirect benefits.” Heng Kackada, Cambodia manager from Intech Associates

Southern Vietnam has a thriving brick making industry and very few hard stone deposits for road building. Clay is locally available and the small local brick kilns make use of rice husk as a renewable energy source to fire the bricks. These traditional bricks are emerging as ideal material for road building. The bricks are as strong and regular as factory made products. They are generally 10cm x 20cm and 7-10cm thick, and laid by hand on a thin, 3-5cm, sand bed over a prepared and compacted road base. The joints are then filled with sand-cement mortar and the surface is then lightly compacted.



Photos 6 and 7 – Rice husk burnt clay brick production and paving

Road Maintenance

Whatever the surface, all traffic causes wear and tear so in addition to good road construction action needs to be taken to ensure their sustainability. One of the most damaging transport issues is the overloading of vehicles – the increasing weight of trucks damages the road surface and causes bridge collapses. Now width restrictors on selected rural roads are stopping the large lorries of two-and-a-half metres wide, and these barriers are helping to preserve the road surface.

Regular maintenance when implemented is also prolonging the life of the existing gravel and earth roads. The gravel roads are built with a camber to assist rainwater run-off, but over a period of time the traffic and rain tend to flatten the surface and potholes start to appear. Carrying out repair work to re-shape the roads every 2-3 months increases the longevity of the roads.

Development Technology Workshop (DTW) has developed a low-cost prototype road grader that can be used to repair road surfaces. The design focuses on making the grader as robust and easily repairable as possible. It has no mechanical gearing or hydraulics, and all labour and parts are Cambodian apart from a steering column that is made from recycled light truck parts from Japan. Using just a small tractor the grader can be towed to its workplace. As this grader costs less than a third of the price of other graders, it reduces the cost of maintaining rural roads.



Photos 8 and 9 – DTW designed towed grader for road maintenance

Results

The initial trial phase of this project in Cambodia and Vietnam has come to an end. The technical results are still being assessed and documented for website and other distribution, but the results so far have been very encouraging. Not only are the roads in better condition, but also income is being generated by local construction enterprises that are in place to provide the long-term maintenance service that the roads require.

Local people confirm the impact of the project, saying that they now have improved access to healthcare, information and education. Improvements in road links have resulted in investment along the roads. Young people are able to find work in the industrial zones because of better links to the district roads and main highways, and local people are enjoying shorter journey times to markets because of improved commune roads.

The Governments of Cambodia and Vietnam are eager to mainstream these new approaches. They are already being incorporated in new World Bank and Asia Development Bank projects worth over £60 million (\$100 million).

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Global Transport Knowledge Partnership
Website: www.gtkp.org

DFID Transport Links
Website: www.transport-links.org

Planning Rural Roads
Website: <http://www.ruralroads.org/>

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Intech Associates
CONSULTING ENGINEERS



DFID Department for International Development



Department for International Development
in cooperation with World Bank
and Asian Development Bank
SEACAP PROGRAMME

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SEACAP 2
CAMBODIA TRANSPORT
MAINSTREAMING PARTNERSHIP
FINAL REPORT

APPENDIX 6
Introduction to Rural Road Surfacing
ITC Rural Development Courses

February 2006

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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

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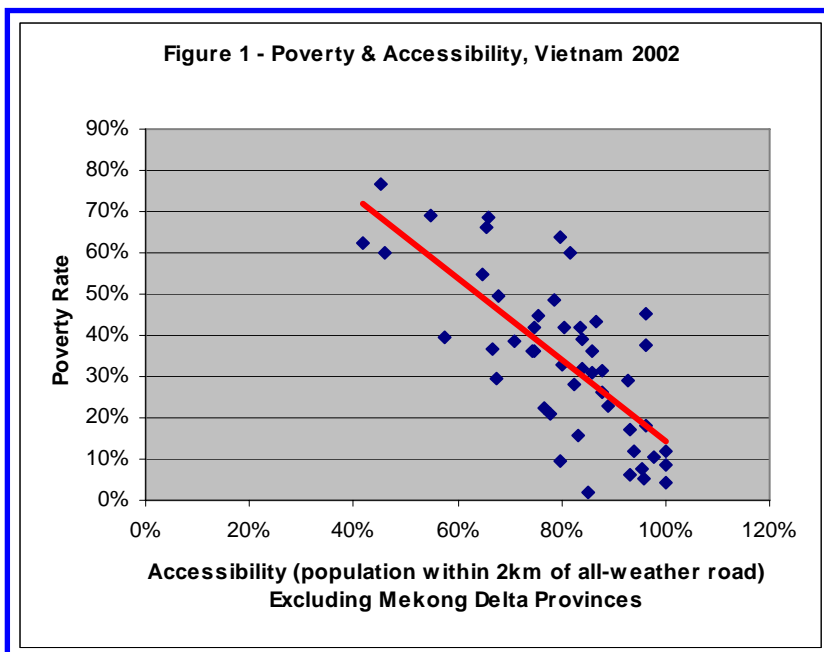
Background

