SEMINAR: SUSTAINABLE ACCESS AND LOCAL RESOURCE SOLUTIONS
Date : 28 – 30 September 2005

TITLE: The Performance of Low-Volume Unsealed Rural Roads in Vietnam

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INTRODUCTION

DFID and World Bank are 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 support for RT2 by World Bank and DFID. The Rural Road Surfacing Trials (RRST) were planned and are currently being implemented, initially in four provinces and now in a further eight.

During the inception phase of these studies, which included the planning, construction and monitoring of trial road sections in four provinces, it became apparent that already constructed RT1 and RT2 roads could provide a database of information on the actual real-time performance of gravel and other unsealed surfacings in a range of Vietnam road environments. This information would be extremely useful in developing guidelines to allow the use of unsealed surfacing in Vietnam where it is economical, sustainable and environmentally appropriate. Such guidelines, in conjunction with information resulting from the RRST programme, would considerably enhance the ability of rural road practitioners to make informed and cost-effective decisions on surface options for future road programmes, such as the upcoming Third Rural Transport Project (RT3).

Consequently, DFID agreed to fund a scoping study to be undertaken by Intech-TRL; to develop an appropriate methodology for a proposed wider Rural Road Gravel Assessment Programme (RRGAP).The RRGAP Scoping Study investigated methodologies for unsealed road condition assessment and identified key issues that needed to be accommodated within the main RRGAP programme (Intech-TRL, 2003). Based on these, a modular methodology was proposed for the collection and analysis of rural road gravel surfaces in Vietnam. This DFID-funded research was subsequently awarded to Intech-TRL and their local partners: the Institute for Transportation, Science and Technology (ITST) under the South East Asian Community Access Programme (SEACAP).

This paper draws on information from the RRGAP along with relevant aspects of the parallel RRST programme, to summarise some current knowledge on the performance of unsealed rural roads in Vietnam and to outline guidelines on the appropriate use of unsealed surfacing.

SCOPE OF THE RESEARCH PROGRAMME

The research approach was based on obtaining a “snapshot” of unsealed rural road conditions by assessment of the current condition of a range of RT1 and RT2 unsealed roads representing the sometimes widely differing rural road environments in Vietnam. An advantage of this approach is that it did not involve the monitoring of a specifically staged construction trial, and therefore provides an assessment of outcomes of works constructed under the normal contract operational environment.

Key aspects of the research programme were:

- Data collected comprised a number of key sets, namely:
  General road environment,

General road link condition,
Detailed condition of selected profiles within in each link,
In-situ and laboratory test results.

- Information on road condition was based on the use of user-friendly road condition data collection pro-formas (Figures 1 and 2).
- The total of surveyed road lengths was large enough to be scientifically valid.
- A co-ordinated road selection process involving the Provincial Departments of Transport (PDoTs) ensured a representative sample of unsealed roads for survey.
- An intensive training phase for the field teams was followed by a cross-checking quality assurance procedure.
- Following an initial drive-over survey the selected roads were sub-divided into segments of similar character and a minimum of 3 profile surveys were undertaken in each segment.
- Representative samples of surfacing material from each road segment were sent to the ITST main laboratory for particle size and plasticity testing.
- Standard database software was used for data storage and manipulation.

Following a training period, fieldwork was undertaken from August to November 2004. The initial target rate of an average of 2 roads per day/team (10 per week) proved to be an accurate estimation of achievable progress and information was collected on 766 road profiles from 269 road lengths in 16 provinces. Figure 3 indicates the locations of each province.

ROAD CONDITION ANALYSIS

Although termed a “gravel” study, the RRGAP survey was in effect a study of a wide range of unsealed surfaces throughout Vietnam comprising; natural gravels; graded crushed stone gravels; mixtures of natural and crushed stone; and non-graded stone surfaces akin to water-bound macadam in character. Even within these groupings there is an apparent wide range of grading and plasticity characteristics, hence the overall deterioration assessments for Vietnam unsealed roads had to take this variation into account and be based on individual material groups as well as the variable climatic and terrain elements.

Given the added complexity and influence of other road environment issues in Vietnam such as construction quality control and maintenance regime, it was considered more effective not to develop a mathematically based deterioration model. The analysis therefore concentrated on identifying relative deterioration patterns and describing those road environments where unsealed roads are performing best and those where, on current evidence, unsealed roads are obviously performing badly. This approach has allowed key defining factors to be identified that can be used in deciding on the use or non-use of an unsealed road option within a defined road environment.

Unsealed roads may be considered to deteriorate in three principal ways:

- Wear and abrasion of surface material under traffic,
- Erosion of surface by surface water, rain and wind,
- Deformation of the surface and road bed under stresses induced by traffic loading and moisture condition.

RRGAP Field Data Collection Form 1

1.Province	**Binh Thuan**		6.Road Type	**Inter-Commune**
2.Road Name	**QL1-Phong Phu**		7.Completion Date	**Nov-03**
3.Road Ref a	**27 04 02**		8.Terrain ©	**2**
b			9. Surface Thickness (mm)	**200**
4.Start Co-ord	**BT1**		10.Overall Condition ©	**4**
5. End Co-ord	**BT2**		11.Visible Traffic ©	**2**

		S1	S2	S3	S4	S5
	12.Chainage	**0+000**	**0+650**	**2+000**		
Carriageway	13.Width (m)	**2.50**	**2.50**	**3.50**		
Geometry	14.Gradient ©	**4**	**3**	**2**		
	15.Curvature ©	**3**	**2**	**1**		
	16.X-Section Shape©	**4**	**4**	**4**		
Carriageway	17.Gravel Thickness (mm)	**150**	**100**	**150**		
Condition	18.Gravel Type(s) ©	**1**	**1**	**1**		
	19.Visual Appearance ©	**2**	**2**	**3**		
M	20.Surface Run-off ©	**1**	**2**	**2**		
1 2 **3**	21.Loose Material ©	**1**	**1**	**1**		
	22.Oversize ©	**1**	**2**	**2**		
	23.Ruts ©	**2**	**2**	**2**		
	24.Corrugations ©	**1**	**1**	**1**		
	25.Potholes ©	**4**	**1**	**2**		
	26.Erosion ©	**2**	**4**	**4**		

Shoulders		**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**
M	27.Width (m)	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**				
1 2 **3**	28..Material ©	**1**	**1**	**2**	**2**	**2**	**2**				
	29.Shoulder Condition ©	**3**	**3**	**3**	**3**	**3**	**3**				
M	30.Side Drain ©	**2**	**2**	**1**	**2**	**2**	**2**				
1 2 **3**	31.Side Drain Condition ©	**4**	**4**	**1**	**4**	**4**	**3**				

