

Regional Seminar on Outputs of African
Community Access Programme

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AFCAP



Innovations in the Design of Low Volume Roads

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Objective of Presentation



To share experiences with practitioners in West Africa of research-based innovations in LVR technology that may offer significant benefits in their quest to provide such roads in a sustainable and more cost-effective manner than hitherto

Presentation Outline

- Background
- Definition and Characteristics of LVRs
- Traditional Approaches to Provision of LVRs
- New Approaches and Innovations in Provision of LVRs
- Summary and Way Forward

- No internationally accepted definition of a LVR.
- In developed countries very LVSRs < +/- 400 vpd
- In developing LVSRs < +/- 300 vpd & ≤ 1 MESA design traffic loading
- Almost exclusive reliance on use of naturally occurring, often non-standard, moisture sensitive materials
- Adoption of an “Environmentally Optimized Design” (EOD)
 - road is designed to suit a variety of task and environmental factors such as rainfall, available materials, construction capacity, terrain, flood risk, etc., in the most cost-effective and sustainable manner.

- Many road users will travel using a slow mode of transport with variable travelling speeds that will seldom exceed about 80 km/h, as dictated by the local topography
- Foot traffic (pedestrians and animals), NMTs and motorised vehicles tend to intermingle in the traffic stream.
 - Consequentially, accidents tend to be dominated by single vehicle type accidents and accidents between motorised and non-motorised traffic.

- “Relaxation” of geometric design standards within an “Extended Domain Design” context
 - without undue increase in the risk of road users, including a significant amount of non-motorized traffic in urban/per-urban areas, coupled with a focus on traffic safety measures in built up areas.
 - alignment not necessarily fully “engineered”, especially at very low traffic levels, with most sections following existing alignment

- Recognition that pavement deterioration is driven primarily by environmental factors (particularly moisture), with traffic loading being a lesser influential factor in deterioration, and drainage being of paramount importance.
- Appreciation that conventional economic analysis often cannot justify the investment of public funds in the construction and maintenance of these roads in which relatively difficult to quantify benefits of a broad socio-economic nature are likely to occur.
- Unique characteristics of LVRs challenge conventional engineering practice in terms of pavement and materials engineering, geometric design, road safety and maintenance.

Types of LVSRs



The Reality of LVR Provision

- Many innovative practices and unconventional techniques often developed and proven through years of research have not found the degree of application and implementation that they should.
- Opportunities often missed that would provide better and lower cost engineering solutions and more sustainable LVRs.
- Wealth of local and international information, experience and research that, when utilized, can change current practices and thinking.
- New, more appropriate, approaches to the provision of low-volume sealed roads (LVSRs) are now required to improve road transport efficiency and attain its broader goals of socio-economic growth, development and poverty alleviation.

- Terminology often counter-productive:
 - Use of “marginal” materials
 - Use of “low-cost” seals
 - Use of “relaxed” specifications

- Have stemmed from technology and research carried out over 40 years ago in very different environments
- Generally inappropriate for application to tropical and sub-tropical countries where locally prevailing circumstances very different in terms of climate, traffic, materials and road users.
- Technology, research and knowledge about LVSRs have advanced significantly in the region thro' research carried out over past 20 -30 years
 - question much of the accepted wisdom on LVSR provision and show quite clearly the need to revise conventional approaches.
- New, more appropriate, approaches to the provision of low-volume sealed roads (LVSRs) are now required if the region is to improve road transport efficiency and attain its broader goals of socio-economic growth, development and poverty alleviation.

“The body of highway engineering knowledge remains empiric rather than rigorously scientific. So, the knowledge taught in our [UK, USA] universities is generally derived from a synthesis of local experience. No wonder it is often irrelevant and sometimes downright misleading in other parts of the world.”

Ray Millard, Highways Advisor, World Bank. 2nd Int. Conf. on Low-volume Roads, 1979.

Limitations of gravel roads

Traditionally gravel is used for rural access roads.

However:

- They are low (initial) cost and relatively easy to construct
- However, they are expensive to maintain – **typically US\$1,600/year**
- **Each Km** of gravel road typically loses more than **70 cubic metres** of material **EACH YEAR**
- A range of constraints means that **maintenance is rarely carried out**, leading to impassability, or the need to repeatedly reconstruct.

.....**SENSIBLE???** **NO!!!**

Why LVSRs?



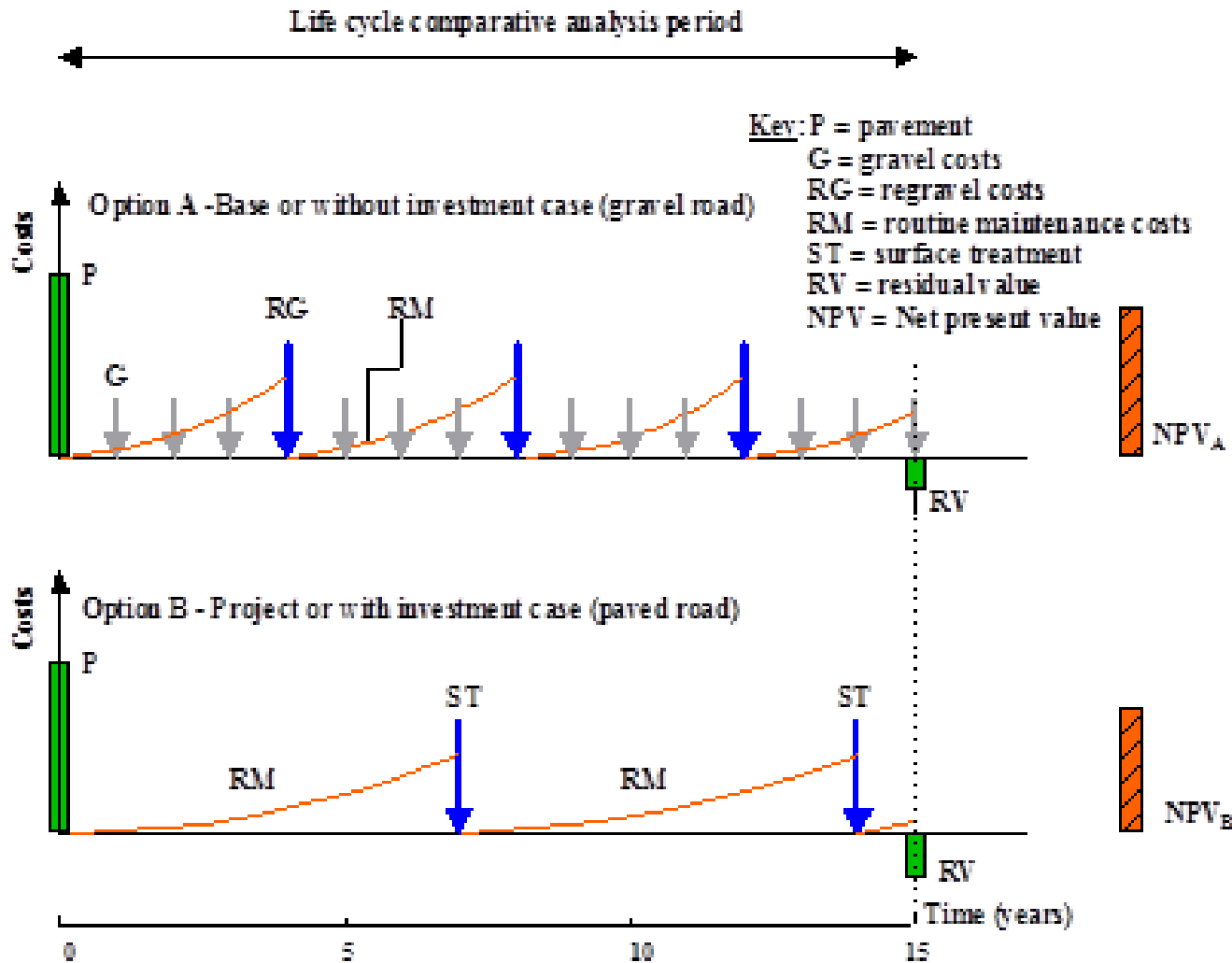
Unpaved roads: dusty, health hazard, pedestrian/vehicle safety; crop, natural habitat and vehicle damage. Is this sustainable? NO!

