

Session 3

Pavement Option Selection and Design



Points to Think About

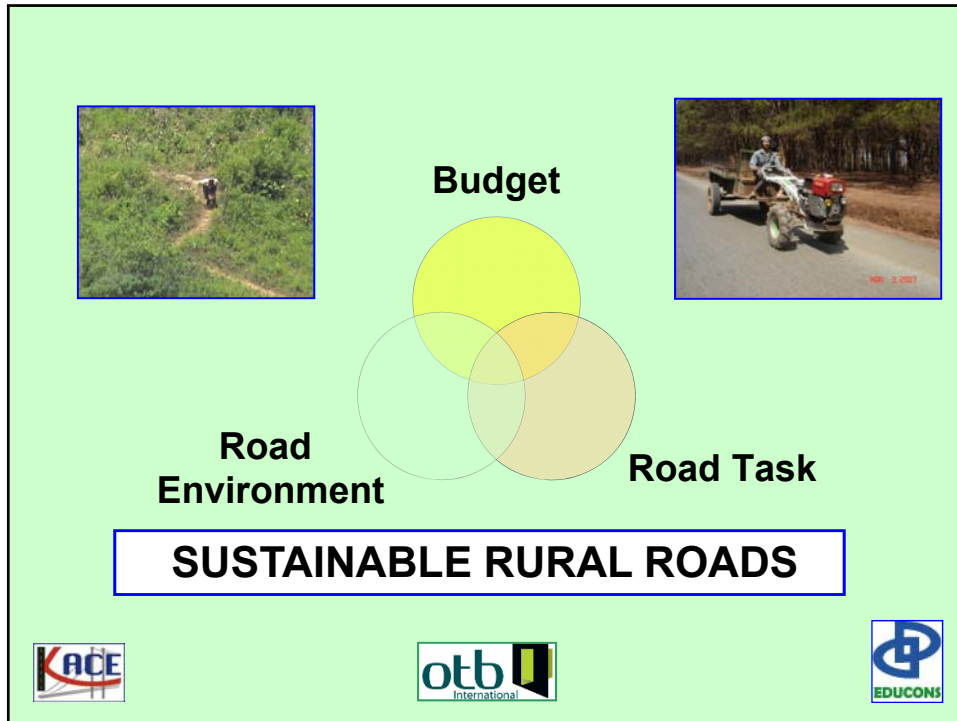
How do I select a pavement option?

What information is needed for pavement decisions?

How do I analyse this data?

How important is drainage ?





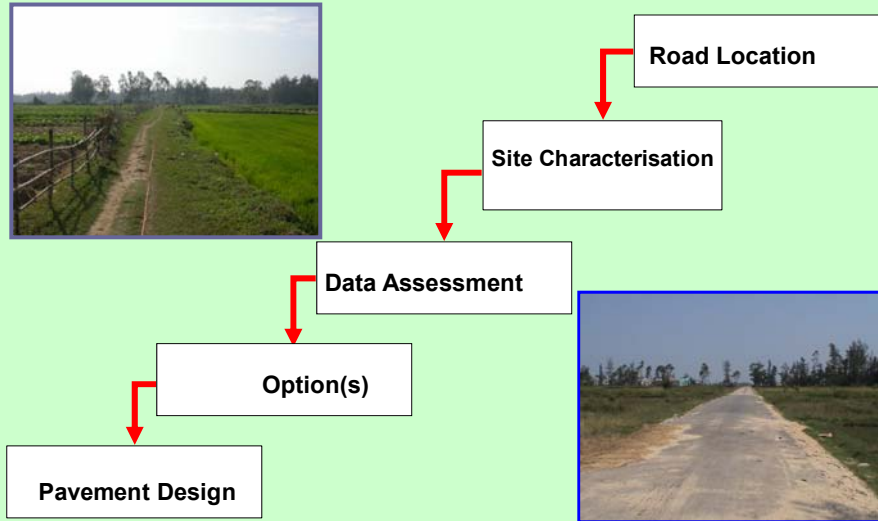
Road Design

The purpose of road design is to allow a road to perform a **Task** in a defined **Environment** within an affordable **Budget**

REMEMBER: To “Over-design” and “Under-design” are BOTH a waste of money !



General Design Sequence



Road Design Elements

- **Pavement**
- **Structures**
- **Drainage**
- **Alignment Geometry**
- **Earthworks**



LVRR Pavement Selection

A pavement selection procedure has been developed from the SEACAP research initiatives - based on two key principles:

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

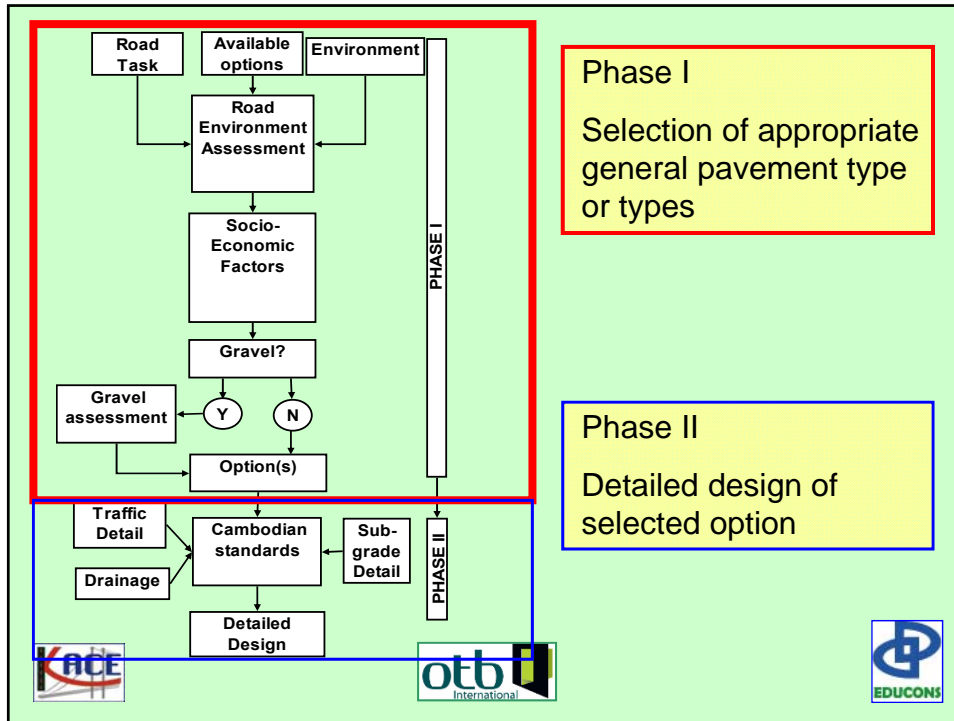


A Two Phase Selection Approach

Phase I: Identification of appropriate pavement **types** compatible with the road environment.