		S1	S2	S3	S4	S5
Testing	32.DCP Ref.	**PL1TP**	**PL2TP**	**PL3TP**		
	33.Sample Ref.	**PL203-2**	**PL203-2**	**PL203-2**		
Environment	34.X-Section Alignment ©	**1**	**1**	**1**		
	35.Current Water Table (m)	**-0.3**	**-0.2**	**0**		
	36.Max.Water Table (m)	**+0.5**	**+0.5**	**+0.5**		
	37.Flood ©	**4**	**4**	**4**		

38.Material	a.Location	b. Type	c. From	d. To	e. Haul
Sources	**Canh Duong**	**1**	**0.0**	**15.0**	**0-15km**

39.Additional Comment

Photos **No. 208-217**

BT1: N 10 54.27'; E 107 58.25'	**High rainfall**
BT2: N 10 55.36'; E 107 56.99'	**Local transport -light trucks**
Maintenance: 3 3 3	**Poor drainage**

Version F

40.Date	**28/08/2004**		41.Operator	**Tuan/Phan**

Figure 1 Typical Completed RRGAP Data sheet

RRGAP Field Data Collection Form 1: Data Codes (Sheet 1)

8 Terrain

1	Flat coastal/delta
2	Flat inland - padi
3	Rolling small hills
4	Moderate to high hills
5	Inter-montain plain
6	Mountainous

10 Overall Condition

1	No visible defects; As built conditions
2	A few minor defects
3	Isolated moderate defects - spot repairs
4	Significant defects - major re-shaping/gravelling
5	Severe defects - overall road rehabilitation

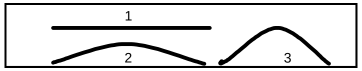
11 Visible Traffic

1	Local two wheel only
2	Local traffic with small trucks
3	Minor commercial traffic - occ. large trucks
4	Several trucks per survey period
5	Steady traffic

14 Gradient

1	Flat
2	0-2%
3	2-4%
4	4-6%
5	>6%

15 Curavature



16 X-Section Shape

1	As built: 4%
2	Good: 2-4 %
3	Flat: <2 %
4	Uneven
5	Bowl shape (-ve)
6	Super-Eleveation

18 Gravel Type

1 Laterite	6.Gravel+Clay
2 Colluvium (Hill gravel)	7.Weathered rock
3 Graded crushed rock	8.Hand-packed
4 Non-graded crushed rock	R.+ Rock
5 Alluvium	10.Other

19 Visual Appearance

1	Good surface shape - no stone protrusion
2	Some deterioration/stone protrusion
3	Up to 25% of sub-grade exposure
4	25 to 50% of sub-grade exposure
5	Extensive sub-grade exposure up to 75%
6	>70% sub-grade exposure

20 Surface Run-off

1	Unimpeded
2	Impeded by road shape
3	Impeded by shoulders

21 Loose Material

1	None
2	<15mm
3	15-50mm
4	>50mm

22 Oversize

1	None
2	Isolated
3	Extensive

23 Ruts

1	None
2	<15mm
3	15-50mm
4	>50mm

24 Corrugations

1	None
2	<15mm
3	15-50mm
4	>50mm

25 Potholes

1	None
2	<2 per 20m road
3	2-5 per 20m road
4	>5 per 20m road

26 Erosion

1	None
2	Slight
3	Moderate
4	Severe
5	Total

28 Shoulder Material

1	Soil
2	Gravel
3	Other

29 Shoulder Condition

1	Good
2	Moderate
3	Poor

30 Side Drain

1	None, but required
2	Yes
3	Not required

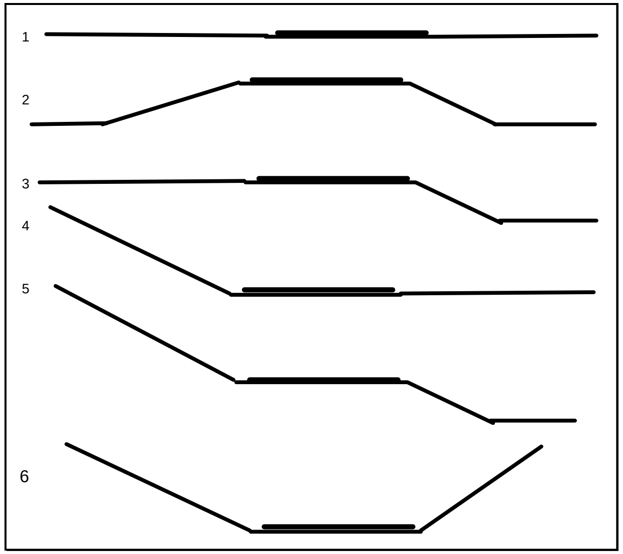
Version F

RRGAP Field Data Collection Form 1: Data Codes (Sheet 2)

31 Side drain Condition

1	As built condition
2	Adequate shape and level - minor silting only
3	Defects /silting evident but can function
4	Significant defects/silting - drainage capacity impaired
5	Serious scouring/defects - no longer effective

34 X-Section Alignment



37 Flood

1	No flood
2	Occ. Minor
3	Occ Major
4	Yearly flood

38 Material Source b.Type

1	Borrow Pit
2	Rock Quarry
3	Road Cut
4	River Bed

M Maintenance

1	Periodic
2	Routine
3	None

Figure 2 Data Codes for RRGAP Survey Sheets

Figure 3 RRGAP Provinces

This deterioration on low traffic volume roads is dependant to great deal on the combined impacts of key road environment factors. It follows that an examination of these impacting factors formed a crucial element of the RRGAP data analysis. Table 1 summarise these factors within the Vietnam context. The ability of the surveyed roads to perform their task within their road environments, and hence their performance was assessed by considering key deterioration indicators, namely:

- Material Loss
- Surface Erosion
- Potholing
- Rutting

Assessed Factors	Description within the Vietnam Environments
Construction Materials	The inter-action of variable geology and geomorphology dictates that a wide range of natural road construction materials is available for exploitation in Vietnam, (Geol. Survey Vietnam, 1991). There is however considerable regional variation in their occurrence, with some areas, such as the Mekong delta, being particularly scarce in natural construction materials.
Climate	Although the Vietnamese climate has significant regional variations it may in general terms be summarised as being tropical monsoonal. Figure 4 presents a summary of regional rainfall variation. This climatic data has the following implications for rural road construction. Periods of intense rainfall with high erosion and flood potential contrast with relatively drier periods when dust may be a significant problem on unsealed roads. Significant periods during the year when equipment based construction and maintenance are likely to be hampered.
Hydrology	Hydrology is seen as a key influencing factor on unsealed surface performances due to: 1. High erosive run-off in hilly terrain during monsoon periods, 2. Flooding and consequences in low-lying areas, 3. Constant high water tables in flat (high density population & network) rice growing areas, 4. Tidal effects and potential storm surges in deltaic areas
Terrain	There is considerable contrast in terrain throughout Vietnam, from actively eroding mountain and hill systems, to actively depositing large deltaic areas. Nguyen Quang My et al classify 37 different terrain types in Indochina. For the purpose of the research a more general 6-fold system was adopted.
Sub-Grade Conditions	In the light of the changeable geology, terrain and climate it is not surprising to note that natural sub-grade conditions in Vietnam are likely to be highly variable. Highland regions produce generally good sub-grade conditions, if allowance is made for local unpredictability and localised flat-lying areas. In contrast the deltaic regions are dominated by poor and saturated sub-grade conditions with potentially low CBRs, sometimes below 3%.
Traffic	A subjective and preliminary assessment of traffic on each road length was obtained by a combination of observation and discussion with PDoTs and local people. This indicated that traffic was dominated by two-wheel and light 4 wheel vehicles, Figure 5, shows traffic count results from the parallel RRST programme from typical regions.
Maintenance Regime	Potentially valuable information on the actual application of maintenance on the RRGAP roads was obtained from local people The maintenance regime existing at the time of the survey may be characterised as largely non-effective; Table 2. There are few financial resources currently available for rural road maintenance. Efforts are principally concentrated on local repair rather than maintenance.
Construction Regime	Most RT1 and RT2 rural roads were constructed by small private contractors and some small state owned enterprises, within a regime that may be characterised by the following: 1. Technologies used are principally equipment based, 2. Limited local community employment or participation, 3. Limited plant options – particularly with respect to compaction, 4. Relaxed specifications and poor quality control, 5. Poor attention to provision of adequate road drainage arrangements, 6. Insufficient technical supervision and resources, 7. Poor compliance with construction material specifications.

Table 1 Key Road Environment factors in Vietnam

Description	Carriageway	Shoulder	Side Ditch
Percentage of road segments >6 months old receiving Routine maintenance.	19%	23%	19%
Percentage of road segments >18 months old receiving Periodic Maintenance	11%	2%	4%

Table 2 Summary of Maintenance Data

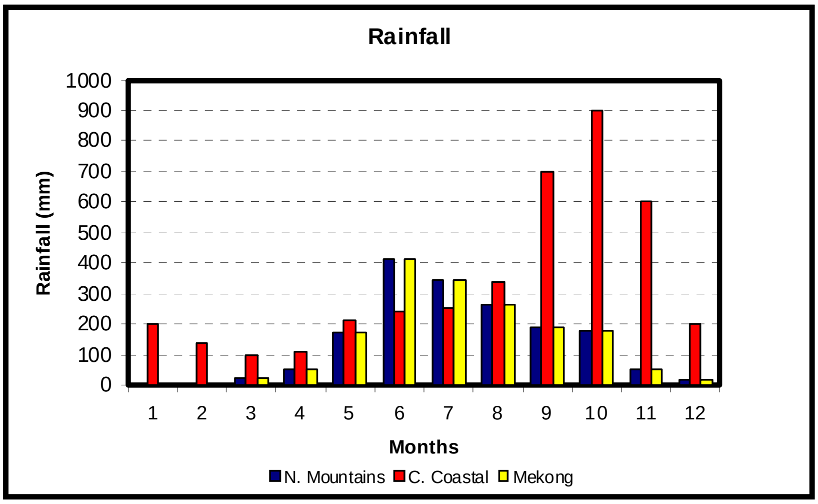
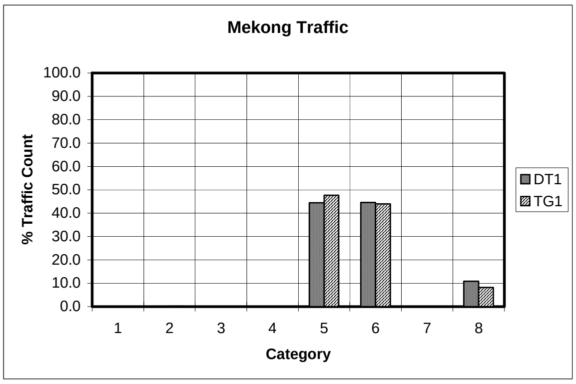
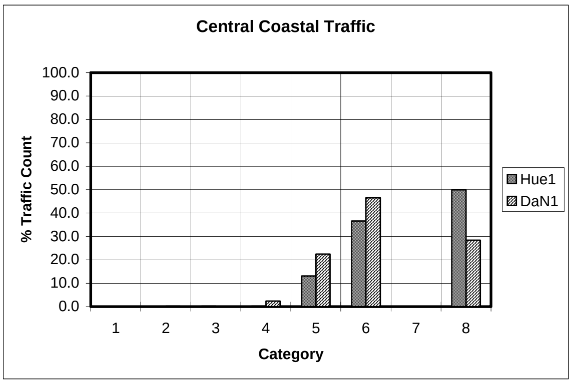
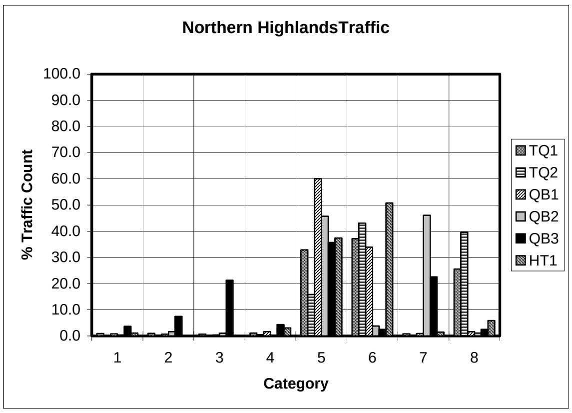


Figure 4 Regional Rainfall Variations







Region	Province: Road	ADT
Mekong	Dong Thap Trial Road	172
	Tien Giang Trial Road	120
Central	Da Nang Trial Road	74
Coastal	Hue Trial Road	18
Northern	Tuyen Quang: Lang Quan	333
Highlands	Tuyen Quang: Thang Quang	92
	Quang Binh: Cam Lien	116
	Quang Binh: Ngu Hoa	327
	Quang Binh: Loc Ninh	790
	Ha Tinh: Thach Minh	198

	Traffic Category	ADT Factor
1	Truck>5t	5
2	Truck<5T	2.5
3	Car	0.8
4	Cong Nong	1
5	Motorcycle	0.1
6	Cycle	0.05
7	Animal/hand Cart	0.2
8	Walker	0.02

Figure 5 Typical Rural Road Traffic Counts from the RRST Programme

Material loss was considered to be the principal performance yardstick in the RRGAP survey, partly due to the substantial relevance to maintenance needs and costs. In most road performance studies or monitoring programmes material loss is assessed by measuring decrease in thickness over periods of time. This allows for an exact measurement of loss. The RRGAP was designed as a one-off condition survey; hence although material thickness was measured it had to be related to design thickness to gain an estimate of loss rather than by exact measurement. This procedure is perfectly adequate to give relative trends in loss.