Unpaved roads: Require continuous use of a non-renewable resource – gravel. This is inherently unsustainable and environmentally damaging. Is this sustainable? NO!

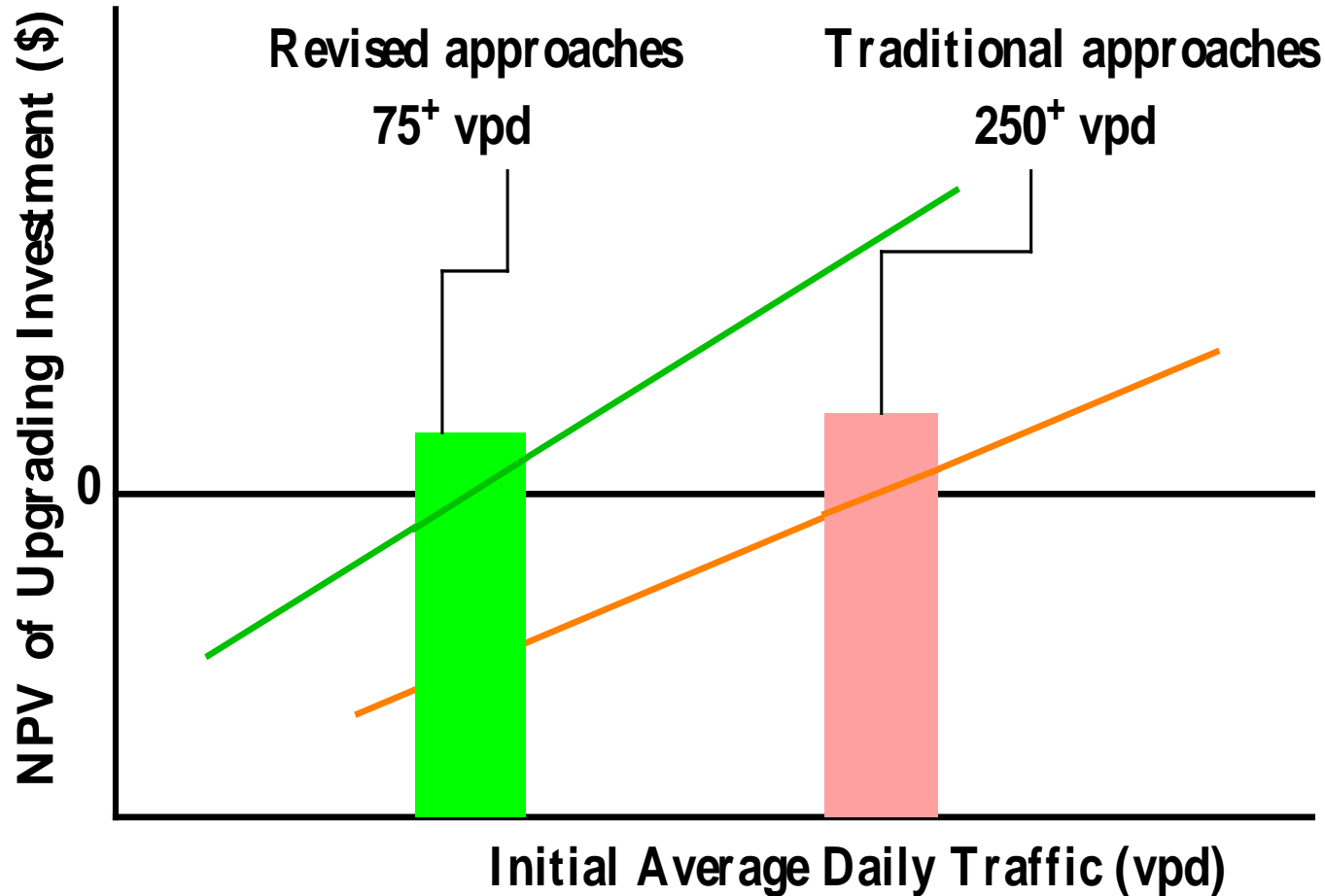


Approx. 175 million cu.m “consumed” annually in SADC region for gravelling purposes

Economic Viability of Gravel Roads



Life cycle cost analysis



Break-even traffic for upgrading: Traditional vs revised approaches

Gravel Roads – the Message

- There is an 'unhealthy' and unsustainable reliance on gravel roads to solve the all-weather access problems of many countries
- Window of opportunity for using gravel is slowly closing. Need for alternative, more sustainable solutions
- A new approach is required which relies on evidenced-based, research information to guide the way forward for providing LVSRs in terms of their planning, design, construction and maintenance.