- Phase II: **Detailed design** of the selected pavement components (e.g. layer thicknesses) compatible with engineering standards and requirements – i.e. traffic, axle load and sub-grade strength.

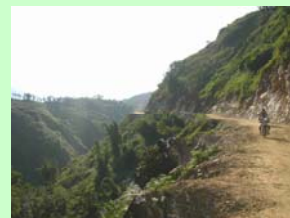




Rural road Pavement Selection

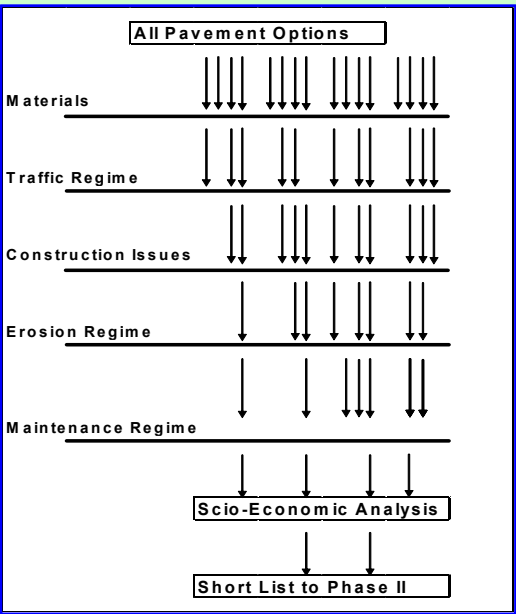
The initial selection of pavement type should be on a whole range of factors that cumulatively can be described as the “road environment”, namely:

- Construction materials
- Climate/rainfall
- Hydrology
- Terrain
- Traffic/axle load
- Construction regime
- Maintenance regime



	Key Issues												
	Local material use *	Labour based	Ease of construction	Maintenance reduction	Sustainability	Resistance to rain/flooding	Load spreading	Suitable for small contractors	Advantages to local economy	Resistance to heavy axes	Local employment	Whole life cost advantages ³⁰⁶	Roughness
1 = positive advantage;													
2 = probable advantage													
0 = no advantage													
x = definite disadvantage													
Emulsion sand seals	2	1	2	0	x	x	0	1	2	0	1	0	1
S and DBST with emulsion	0	1	2	2	2	2	0	1	2	0	1	2	2
Penetration Macadam	x	x	0	2	2	2	2	0	0	2	0	0	2
S and DBST with hot bitumen	0	2	0	2	2	2	0	2	0	0	x	2	2
Lime stabilised base and subbase	1	0	2	0	1	0	x	1	0	0	x	2	0
Cement stabilised base and subbase	1	0	2	0	1	0	x	1	0	0	x	2	0
Sealed Dry Bound Macadam	0	0	2	2	2	2	0	2	0	2	0	2	2
Sealed Water Bound Macadam	0	0	2	2	2	2	0	2	0	2	0	2	2
Dressed Stone/Cobbles	1	1	2	1	1	2	1	1	1	1	2	0	x
Bricks, Concrete and Clay	1	1	2	2	1	2	1	1	1	2	1	2	2
Sealed Armoured Gravel	2	0	2	2	2	2	0	2	0	x	0	2	2
Un-reinforced concrete	2	1	2	1	1	1	2	1	2	1	0	2	1
Unsealed Natural Gravel	1	0	1	x	x	x	0	1	2	0	0	x	x

The collected road environment data is used in Phase I in filtering process to identify likely pavement options



Primary Engineering Filter																	
	Seals and Load Bearing Surfaces							Bases									
	Sand seal	Chip seal	Penetration macadam	Steel reinforced concrete	Bamboo reinforced concrete	Engineering clay bricks	Concrete bricks	Stone setts	Unsealed wet/dry macadam	Unsealed gravel	Waterbound macadam	Drybound macadam	Natural gravel	Armoured gravel	Cement stabilised soil	Lime stabilised soil	Emulsion stabilised soil
Economically available																	
Materials																	
Crushed stone aggregate		√	√	√	√		√		√		√	√		√			
Stone blocks								√									
Laterite gravel									√				√	√			
Colluvial/alluvial gravel									√				√	√			
Weathered rock														√			
Fired clay bricks						√											
Clay soil						√									√		
Sand	√			√	√		√								√		√
Cement				√	√		√								√		
Lime																√	
Bitumen			√														
Bitumen Emulsion	√	√															√



Specific Health-Environment Issues

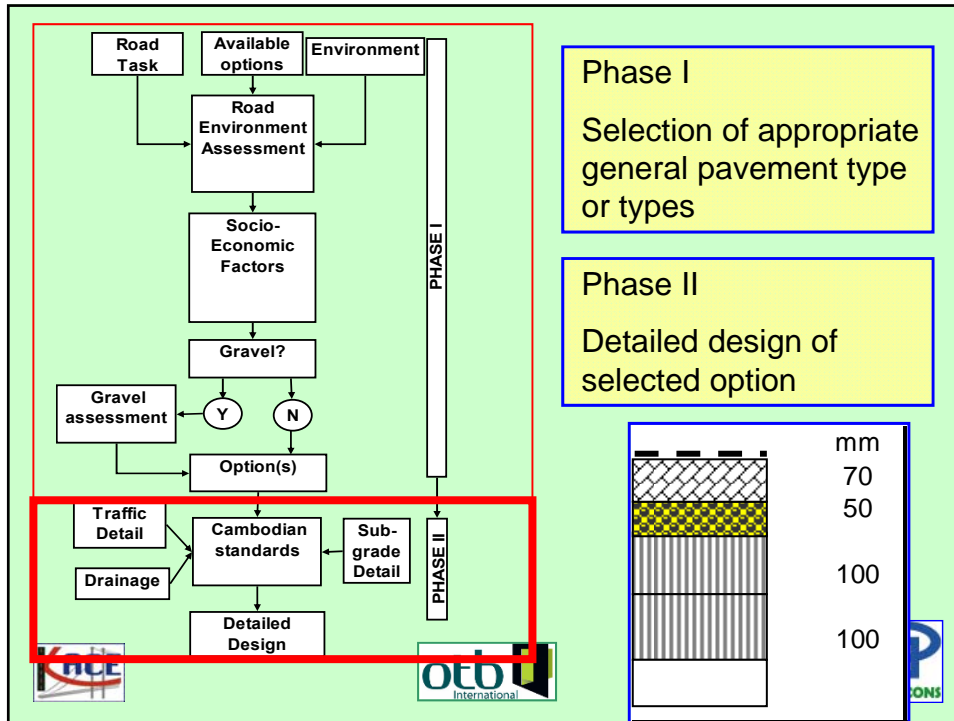
If the road is:.