Material loss trends were evaluated by examining the loss per year over a range of sites. Any anomalously high or low figures were not included in the detailed evaluations.

For the purposes of this study, gravel loss of 20mm/year was selected as the limiting figure for road sustainability, based on an extrapolation of existing TRL deterioration models in conjunction with engineering judgement and experience, (TRL, 1984). This level of loss allows for 100mm of gravel to be lost over a 5 year life without re-gravelling, assuming a constant deterioration rate. Depending on the original laid thickness, this would leave from only 50 to 100mm of residual wearing course, which is a reasonable minimum allowable thickness for network management purposes. A deterioration of 20mm/year can sensibly be considered a maximum loss figure on a combined financial, operational and environmental basis, for sustainability in a situation where periodic maintenance including re-gravelling is not the normal practice due to a range of constraints. In practice, local circumstances could suggest a lower limiting rate of loss for pragmatic management policy and operational purposes.

Erosion was also adopted as a key indicator of road deterioration, both with regard to formation of surface rills and gullies and as a pointer to road roughness conditions. Potholing and rutting were also selected as suitable deterioration indicators. Regular routine surface reshaping is required on gravel roads to correct minor defects and maintain the crossfall within the desirable range of 3 – 7% to shed rainwater. Data show that due to funding and organisational constraints this activity is rarely achieved. Consequently standing water occurs and accelerates the formation of potholes, ruts and loss of material. A summary of pothole and erosion data related to drainage is included as Table 3. Visual appearance, together with the site photographs of each profile survey section provided a valuable cross-check on other data sets.

Road Condition	Impeded Run-off Sites	Non Impeded Run-off Sites
Potholed	53%	24%
Non potholed	47%	76%
Significant erosion	48%	18%
Slight or no erosion	52%	82%

Table 3 Summary of Potholing and Erosion Data

KEY UNSEALED ROAD PERFORMANCE ISSUES

Material loss has been calculated for the purposes of this project in millimetres of material lost per year (12 months) and is plotted in terms of loss per site for the whole RRGAP investigations in Figure 6. Table 4 summarises material loss on a province-by-province basis together with terrain, rainfall and erosion condition. Key issues identified with respect to the material loss and erosion data are as follows:

1. Overall material loss figures indicate that around **58%** of the surveyed sites are suffering unsustainable deterioration over a five-year design life, while **28%** are losing material at twice the sustainable rate.
2. On a province-by-province basis, only 4 provinces have greater than 50% of sites below the sustainable material loss limit. Of these two, Lao Cai and Bin Thuan also have high erosion figures, resulting largely from the use of unsealed stone macadam surfaces allied to steep terrain.
3. The performance of the road segments as a whole, however, is likely to be slightly better than the above figures for individual survey sites. This is largely because the survey was designed to sample typical surfacing conditions and environments on each segment and not to be representative of the entire road segment lengths.

Province	Apparent Gravel Loss			Annual Rainfall mm/year	Survey Roads No.	Profile Sites No.	Erosion		Terrain					
	Median mm/year	>20mm/ year % Sites	>40mm/ year % Sites				Slight % Sites	Significant % Sites	No. of Sites					
									1	2	3	4	5	6
Binh Thuan	19	42	21	2674	23	61	35	65		13	10			
Ca Mau	26	67	40	2828	5	15	53	47	5					
Can Tho	40	97	47	1919	13	34	97	3	13					
Dien Bien	21	57	3	2448	12	29	46	54				10		2
Dong Nai	44	90	64	2211	18	42	81	19		6		2	10	
Ha Tinh	12	26	8	1550	25	65	72	28	4	12		2	7	
Hung Yen	21	50	24	1500	20	50	57	43		20				
Lam Dong	62	100	80	1887	11	20	86	14				10	1	
Lao Cai	5	0	0	2105	21	55	23	77				12	3	6
Ninh Thuan	19	40	7	856	20	57	56	44		8	11		1	
Quang Nam	21	50	10	3050	21	49	79	21	9	1	11			
Quang Ninh	60	84	68	2457	20	38	41	59			3	11	1	5
Tien Giang	34	88	50	1312	8	17	96	4	8					
Tuyen Quang	34	75	45	1990	21	53	67	33		2		19		
Vinh Long	35	80	33	1237	11	30	97	3	11					
Vinh Phuc	44	79	52	2038	20	42	81	19		14		6		

Notes: Terrain
1 Delta/Coast
2 Inland flat
3 Rolling hills
4 Moderate to high hills
5 Inter-montain valley/High Plain
6 Mountainous