Gravel Roads – Paving the Way Forward



Before

Not possible to upgrade all unsealed roads

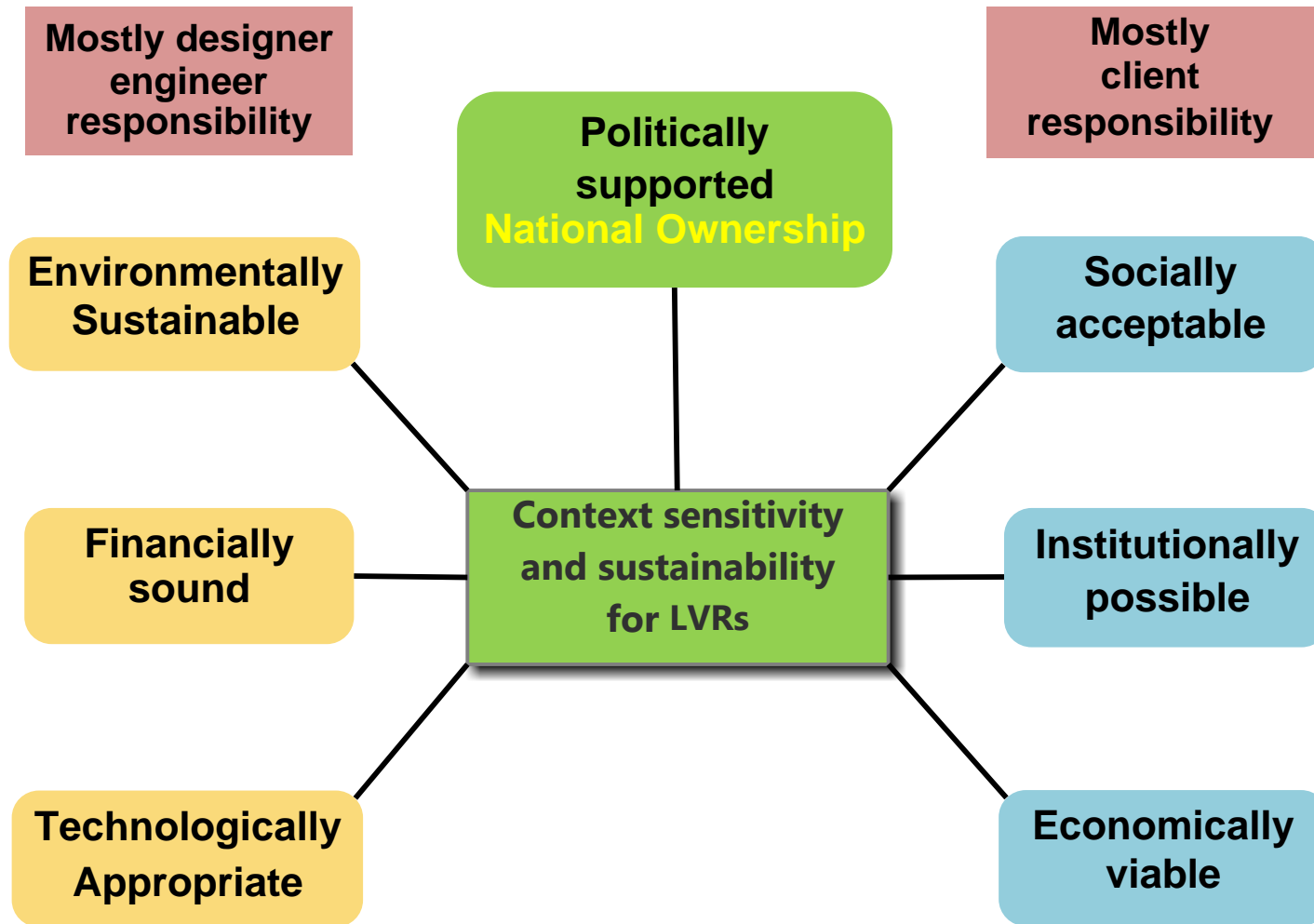
But, many thousands of km of rural access roads carrying light traffic that can be justifiably upgraded using appropriate approaches

After



Need to provide opportunities for better market accessibility and making products and services much easier to access

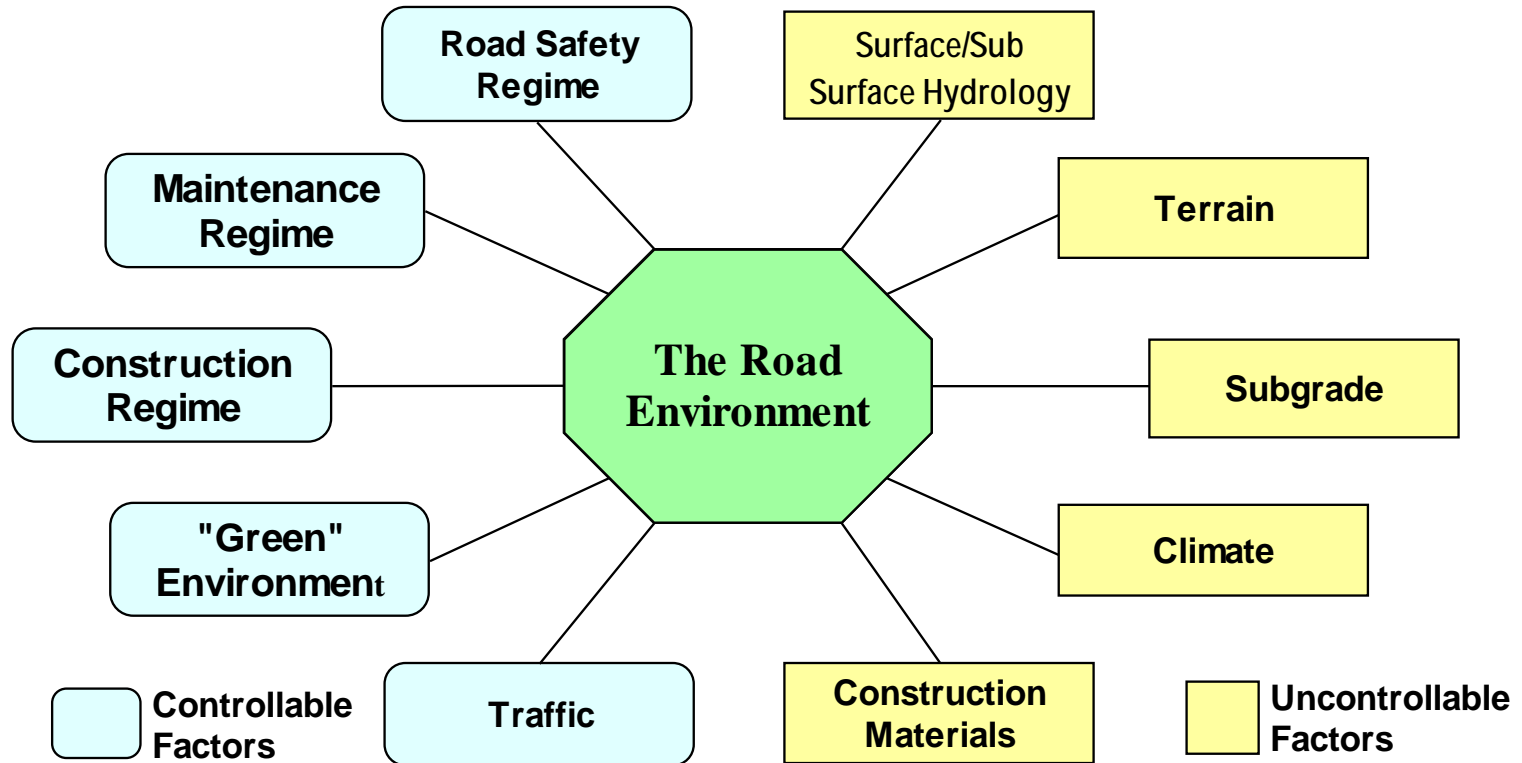
Framework for Provision of LVSRs



Approach to LVR Design

- Follows general principles of any good road design practice, **BUT**
- Important differences from traditional road design practice .
- Optimizing design requires a multi-dimensional understanding of all the design elements which become context sensitive w.r.t various road environment factors
- Pavement design process must be fully responsive to the Ghanaian road environment
- Need for adoption of an Environmentally Optimized Approach (EOD)