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 referred 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 regions¹. 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 network².

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 research³ 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 not 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, CAFE0 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 intervals⁶. 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 SEACAP⁷, 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.

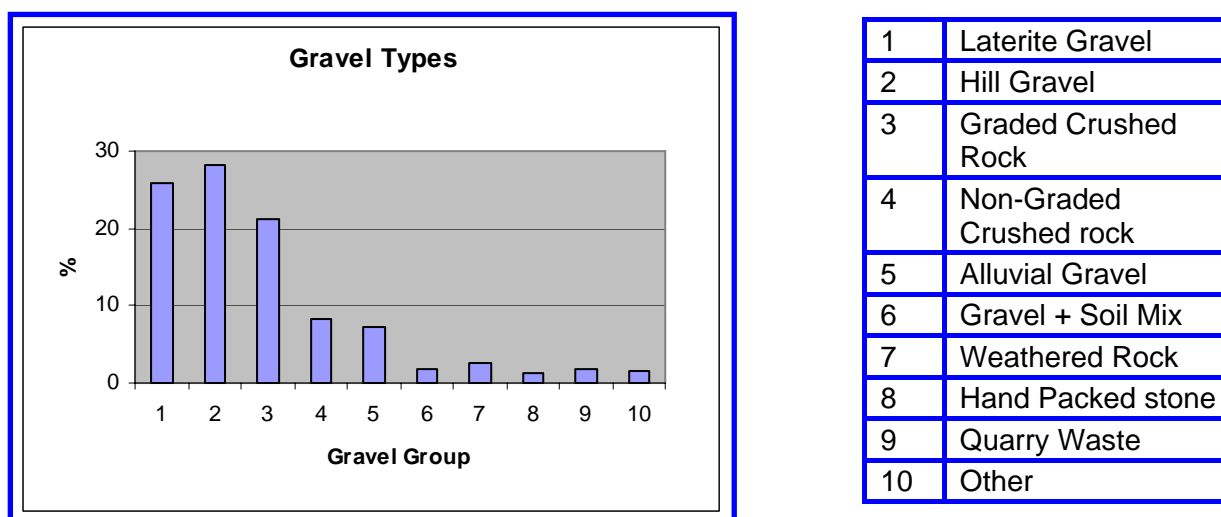


Figure 1.1 – RRGAP Range of Materials Employed as Unsealed Road Surfaces

Analysis of the results has been finalised⁸. 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 overlaid 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.