Table 4 Apparent Gravel Loss and Erosion Per Province

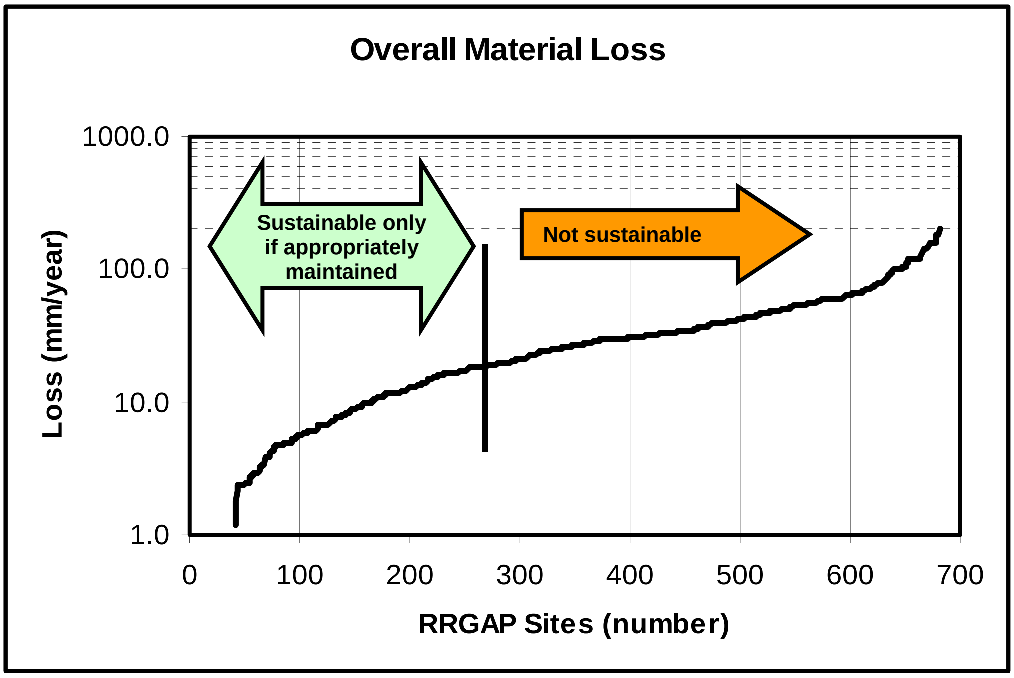


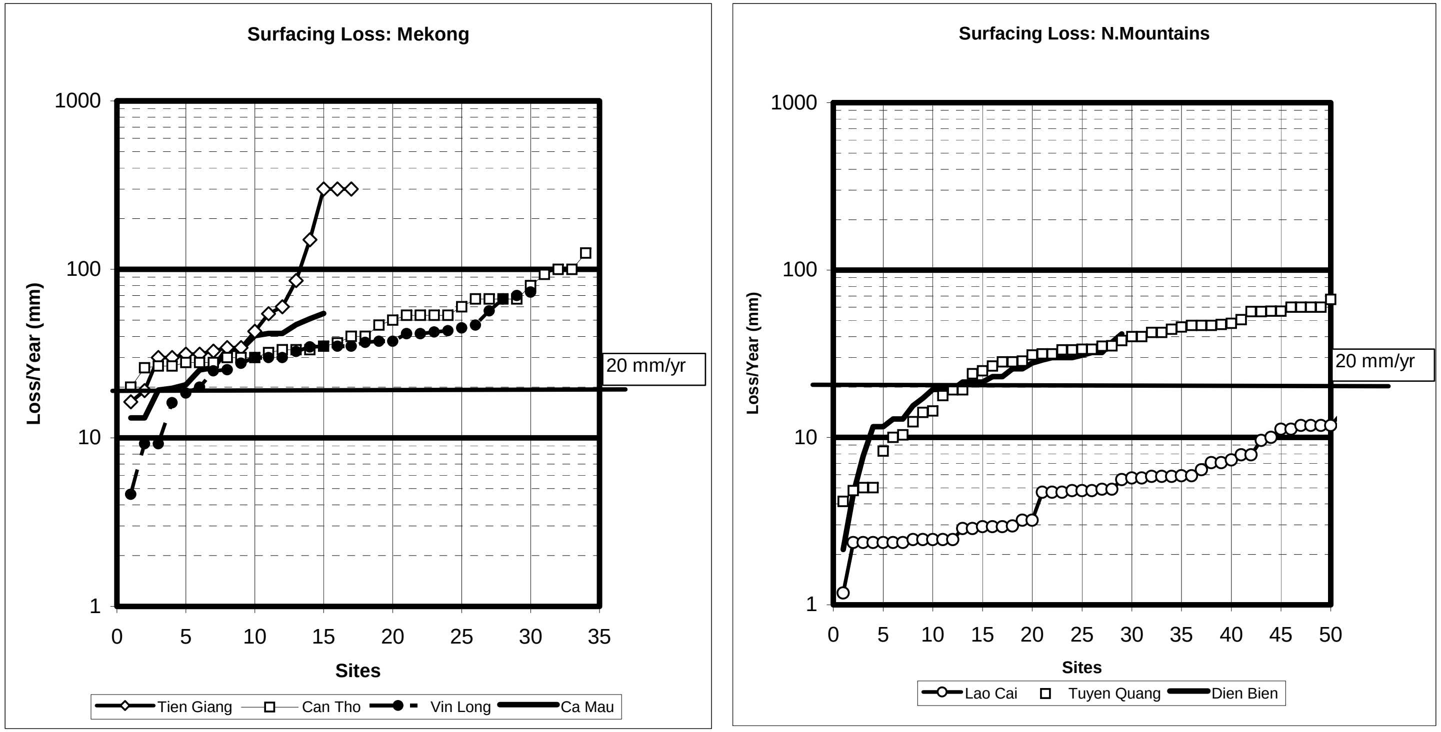
Figure 6 Adjusted Material Loss for RRGAP Survey as a Whole

The overall visual assessment data indicates representation by a composite road performance model comprising the differential "spot" deterioration of short critical lengths separated by lengths of road in better condition, but nevertheless subject to a general overall deterioration.

The material loss data for two regions; the Mekong Delta and the Northern Mountains, have been selected to exemplify contrasting road environments influencing unsealed road performance; Figure 7. The key road environment aspects of these two regions are summarised in Table 5.

Factors	**Mekong**	**Northern Mountains**
Construction Materials	No local rock or gravel. Imported laterite and graded crushed stone gravel. Haulage 100-300km	locally available colluvial, alluvial gravel and crushed rock.
Climate	Seasonal wet. Subject to coastal tropical storms	Seasonal wet.
Hydrology	Most roads subject to seasonal flooding. High water tables	Some local hillslope run-off flooding. High water tables in valleys
Terrain	Flat	Variable with road gradients up to 8%
Sub-Grade Conditions	Generally poor clayey road foundations; CBRs may be below 3%	Variable but sub-grade CBRs generally >10% and frequently higher.
Traffic	Predominantly 2-wheeled with occasional light 4 wheeled. Heavy loads tend to be transported by boat.	Largely 2-wheeled but some 5t and over trucks.
Construction & Maintenance	Generally – see comments in Table 1	

Table 5 Comparison of Road Environments: Mekong Delta and Northern Mountains



Region	Province	Rainfall(mm)	Predominant Materials	% Sites with Non-Spec Grading	Haulage (km)	%Sites with loss >20mm/yr	% Sites with Significant Erosion
Mekong	Tien Giang	1312	Laterite Gravel	93	145	88	4
	Can Tho	1919	Graded crushed stone	75	165	97	3
	Vin Long	1237	Graded crushed stone	50	135	80	3
	Ca Mau	2828	Graded crushed stone	80	350	67	47
N.Mountains	Lao Cai	2105	Stone macadam	n/a	6	0	77
	Tuyen Quang	1990	Colluvial and alluvial gravels	30	7	75	33
	Dien Bien	2448	Graded crushed stone and alluvial gravels	75	11	57	54