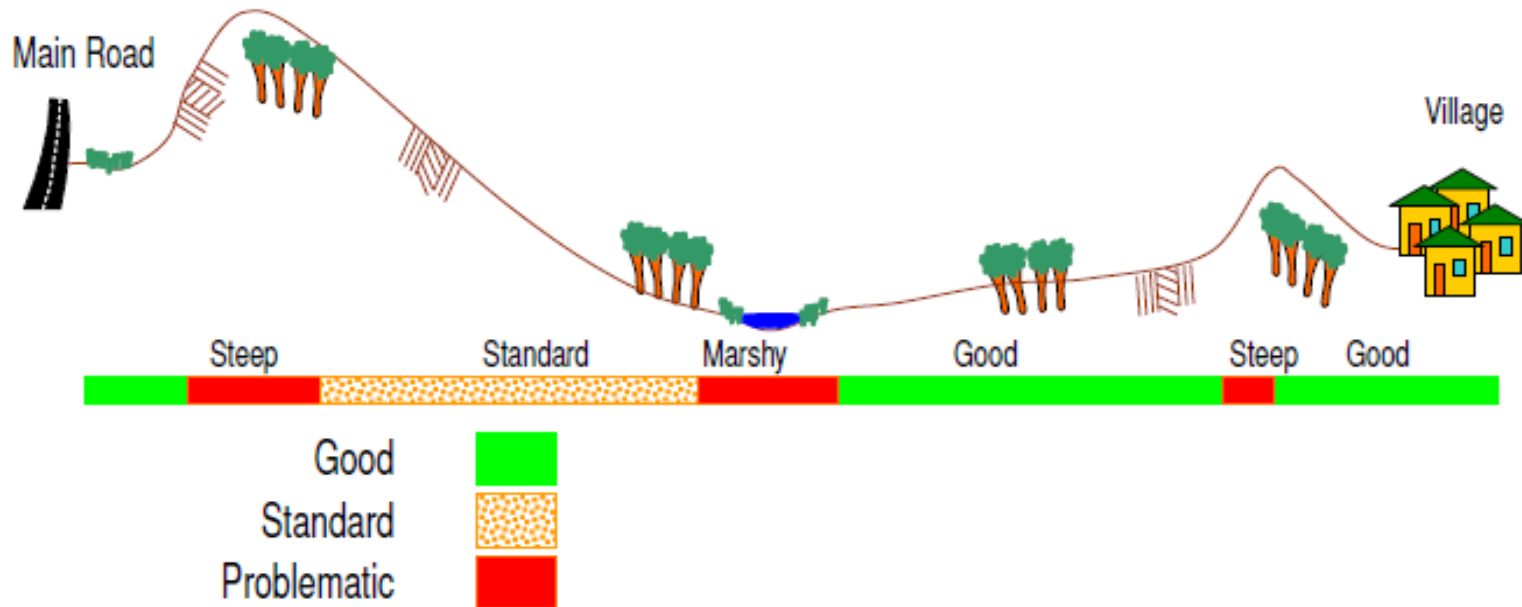
Road Environment Factors



Adoption of “Environmentally Optimized Design”(EOD) approach

- ❖ **EOD** – utilising the available resources of budget, manpower and materials to meet the challenges of the “road environment” to provide appropriate access in the most cost effective and sustainable manner.
- ❖ **EOD** – offers a spectrum of options and solutions for providing low-volume rural road access ranging from a Spot Improvement to a whole link length.

Adopting and EOD/SID Approach

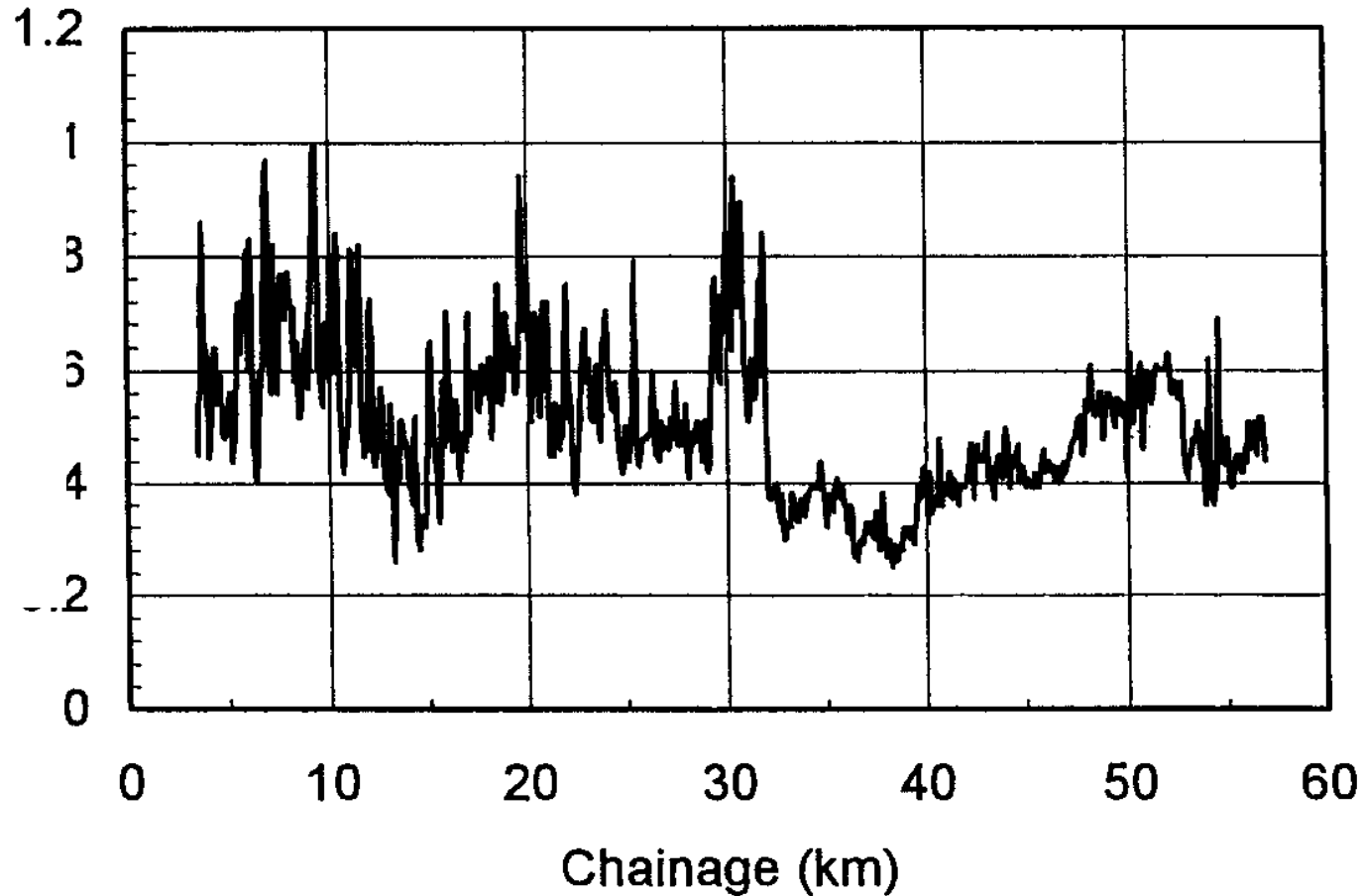


EOD – utilising the available resources of budget, manpower and materials to meet the challenges of the “road environment” to provide appropriate access in the most cost effective and sustainable manner.