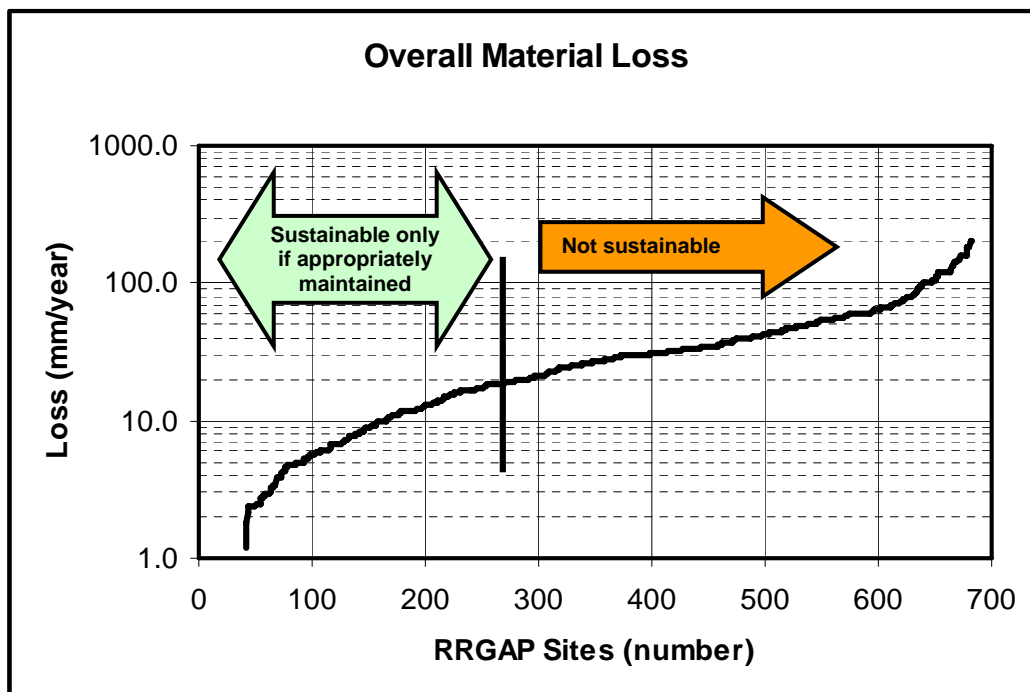


Figure 1.2 – Adjusted Apparent Material Loss Summary

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.

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 cost¹¹ 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.



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

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- 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.

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 and 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.

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 intervals¹². The funding and resources are usually not available to achieve this and the surface will invariably deteriorate and revert to an earth surface.



Figure 2.1 Dust emissions from gravel road in the dry season

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

experiences¹³ 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

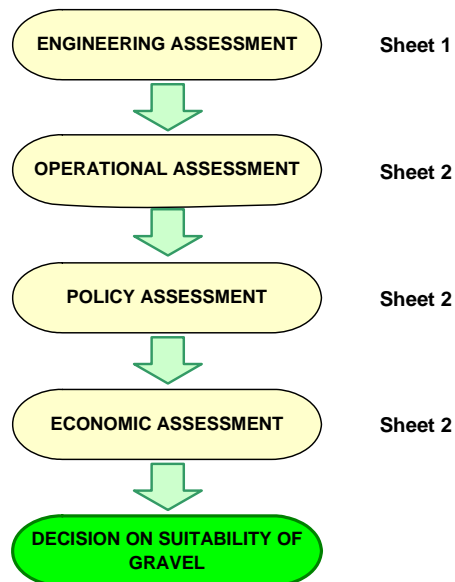
Research work based on the Puok Market and other trials in Cambodia, and the Vietnam surfacing trials, is currently being finalized. This will allow detailed recommendations of the various surface options to be made in the near future. The table in Figure 2.5 provides the preliminary listing of the various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

Figure 2.4 (3 pages)

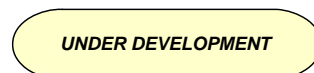
APPROPRIATE RURAL ROAD SURFACE SELECTION A Decision Management System for the Assessment of Gravel as a Paving Option