In a village
Beside a school or health centre

Ideally road should not have a dusty unsealed surface

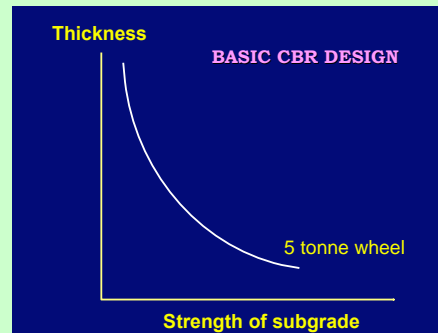
The is in addition to other engineering considerations such as rainfall, gradient etc

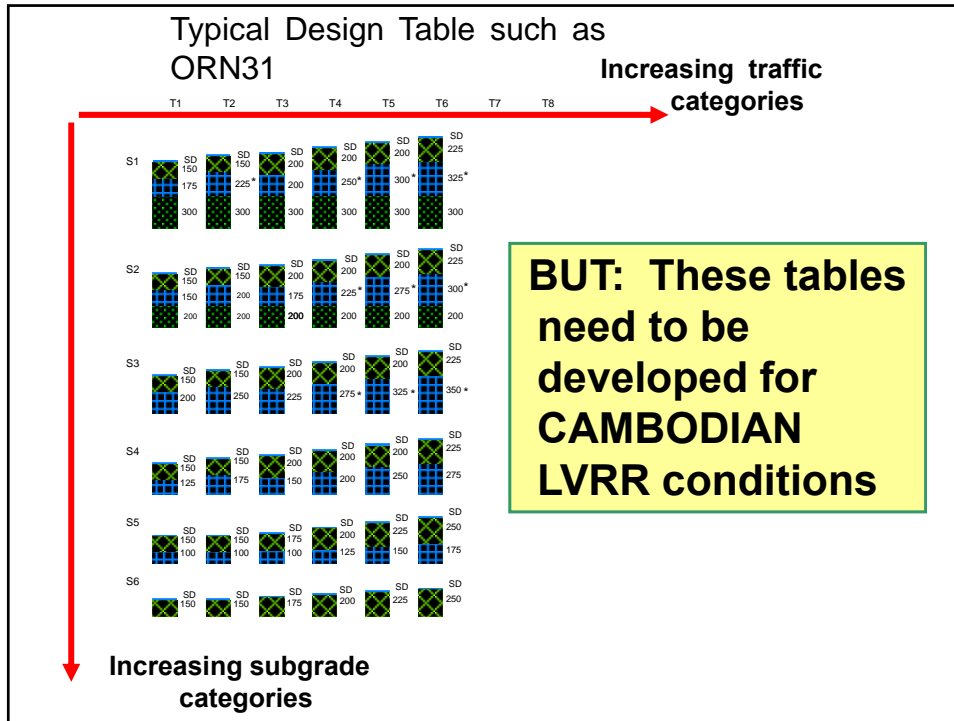




Detailed Design

Essentially based on developed relationships between subgrade strength and traffic loading - common to use standard charts -





Overseas Road Note 31

- Suitable for tropical and sub-tropical climates
- Simple to use charts and a wide range of materials
- However, no LVRR traffic loading sub-divisions
- Therefore it is conservative (expensive) for LVRRs
- Like most methods, it does not specifically deal with roadbase materials that do not meet the standard strength requirements




Layer thickness based on subgrade strength and traffic: typical example from Lao

Subgrade Soaked CBR%	Pavement Layer	Traffic A Layer Thickness (mm)	Traffic B Layer Thickness (mm)
2-3.9	Surface Base Sub-Base	Seal 100 175	Seal 120 200
4-6.9	Surface Base Sub-Base	Seal 100 150	Seal 120 175
7-10.9	Surface Base Sub-Base	Seal 100 100	Seal 100 175
>11	Surface Base Sub-Base	Seal 100 100	Seal 100 150


Pavement Option Lists

OPTION B
Steel reinforced 20MPa concrete
Bedded on compacted sand
Lime/cement stabilised soil, CBR >30%




120	150	200
120	150	200
50	50	50
100	120	150

OPTION M
Emulsion sand & stone chip seals
Emulsion stabilised soil; CBR 45%
Emulsion stabilised soil; 30%



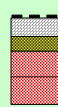
100	120	150
100	120	150
100	120	150

OPTION C
Bamboo reinforced 20MPa concrete
Bedded on compacted sand
Natural gravel base CBR>30%




120	150	200
120	150	200
50	50	50
100	150	200

OPTION N
Emulsion sand seal
Concrete bricks
Compacted sand
Natural gravel; CBR >30%
Natural gravel; CBR >30%




70	80	100
70	80	100
50	50	50
100	120	150
100	120	150

OPTION D
Bamboo reinforced 20MPa concrete
Bedded on compacted sand
Compacted sand base, CBR > 30%




120	150	200
120	150	200
50	50	50
100	120	150

OPTION O
Emulsion sand seal
Concrete bricks
Compacted sand
Dry bound macadam
Dry bound macadam