EOD – offers a spectrum of options and solutions for providing low-volume rural road access ranging from a Spot Improvement to a whole link length

Need for Comprehensive Investigations

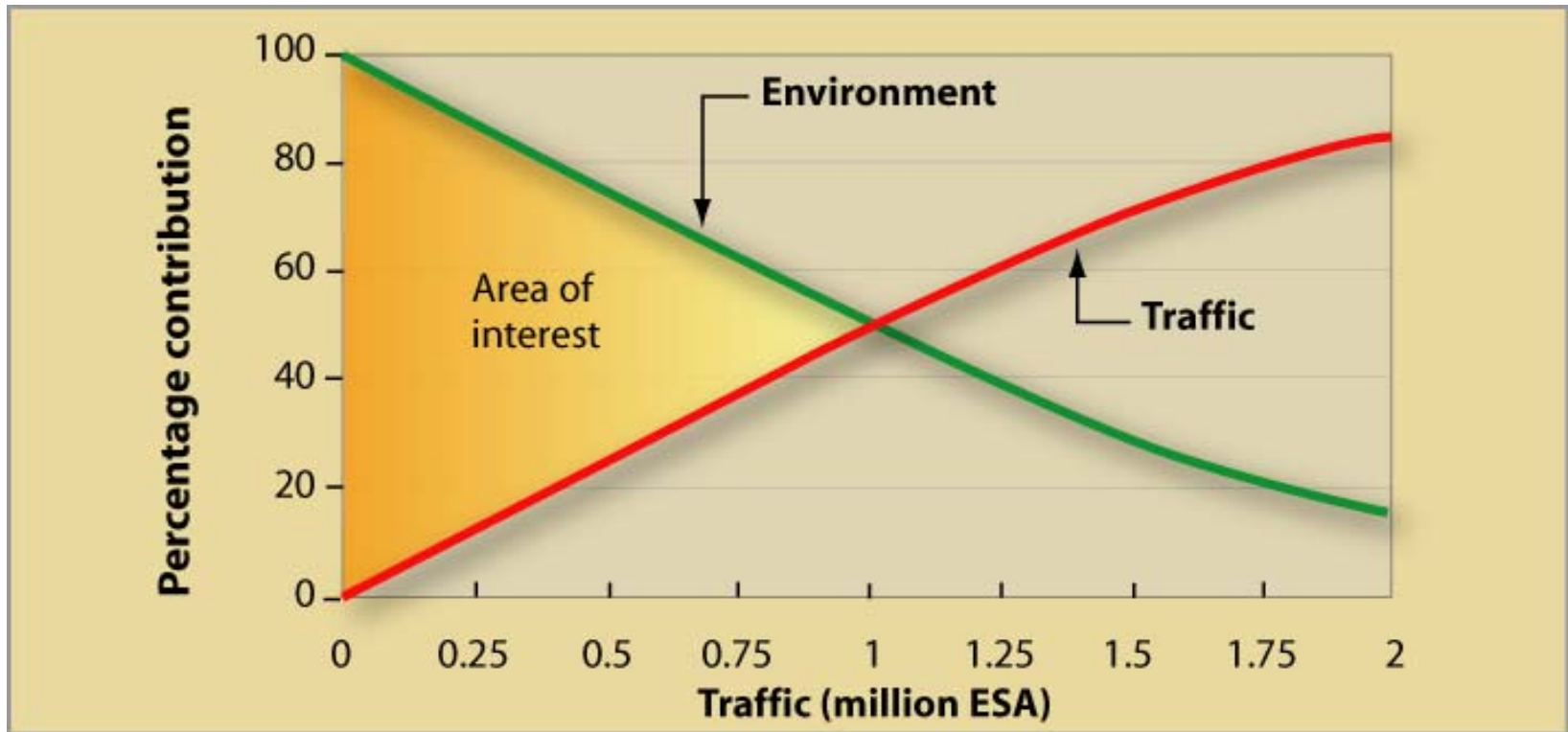
DN
Value
(mm/
blow)



— OWT

Need to provide a good "picture" of in situ ground conditions

Recognition of Dominant Mode of Deterioration

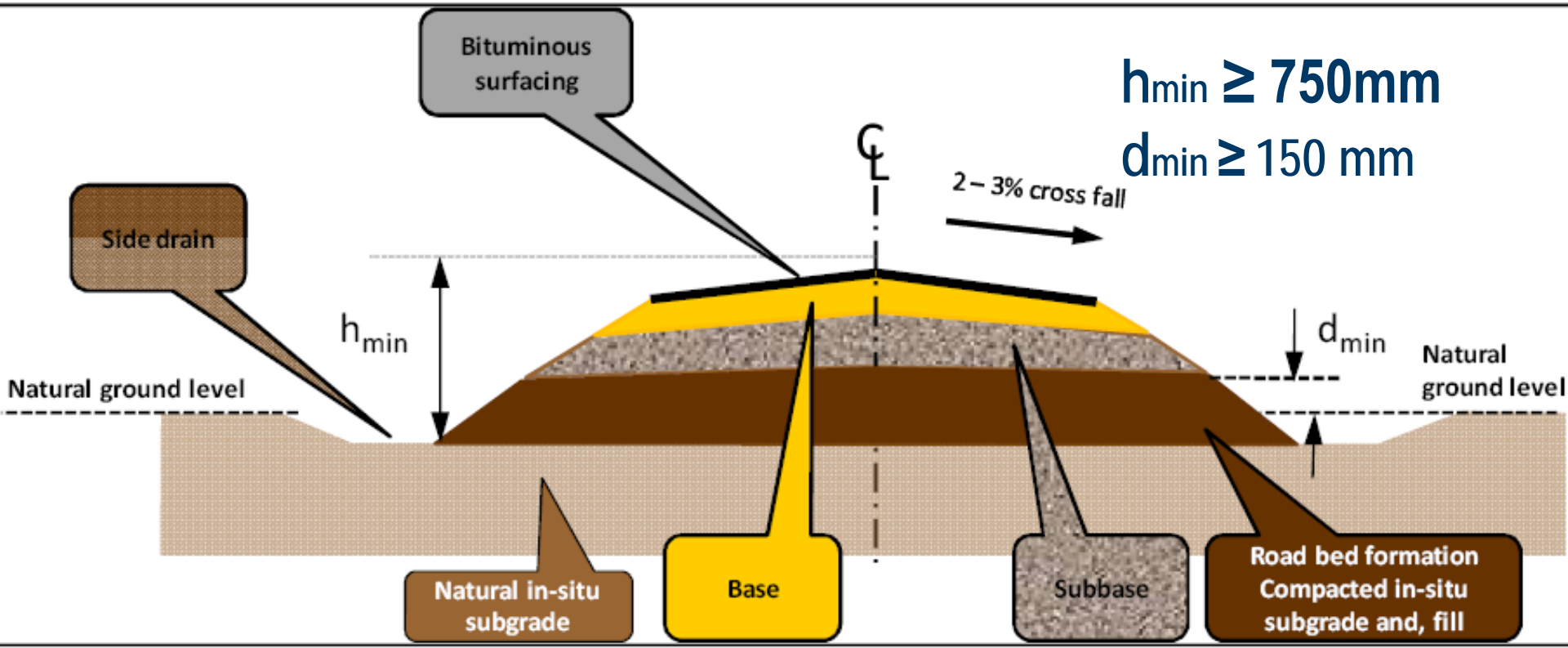


Deterioration of a LVR is driven primarily by environmental factors, with traffic load a lesser factor in deterioration