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

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

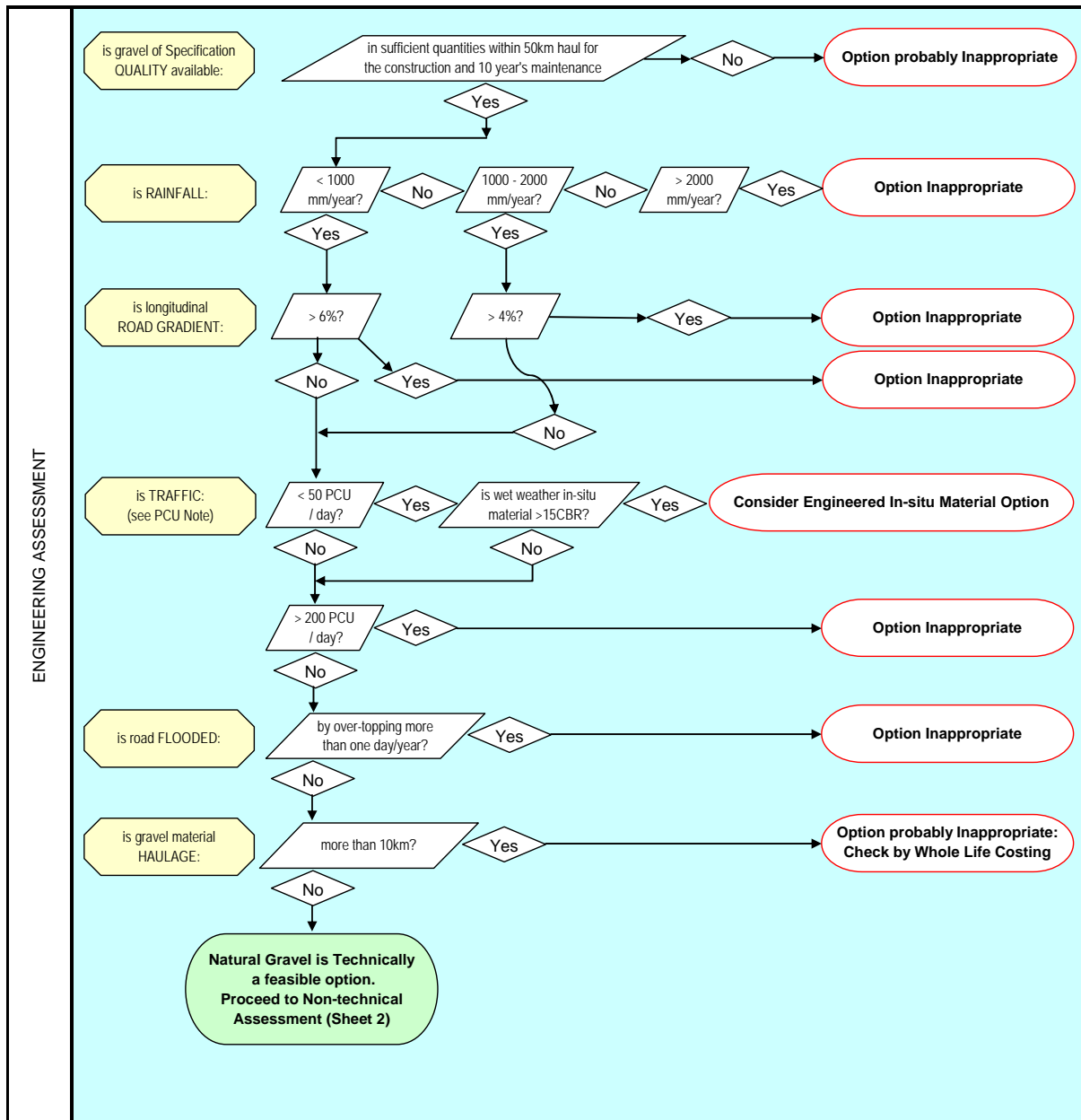


STEP 2 - If Gravel is not suitable, Selection of Appropriate Surface Option



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

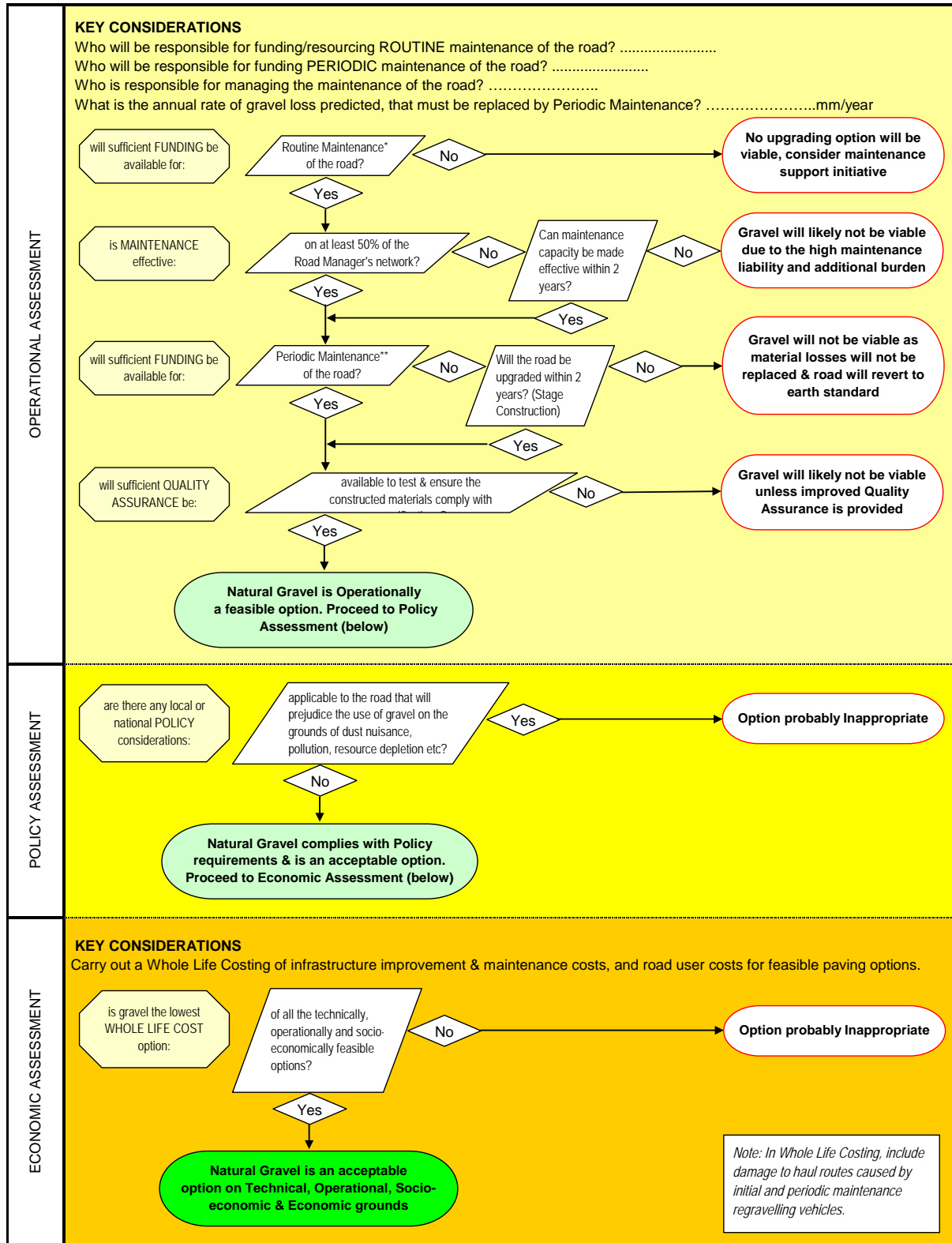
SHEET 1 - Engineering Assessment



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	SUITABILITY FOR TRAFFIC		
		Light	Medium	Heavy
1	Engineered Natural Surface	Light		
2	Soil Stabilisation	Light		
3	Natural Gravel / Laterite	Light	Medium	
4	Water Bound Macadam	Light	Medium	
5	Dry Bound Macadam	Light	Medium	
6	Crushed Stone Macadam	Light	Medium	
7	Hand Packed Stone	Light	Medium	Heavy
8	Telford Paving	Light	Medium	Heavy
9	Cobble Stones	Light	Medium	Heavy
10	Stone Setts or Pavé	Light	Medium	Heavy
11	Dressed Stone	Light	Medium	Heavy
12	Mortared Stone	Light	Medium	Heavy
13	Stone Chippings	Light		
14	Slurry Bound Macadam	Light	Medium	
15	Bituminous Sand Seal	Light	Medium	
16	Bituminous Chip Seal	Light	Medium	Note 3
17	Slurry Seal	Light	Medium	Note 3
18	Ottaseal	Light	Medium	Heavy