70	80	100
70	80	100
50	50	50
100	120	150
100	120	150

OPTION E
Steel reinforced concrete 15cm
Compacted sand base, CBR > 30%




120	150	200
120	150	200
50	50	50
100	120	150

OPTION P
Emulsion sand seal
Crushed stone armouring; CBR 50%
Natural gravel, CBR >30%
Natural gravel, CBR >30%




50	70	100
50	70	100
100	120	150
100	120	150

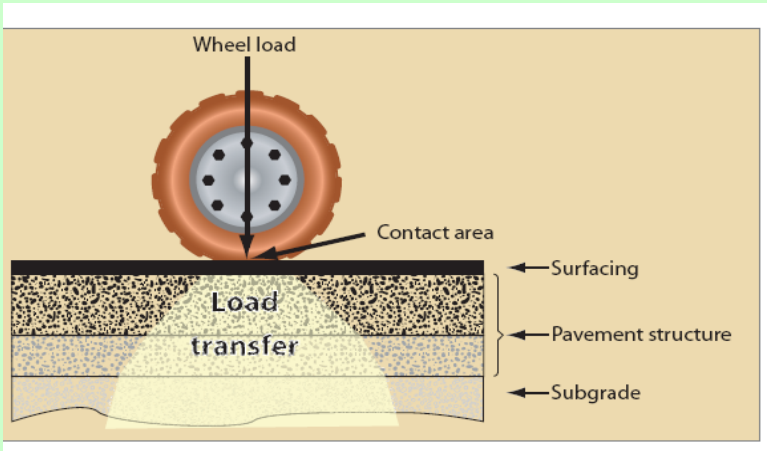
OPTION F
Emulsion sand & stone chip seals
Dry bound macadam
Dry bound macadam
Compacted sand sub-base, CBR >30%



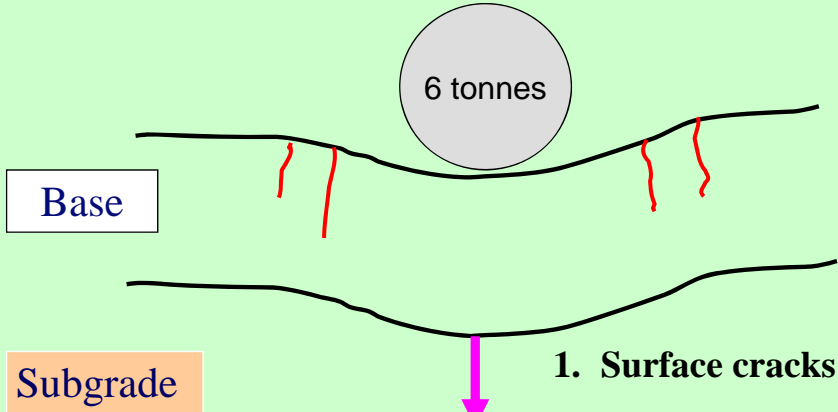
100	120	150
100	120	150
100	120	150
100	120	150



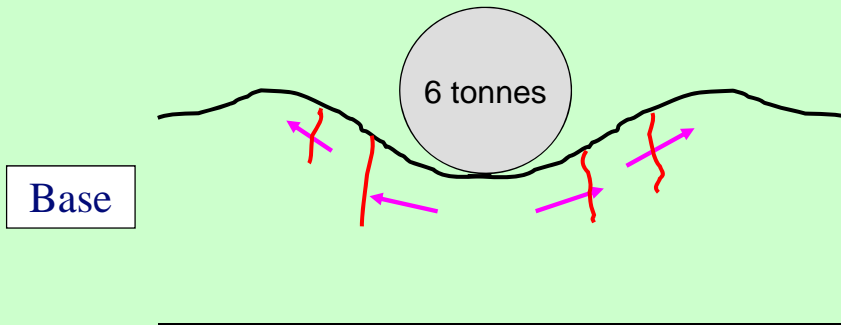
Transfer of wheel load



Roadbase Thickness insufficient



Strength of Base Insufficient



1. Shear failure, and heave

2. Surface cracks



Flexibility in Pavement Design

Modify the material to suit the pavement options



Modify the options to suit the materials available,



Materials – A Key to Sustainable Road Construction





A fundamental principle, or message, that needs to be carried forward from current research into practice is that appropriate road construction materials need to be selected on a “fitness for purpose” basis; that this is related to their actual service performance.








Locally Available Materials


Use of local materials is essential where reserves are limited or of marginal quality, as they are in certain rural areas of Cambodia. That means that specifications and designs must be suited to local materials.









Bamboo reinforced 20MPa concrete		Thickness mm 150
Bedded on compacted sand		50
Natural gravel base CBR>30%		100
Sub-grade CBR 5-6% (H1, H2)		

Gravel may be used as a sub-base or base as well as being used as an unsealed option in appropriate situations

Emulsion sand seal		Thickness mm 70
Crushed stone armouring; CBR 50%		
Natural gravel, CBR >30%		100
Natural gravel, CBR >30%		100
Sub-grade CBR 3-5% (H9)		






Natural Gravel		Thickness mm 100
Natural Gravel		
Sub-grade CBR 3%		100

Identifying Available Materials

Even for limited scope LVRR projects, materials testing should aimed at defining service performance in terms of:

- The load bearing capacity of the compacted material,
- Its volume stability in response to soaking-drying,
- Its component particle strength and durability (granular materials).