Figure 7 Comparison of Mekong Delta and Northern Mountains Information

The comparison of these two regions indicates the need to develop surfacing solutions appropriate to the differing regions within Vietnam. Key points to arise are:

1. The impact of flooding on the Mekong Delta sites appears to be a major factor in their high material erosion rates. This overrides the influences of higher traffic and steeper gradients of the Northern Mountain gravel sites.
2. The laterite and crushed stone gravels of the Mekong are characterised by long haulage distances and poor grading.
3. Within the Mekong Delta the out-of-specification laterite gravel is the worst performing material.
4. The Northern Mountains crushed stone gravel sites, although performing better than those in the Mekong, still have 60-75% of sites exhibiting greater than 20mm/year loss.
5. The crushed stone macadam sites have low material loss figures, but this is balanced by high surface erosion and hence roughness.

More general material related issues to arise out of the survey data were:

1. Significant amounts of material fall outside the current RT2 specifications for gravel.
2. The naturally occurring laterite, hill gravel and alluvial gravels have a high number of sites (>60%) with greater than 20mm/year material loss. The implication is that these materials are not suitable for use as an unsealed road surfacing within the majority of Vietnam road environments. Similar comments also apply to graded crushed stone as an unsealed surfacing material.
3. Where natural materials have been mixed with additional crushed rock, weathered rock or alluvial gravel and cobble, then the material loss figures show a distinct improvement.
4. Coarse non-graded stone surfacing performs significantly better than other options in terms of material loss. Given the nature of this surface, which is in many instances close to water bound or dry bound macadam in character, its resistance to material loss is not surprising. However, it does suffer significantly from surface erosion of fines, leaving a rough surface susceptible to localised deterioration.
5. The natural gravel-stone mixtures also have lower than average material loss figure, but as with the non-graded stone they also appear to have a higher than average erosion/roughness potential.

Examination of terrain data indicates that erosion increases significantly between 2% and 6% road gradient, Table 6. It has been commonly acknowledged that gradients above about 6% are not usually suitable for gravel surfacing, however the RRGAP data suggest that, for some materials at least, this limiting figure should be lowered to 4% for the higher rainfall environments in Vietnam.

	Road Gradient at Survey Point				
	Flat	>0-2%	>2-4%	>4-6%	>6%
% Slight or no erosion	91	67	47	47	26
% Significant erosion	9	23	53	53	74

Table 6 Summary of Gradient-Surface Erosion Relationships

Information on visual appearance related to material type would seem superficially to contradict the data on material loss and erosion by implying that the large majority of road segments looked to be in a fair condition. This apparent anomaly should be considered in the light of the following:

1. Unlike most sealed surfaces, the deterioration of a gravel road surface through material loss is not initially a visible feature and only becomes so when the loss approaches a critical stage.
2. There tends to be differential deterioration along the road segments with visible deterioration features, such as rutting and potholing of the road surfaces being concentrated within certain road sections. This results in a “spot” deterioration pattern, as discussed previously.

Good drainage is considered a fundamental aspect of road engineering in almost all relevant guidelines and design manuals. In a high rainfall country such as Vietnam this aspect of road construction should have a particularly high priority. The RRGAP survey has, however, indicated that drainage, in the form of side ditches and carriageway run-off capacity, has not been given a high enough priority either in construction or in maintenance in the Vietnam rural road network.

IMPLICATIONS FOR UNSEALED ROADS IN VIETNAM

There is a clear need to improve the evaluation of the correct usage of local gravel materials in rural road programmes in Vietnam. It is now recognised that a key objective in sustainable road construction is to properly match the available material to its road task and local environment. Greater use should be made of adapting local non-standard materials within appropriate designs (Cook et al , 2002). The RRGAP data has highlighted an apparent mis-match between the design options currently being used and many of the materials being used to construct them. The general options for dealing with this situation are:

1. Modify the material to suit the designs,
2. Modify the design options to suit the materials available,
3. Define areas where the existing unsealed options are suitable.

Options 1 and 2 above are being addressed by the expanding RRST programme which will report later this year on alternatives to gravel, whilst the RRGAP has identified some key factors relevant to Option 3, as outlined below.

The extremely long haulage figures for the Mekong area raise serious issues regarding the current use of inappropriate rural road design options for this region, particularly in the light of their apparent poor sustainability in terms of material loss and poor specification compliance. It cannot be considered a reasonable option to haul marginal material over 100km to construct unsustainable roads.

The RRGAP data, based on locally based information, indicated that up to the date of the survey, adequate maintenance is not being achieved on the large majority of RT1 & RT2 roads. Gravel roads suffering more than 20mm/year of material loss without appropriate maintenance are largely non-sustainable beyond 4-5 years and may well deteriorate at a significantly greater rate in some sections within that timescale.

Construction of gravel roads should also allow for maintenance to be carried out cost effectively. The common practice of placing soil shoulders against gravel road surfaces prevents the gravel from being graded, as such operations would mix the soil into the higher quality running surface. Soil shoulders also impede sideways drainage of the surface as the gravel surface wears, thus accelerating the surface deterioration.

The availability of local materials for maintenance is also an important issue. Commune-based maintenance will usually require the availability of suitable materials close to the road. It is unreasonable to expect local communities to support the haulage of materials for the long distances of up to 100km or more noted in the survey. Instead, there is evidence to indicate that local communities tend to use unsuitable local materials available within shorter hauls, and thus add to the rate of road deterioration.

Maintenance is a key issue for the sustainability of gravel roads. The loss of material must be replaced by periodic regravelling. This is an expensive operation with costs that increase substantially with material haul distance. If regravelling is not carried out in a timely manner, then the layer thickness will reduce below a critical residual thickness of about 5 – 10 cm and accelerated deterioration will take place. The road will effectively revert to an earth standard and require even more costly rehabilitation.

Gravel is therefore a low-initial-cost:high-maintenance road surface. Most gravel road design guidelines and network management models either assume or strongly recommend an appropriate maintenance regime that includes both routine grading and periodic re-gravelling in timely cycles. The high rainfall environment of Vietnam makes this an essential component of unsealed rural road asset management. In reality the funding and operational constraints dictate that this is rarely achieved. Recognising this situation, some provinces and even communes use local resources to 'seal' the gravel surfaces provided through external funding very soon after construction to reduce the maintenance burden.