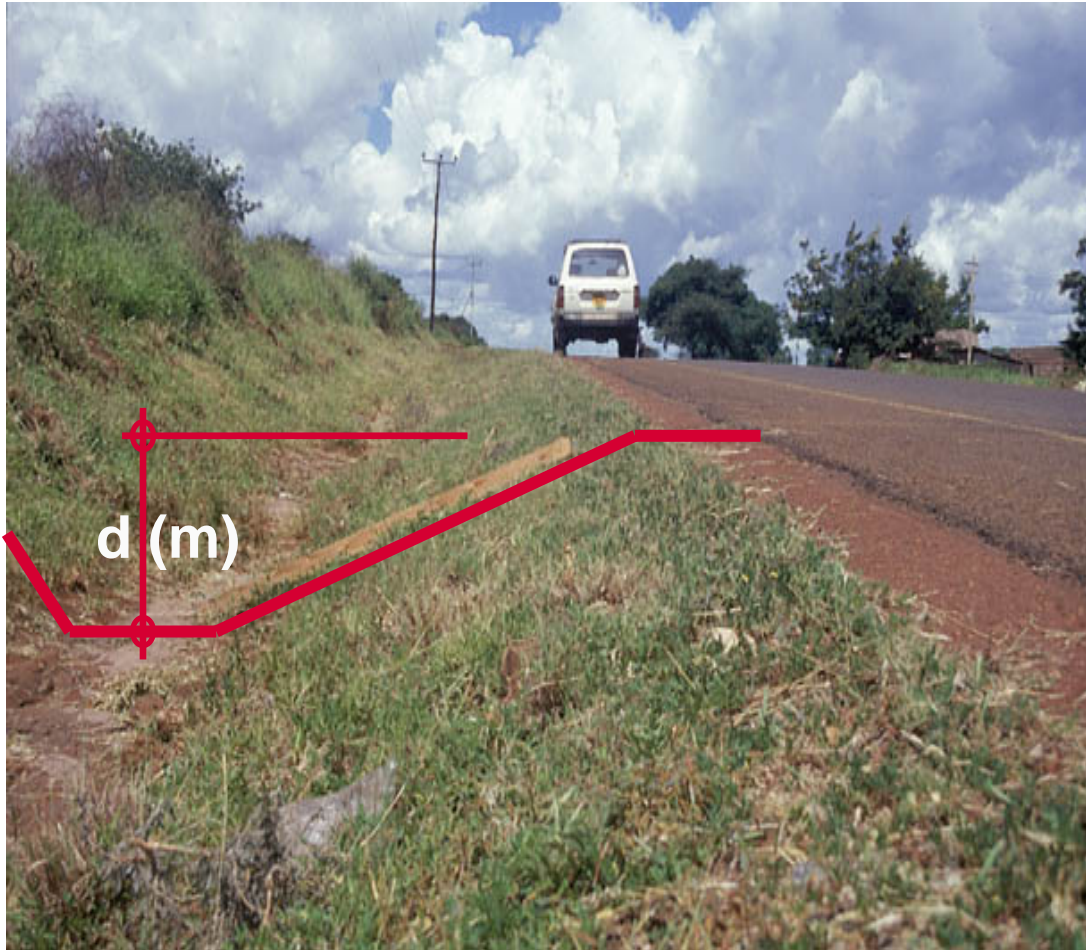
Optimization of Local Moisture Conditions

By observing minimum drainage requirements:

- Moisture content in pavement materials in OWT will stabilize below OMC
- Pavement design moisture content based on OMC (not SOAKED)