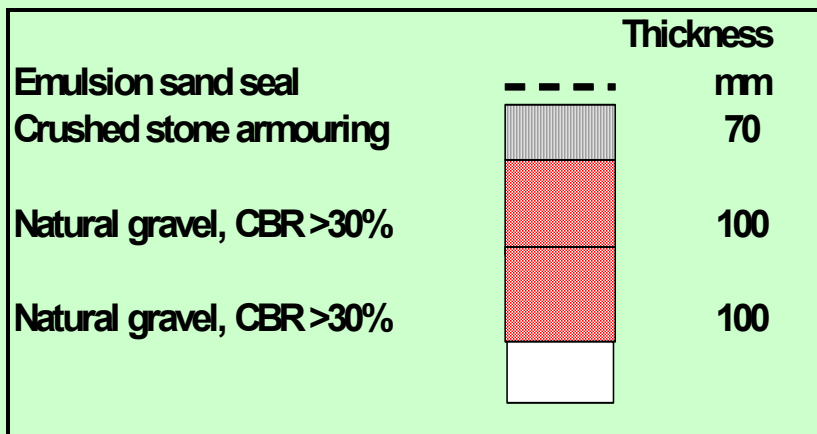




Appropriate Use of Materials

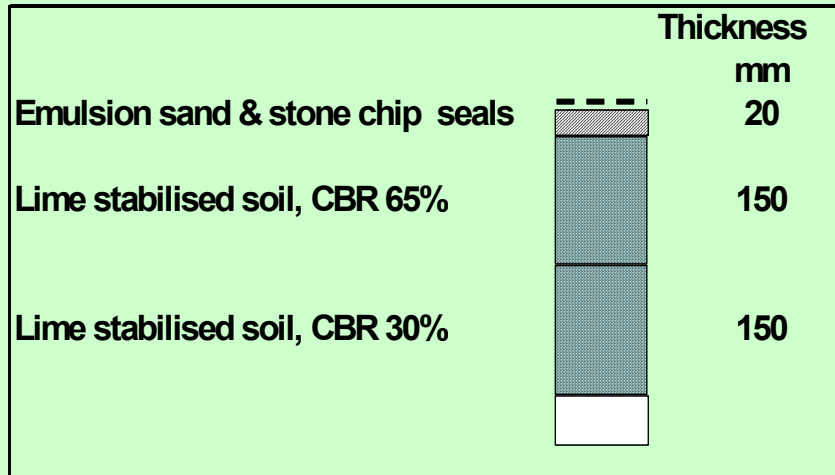
It is important to use materials relevant to their role in the road, that is, to ensure that they are neither sub-standard nor wastefully above the standards demanded by their engineering task.



Good Natural Gravel Available



Lack of Good Aggregate



Key Question For a LVRR Designer

What appropriate road can I build with these local materials ?

NOT

Where can I find materials to meet these general specifications?



Summary

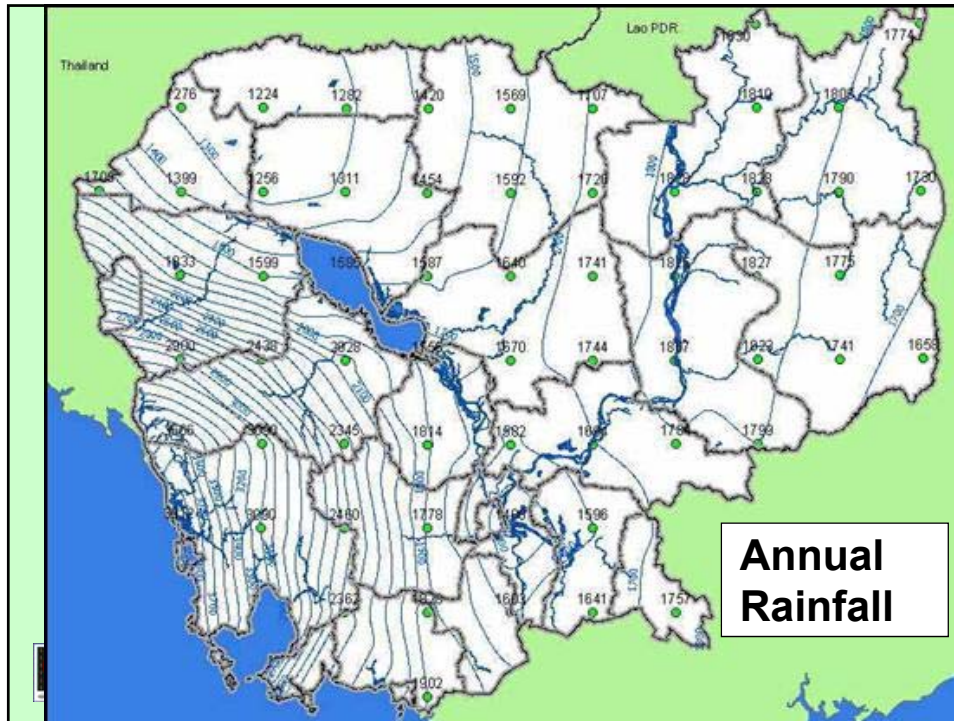
This session outlines a general approach to the selection and design of LVRs that is based upon the task the roads have to perform; the environments in which they have to operate; and their anticipated whole life costs.

The pavement design process has to be compatible with existing Cambodian Standards and based upon the collection and analysis of appropriate data. Options should take into account not only the immediate construction cost but also their likely maintenance costs – together making up what is termed the Whole Life Asset Costs

Road Design Data Collection

- **Climate**
- **Terrain**
- **Hydrology**
- **Subgrade**
- **Construction Materials**
- **Traffic**





Terrain:

- Flat
- Rolling
- Mountainous



Hydrology

Information on apparent water levels and liability flooding can be collected by observation, measurement and investigation as part of the geotechnical surveys.



The Dynamic Cone Penetration (DCP) test.

Assesses in situ strength of pavement layers

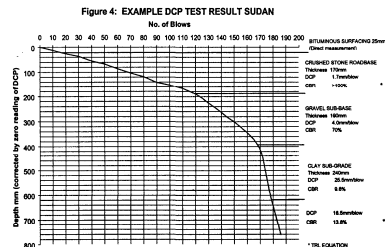


DCP Analysis

- Relationships have been developed to relate number of blows/mm to CBR
- Can be analysed graphically using charts

SITE / ROAD		KENANA, SUDAN		DATE		29-8-90	
				TEST NO.		6	
SECTION NO./CHAINAGE		248		DCP ZERO READING		60 mm	
DIRECTION		SOUTH		TEST STARTED AT		TOP OF BITUMINOUS SURFACE	
WHEEL PATH		VERGE SIDE					

NO. OF BLOWS	TOTAL BLOWS	READING MM	NO. OF BLOWS	TOTAL BLOWS	READING MM	NO. OF BLOWS	TOTAL BLOWS	READING MM
0	0	63	5	165	434			
10	10	75	3	168	457			
10	20	89	1	169	466			
10	30	99	1	170	477			
10	40	110	1	171	491			
10	50	130	1	172	513			
10	60	149	1	173	539			
10	70	166	1	174	565			
10	80	181	1	175	592			
10	90	204	1	176	620			
10	100	215	1	177	647			
10	110	230	1	178	664			
10	120	253	1	179	686			
5	125	269	1	180	705			
5	130	288	1	181	724			
5	135	307	1	182	744			
5	140	326	1	183	764			
5	145	347	1	184	784			
5	150	364	1	185	804			
5	155	385	1	186	824			
5	160	408						