With regard to already constructed unsealed rural roads, it is clear that there are key factors that could be addressed to improve their condition and sustainability. These are:

1. Funding/resourcing and implementation of appropriate routine and periodic maintenance regimes that include both re-shaping and re-gravelling activities, where the existing gravel surfaces are deemed to be sustainable.
2. Construction of additional side ditches to ensure that the road surfaces can effectively shed rainwater from the road and disperse it satisfactorily. Shoulders should also be reshaped if necessary to ensure water can be shed from the road surface.
3. Sealing of appropriate road links, e.g. with excessive hauls for periodic regravelling, or with unacceptable dry weather dust problems. In a resource constrained environment, a spot improvement strategy of selectively treating problematic lengths within a road link should be considered, e.g. sections liable to flooding or with steep gradients.

Apart from assessing gravel performance, the RRGAP has raised other important issues, such as:

1. The investigations have indicated the effectiveness of unsealed stone macadam in providing a sustainable surface/road-base, albeit with high surface erosion or roughness penalties. It is suggested that this option would be ideally suited to a staged construction approach, with an appropriate sealing option following-on at a later date from the initial construction. The RRST programme is already trialling stone chip and sand bitumen seal options over dry bound macadam.
2. Other techniques utilising natural stone, without bitumen or cement binder, could have superior performance to gravel, but with reasonable initial costs and lower maintenance liabilities. These surface options include hand packed stone and cobble stone paving. These options should be trialled in the planned expansion of the RRST.
3. Staged construction using gravel as the initial construction material has the disadvantage that significant degradation may occur on the surface unless the seal is applied within 6 months, or at least before the first rainy season. The use of armoured gravel (as trialled in Thua Thien Hue RRST) could be considered in areas where suitable gravel exists, but where other factors such as gradient, flooding or maintenance issues would mitigate against unsealed gravel.
4. Composite construction should be considered as a strategy in future rural road programmes. This involves the construction of different surfacing options along a road link in response to differing environment impacts. In appropriate cases this could involve employing an engineered natural surface option.
5. There is a clear requirement to make PDoTs, contractors and local consultants more aware of the importance of Quality Control and to place more emphasis on effective and contractually empowered construction supervision of rural road projects. At the same time there is a need to advise local contractors on the construction techniques required for the alternative pavement options likely to be mainstreamed from the RRST programme experiences. Some form of advisory unit or panel, and knowledge dissemination programme would be appropriate in this context.

ROAD SURFACE SELECTION GUIDELINES

The RRGAP research has highlighted the need for guidelines on the appropriate use of unsealed road surfacing. Gravel can only be considered as a serious viable pavement option for Vietnam rural roads on engineering and economic grounds under the following conditions:

1. Where specified quality **material is locally available** in sufficient quantities both for construction and maintenance (probably within 10km of the road). This should be verified with a detailed whole life costing of surfacing options if the materials hauls are longer than 10km. A realistic assessment of the likelihood of routine and periodic maintenance being carried out should be included in the whole life costing, including the risks and consequences of inadequate maintenance.
2. Where road **gradients are less than 4%** in medium rainfall areas (1,000 – 2,000 mm/year). Gravel will probably be unsustainable at any gradient for higher levels of rainfall. 2,000 mm/year is at present an arbitrary recommended limiting figure based on general experience elsewhere and on the policy of the high-rainfall provinces such as Da Nang and Thua Thien Hue to seal their RT2 gravel roads almost immediately after construction. For the few areas of Vietnam that experience rainfall of less than 1,000 mm/year, gravel may be suitable for longitudinal gradients up to 6%.
3. Where **adequate drainage** (crossfall, side and dispersion) can be guaranteed.
4. Where **adequate quality assurance** controls are in place for construction supervision to ensure contract and specification compliance.
5. Where an appropriate **maintenance regime** can be guaranteed as part of a whole-life construction and maintenance specification.
6. Where **flooding** is only a minor local occurrence.
7. Where **traffic** is below 200 motor vpd equivalent. This is recommended from international experience. However it is possible that alternative, more durable, surfaces could be justified at traffic levels below 100 motor vpd in some circumstances in Vietnam.

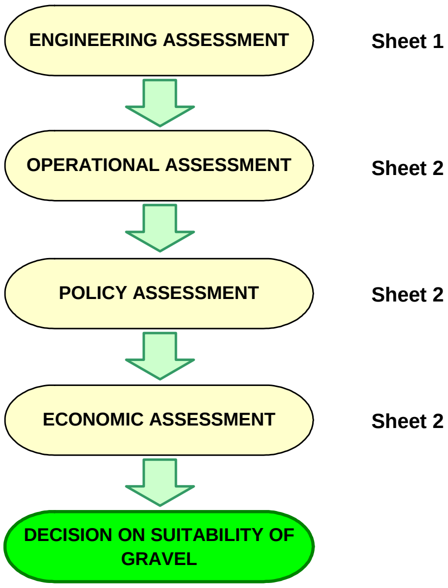
The above criteria have been incorporated into the Engineering element of a proposed overall "**Preliminary Decision Management System for the Assessment of Gravel as a Paving Option".** This system comprising Operational, Economic and Policy elements in addition to the Engineering aspects is include in this paper in its initial draft form on the following pages.