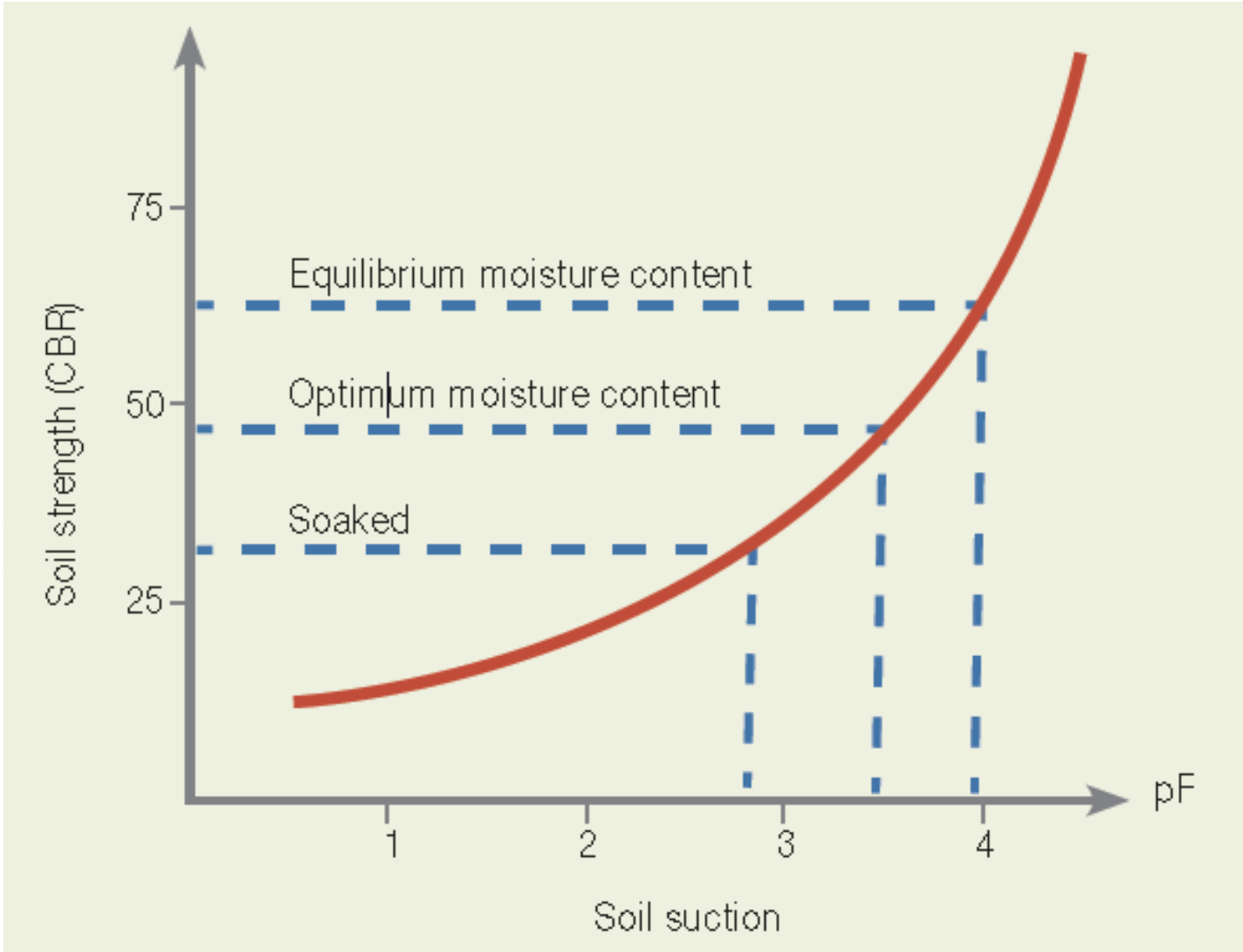


Ideal Cross Section



- Crown height is a critical parameter that correlates well with the actual service life of pavements constructed from natural gravels ($d \geq 0.75$ m)
- Sealed shoulders reduce/eliminate lateral moisture penetration under carriageway
- Avoiding permeability inversion facilitates good internal drainage

Typical Moisture Related Relationship



d (m)

- The selection of appropriate (mostly local) materials for LVRs can make or break a project.
- The cost of materials can comprise up to 70% of the cost of a road.
- In cost-benefit analyses - inappropriate construction materials increase the construction and maintenance costs, making the upgraded road option less economically viable in a C/B analysis
- Recent developments in understanding the behaviour of local materials when used in the construction of LVRs have allowed the use of materials that were previously considered unsuitable for road construction.

Use of Non-Standard Materials

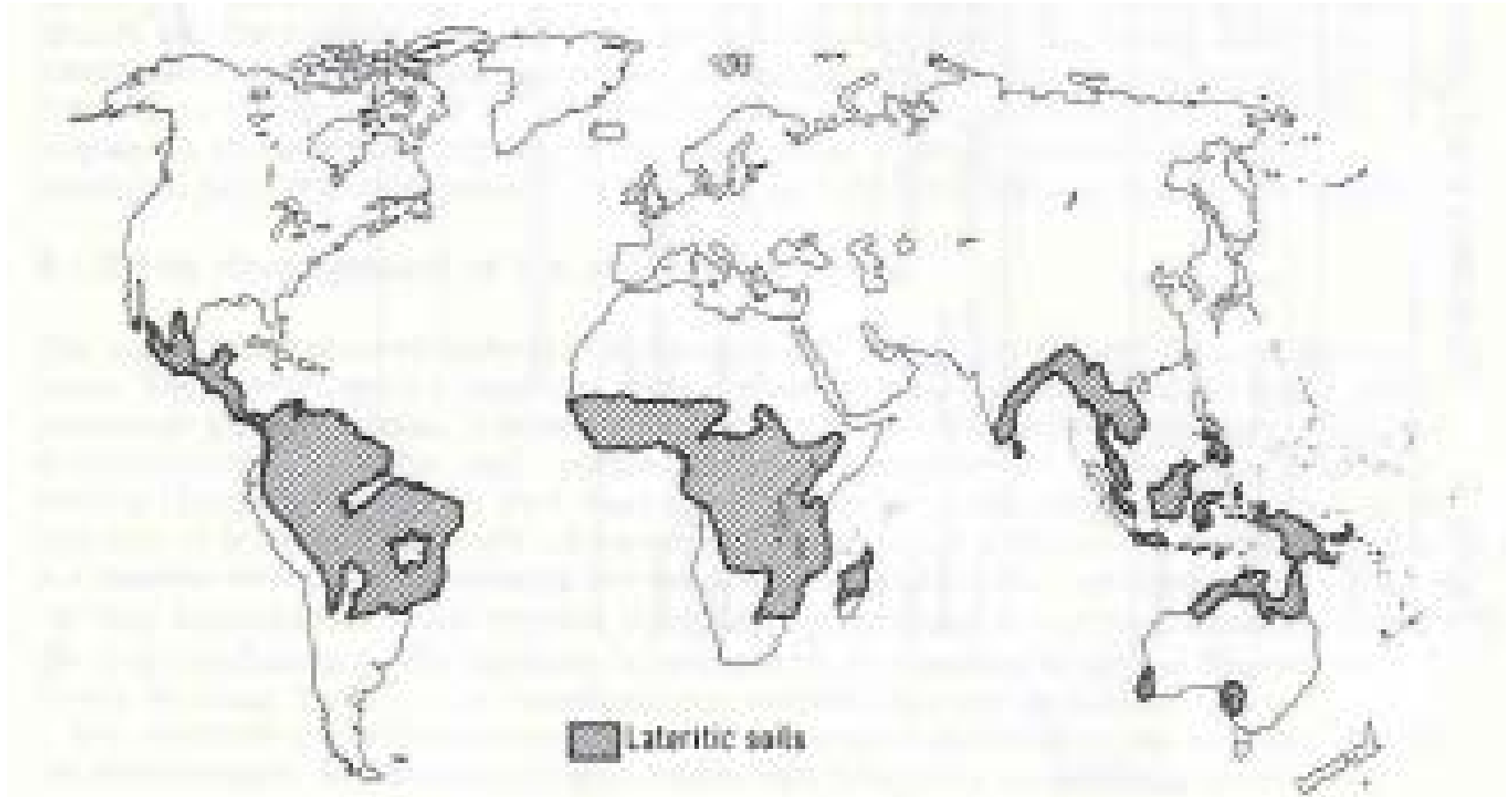


- Locally available, but possibly non-standard, materials should play a significant role within LVSR Standards and Specifications. Unfortunately, force of habit and rigid application of conventional specifications & lack of innovation have suppressed the more wide-spread use of local materials
- Need to make specifications fit the materials rather than materials fit the specifications. In other words – *“what appropriate road can I build with these materials” rather than “Where can I find materials to meet these general specs”.*

Effective Borrow/Pit Management



Distribution of Laterites in Africa



AFCAP Research on Laterites



**Verification of Specifications for the
Use of Laterite in Road Pavements
Phase 1: Literature Survey and Awareness Raising**