19	Penetration Macadam (Bitumen)	Light	Medium	Heavy
20	Pre-Mix Macadam (Bitumen)	Light	Medium	Heavy
21	Burnt Clay Brick	Light	Medium	
22	Concrete Brick	Light	Medium	Heavy
23	Un-reinforced Concrete	Light	Medium	Heavy
24	Steel Reinforced Concrete	Light	Medium	Heavy
25	Bamboo Reinforced Concrete	Light	Medium	Heavy
26	Geo-cell Paving	Light	Medium	Heavy
27	Stone Chipping Blinding	Light		
	Type of Roadbase or Subbase	<i>Application suitability depends on various factors.</i>		
1	Soil Stabilisation	Light	Medium	Heavy
2	Natural Gravel / Laterite	Light	Medium	Heavy
3	Water Bound Macadam	Light	Medium	Heavy
4	Dry Bound Macadam	Light	Medium	Heavy
5	Crushed Stone Macadam	Light	Medium	Heavy
6	Hand Packed Stone	Light	Medium	Heavy
7	Telford Paving	Light	Medium	Heavy
8	Slurry Bound Macadam	Light	Medium	Heavy
9	Sand Aggregate	Light	Medium	Heavy
10	Armoured Laterite	Light	Medium	Heavy
11	Pulverised Fuel Ash	Light	Medium	Heavy

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

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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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