APPROPRIATE RURAL ROAD SURFACE SELECTION

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

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

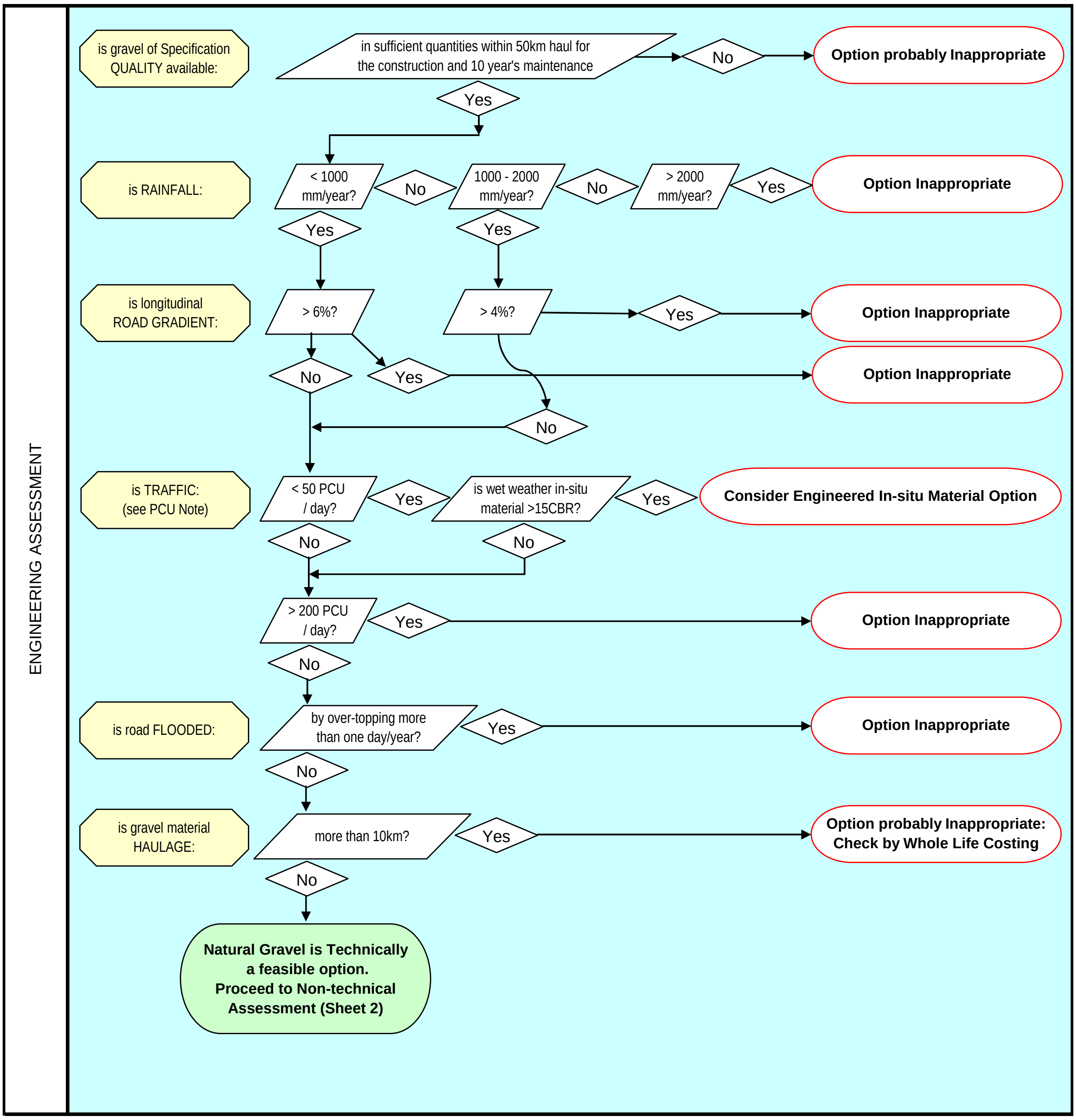
STEP 1 - Consideration of Natural Gravel as a Rural Road Surface Option



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

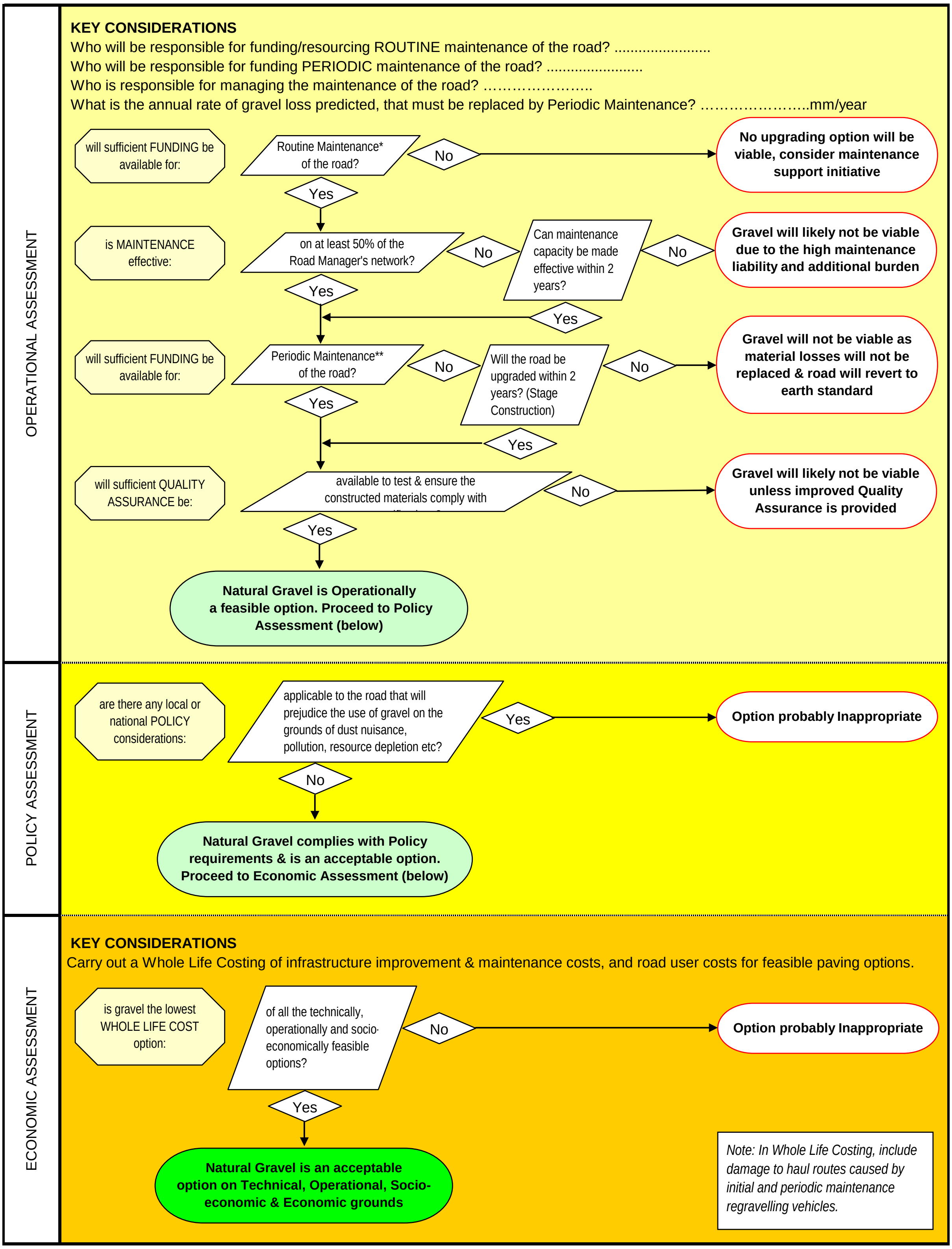
SHEET 1 - Engineering Assessment



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

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