Traffic Counts

Simple traffic count procedures suitable for use by district or commune staff have been developed and successfully employed on SEACAP project roads. These procedures, involve the use of simple field data forms followed by the adaptation of the counts into equivalent Average Daily Traffic



FORM: Manual Classified Traffic Count

Province					SURVEYOR	
District					LOCATION	
Daily 12 hour counts	DATE					Daily Average
Traffic Class						
MOTORCYCLE						
CAR, 4WD, PICKUP						
CONG NONG & Tractor						
LIGHT TRUCK =< 5 TONS GVW						
TRUCK > 5 TONS GVW						
Mini-bus/Bus						
PEDESTRIAN, WALKER						
ANIMAL/HAND CART						
BICYCLE						
TOTALS						
Rain This Period?						
Daily Survey Period:	8.00 hours to 18.00 hours				GVW = Gross Vehicle Weight	





Traffic Volume Calculation

From completed site forms the daily average flow counts for each vehicle type can be calculated and then converted into an equivalent daily traffic using the factors in the following table to determine the **Average Daily Traffic (ADT) or motorised ADT**.

If traffic is known to pass at night, then a multiplication by 1.2 should be applied to estimate the 24 hour count.

Take account of unusual days – eg market days.



Traffic Counted	ADT Factor
Truck >5t	5
Large Bus	5
Truck <5t	2.5
Small Bus	2
Motor cycle trailer	1
Car	0.8
Animal	0.2
Motorcycle	0.1
Bicycle	0.05
Pedestrian	0.02

Traffic Analysis

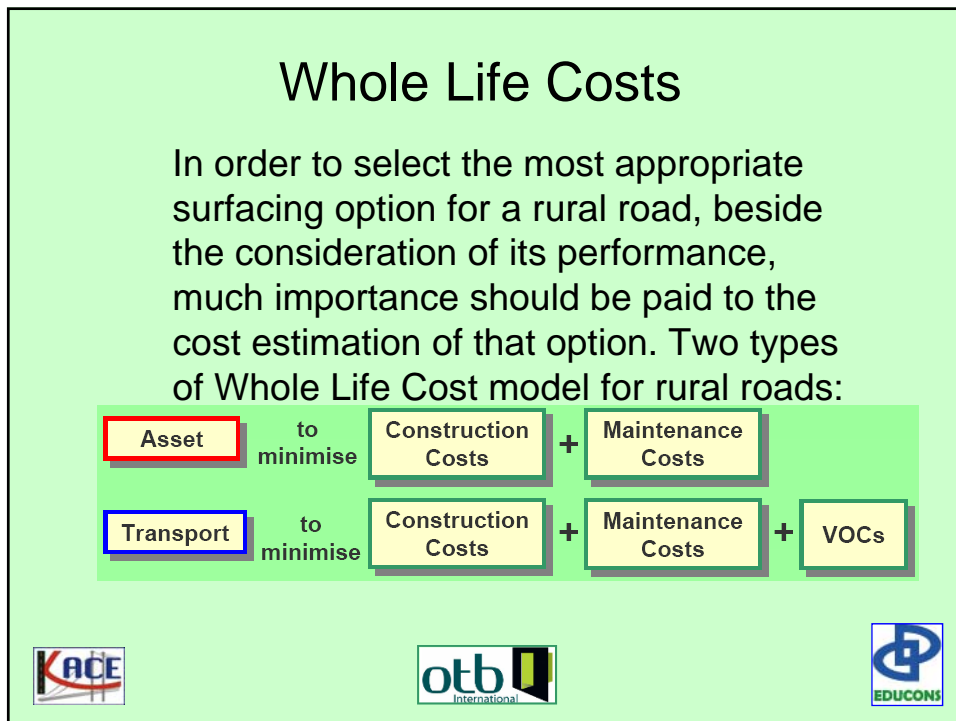
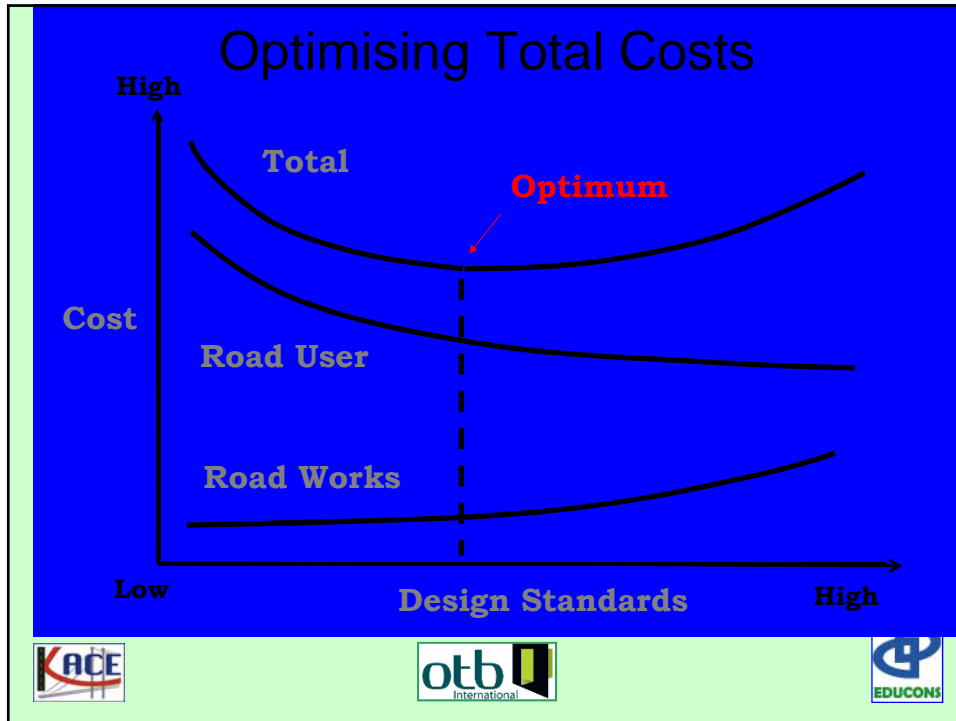
**4 wheel (2 axle)
Motorised traffic**



Session 3

WHOLE LIFE COSTS ASSESEMENT

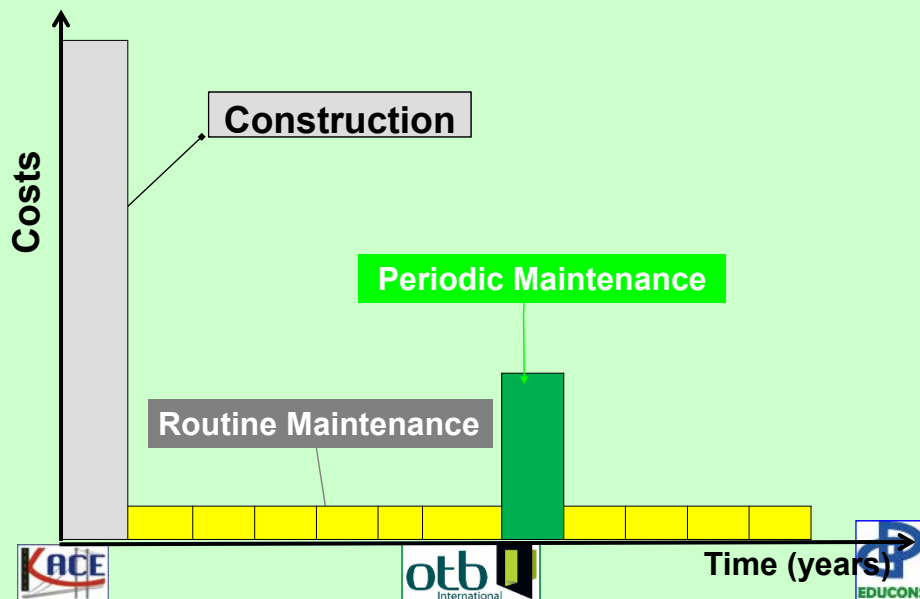




- ❑ Whole life Asset Costing is a process of assessing all cost associated with an investment over its intended (initial) or design lifetime.
- ❑ The aim is to minimize the sum of these values to obtain the minimum overall expenditure on the asset, yet achieving an acceptable level of service of the asset.
- ❑ The principal cost components are the initial investment or construction cost and the future cost of maintaining (or rehabilitating) the asset period selected;
- ❑ Any rehabilitation cost will need to be included in total cost. Usually an assessment of the residual value of the asset at the end of the assessment period is included.
- ❑ From an economic evaluation viewpoint, an important decision is the reduction in value that is assigned to future costs.
- ❑ A discount rate is usually used to reflect future cost and benefits.



4. What are Road Costs?



Whole Life Cost of Road Assets

WLC

$$\sum_{t=0}^n \frac{C_t}{\left(1 + \left(\frac{r}{100}\right)^t\right)}$$

=

R =

$$\frac{R_n}{\left(1 + \left(\frac{r}{100}\right)^n\right)}$$

Net WLC = **WLC - R**



Example of WCL Assessment



Gravel

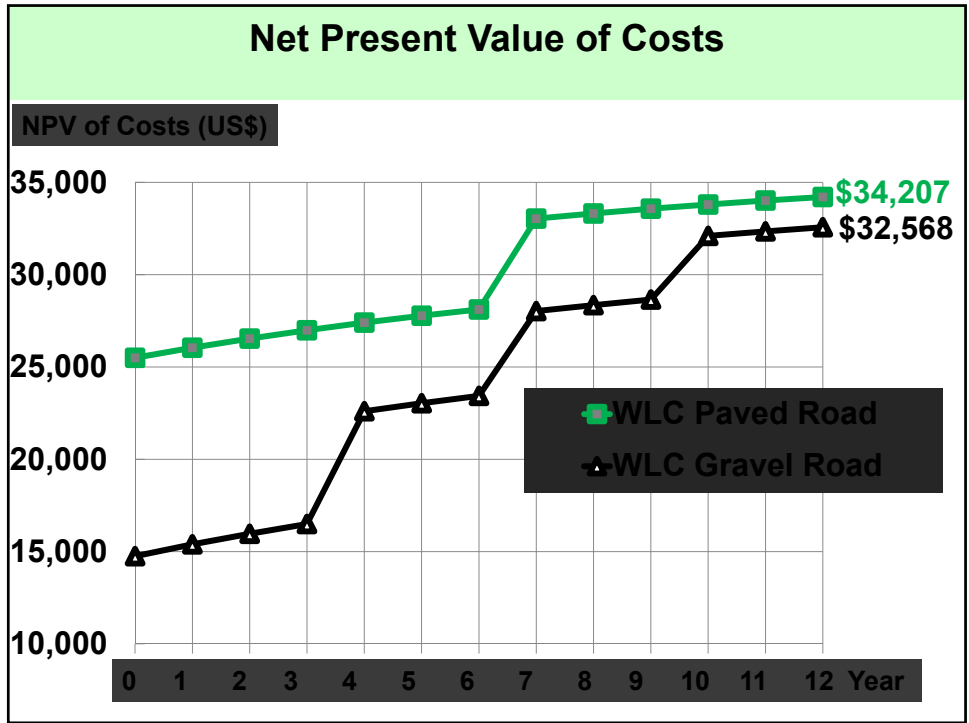
Lower initial investment
but
high maintenance



Paved

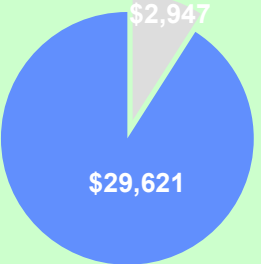
Higher initial investment
but
lower maintenance






2. Whole Life Costs (WLC)

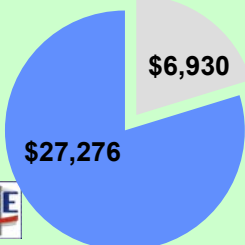
Final Decision?



Gravel Option
WLC: \$32,568


- R = \$2,947
- Net WLC = \$29,621








Paved Option
WLC: \$34,207

- R = \$6,930
- Net WLC = 27,276



Pavement Drainage



Importance of Drainage

Pavement drainage is frequently emphasised in design manuals as being of the utmost importance, however, there is a significant problem in applying drainage principles in construction and maintenance practice .



Commonly observed problems

- Inappropriate “boxed-in” pavement design
- Missing and poorly maintained side drainage
- Insufficient or badly sited cross drainage (culverts)
- Lack of maintained road shape (cross-fall) on unsealed roads
- Build-up of vegetation and debris on shoulders preventing adequate run-off

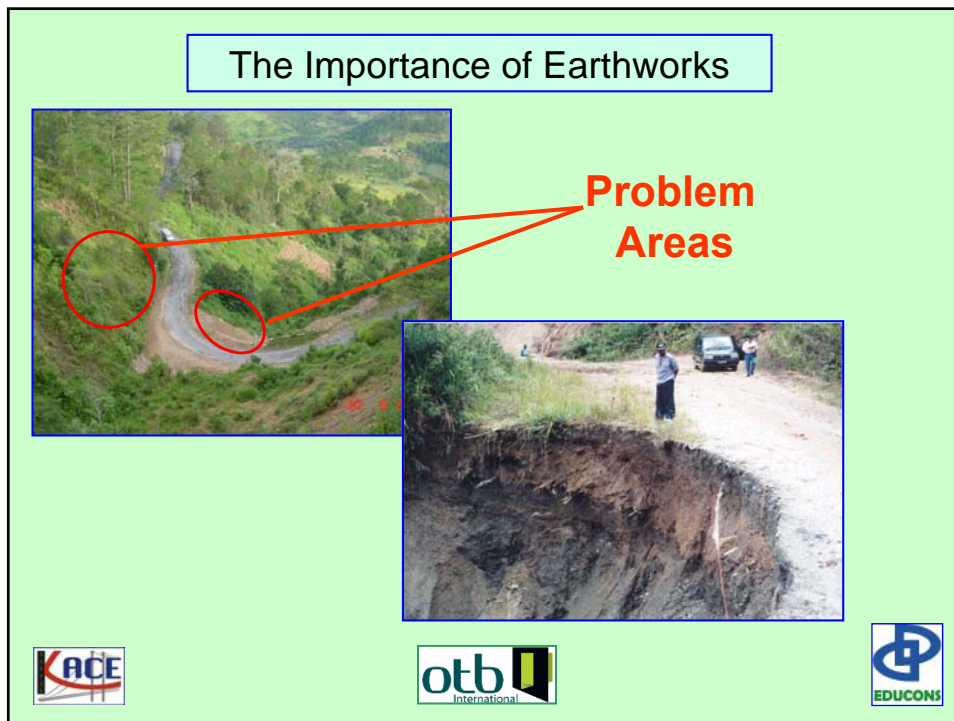
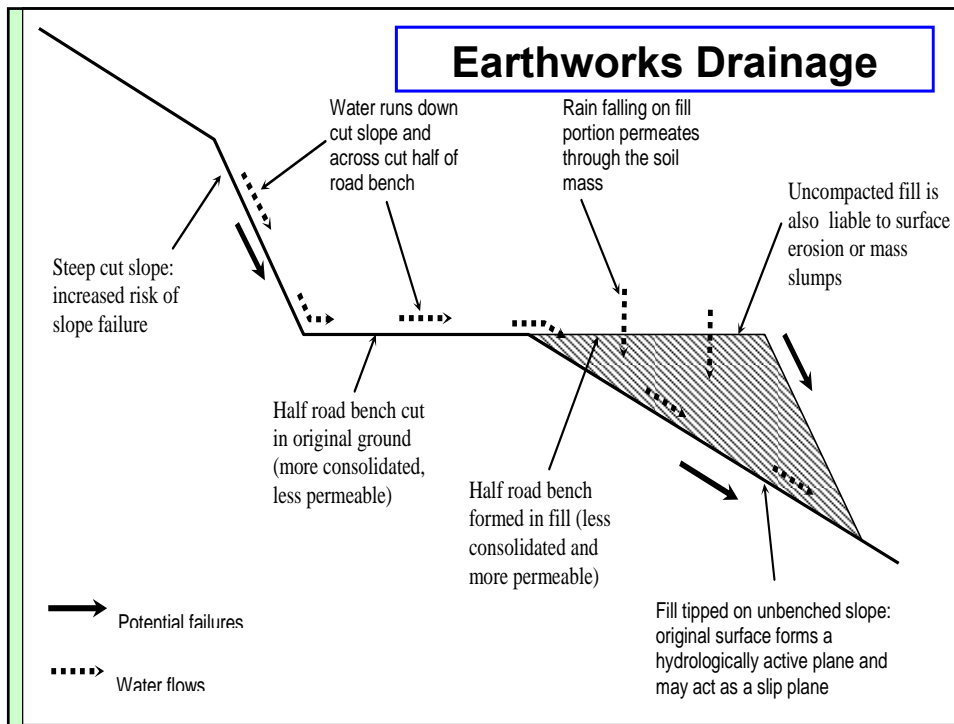


Main Functions

A good road drainage system, which is properly maintained, is vital to the successful operation of a road. It must:

- ❑ Convey rainwater from the surface of the carriageway
- ❑ Control the level of the water table in the subgrade
- ❑ Intercept surface water flowing towards the road
- ❑ Convey water across the line of the road

The first three functions are performed by side drains and the fourth by culverts, drifts and bridges



Carriageway Drainage

If water is allowed to enter the structure of the road, the pavement will be weakened. Water can enter the road as a result of rain penetrating the surface or as a result of the infiltration of ground water.

The road surface must be constructed with a camber so that it sheds rain water quickly and the formation of the road must be raised above the level of the local water table to prevent it being soaked by ground water



Poor Crossfall and Road shape – Collection of Water and Pavement Deterioration



Poor Drainage
Leads to Road
Failure



Missing Culvert?
No Side Drains ?
Earthworks too low ?



Adequate Side
Drainage
(Some routine
maintenance
required)



Discussion

How do I select a pavement option?

What information is needed for pavement decisions?

How do I analyse this data?

How important is drainage ?