AFCAP Research on Use of Sand in Road Construction



**Research Consultancy for the Development of Guidelines for
The Use of Sands in Road Construction in the SADC Region**

Serowe-Orapa Road After 22 Years



**Traffic to date
+/- 0.5 MESA**

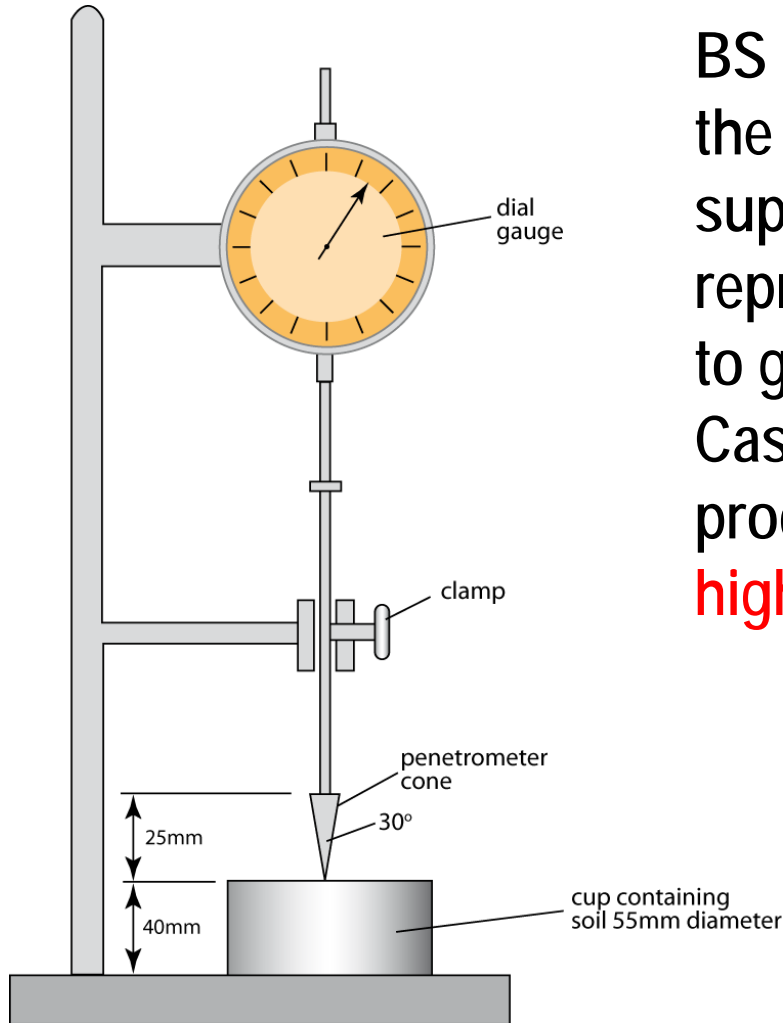
**Serowe-Orapa Test Section:
Constructed in 1989**



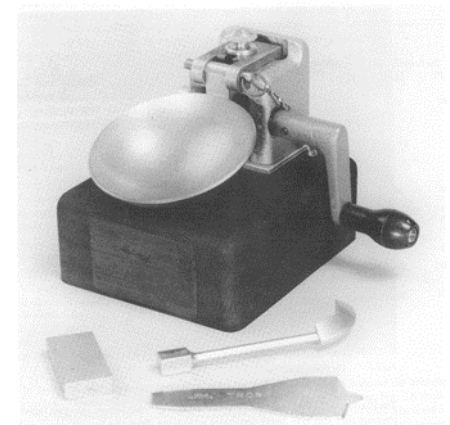
Testing Standards

- Different testing standards used in region
- Results sometimes not comparable due to differences in test procedure and/or equipment.
- Inconsistency in quality of materials selection for incorporation in road works.
- Often lack of appreciation of differences in test results emanating from different testing standards

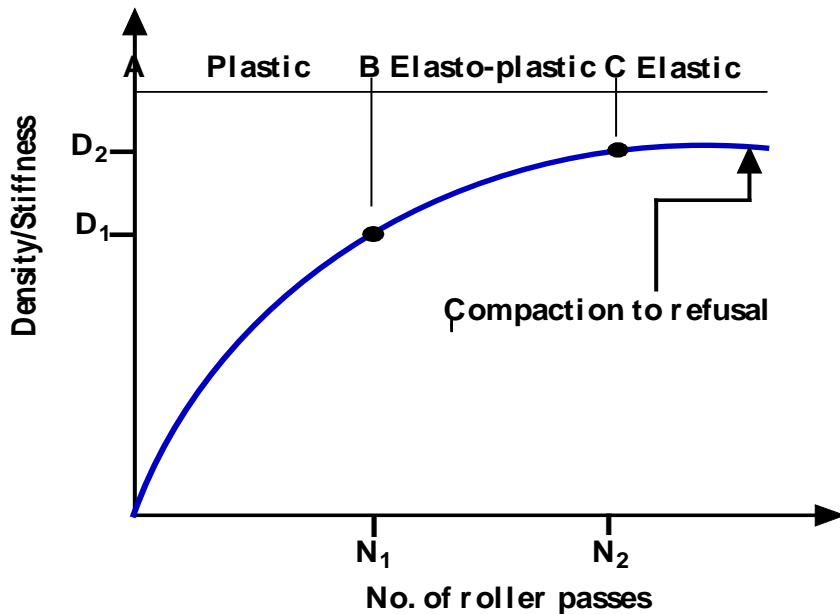
Determination of Liquid Limit of Soil



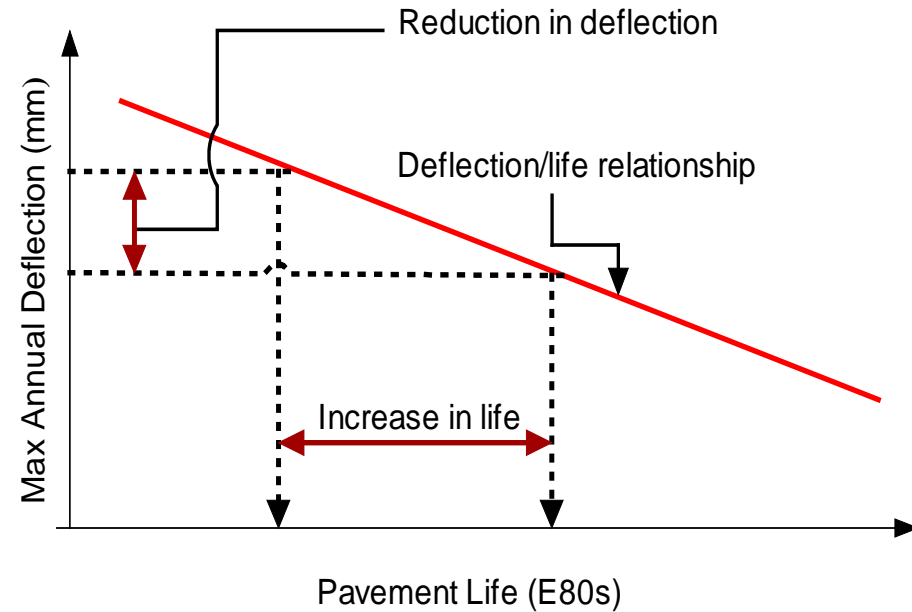
BS standard recommends the use of the cone penetrometer due to its superior precision (repeatability and reproducibility) but has been designed to give same results as BS Cassagrande cup device which produces LL (and PI) results **4 units higher** than AASHTO-type LL device.



Construction - Lessons Learned



Compaction to “refusal”



Deflection/life relationship

Level of compaction in pavement layers influences pavement life – increasing compactive effort is often economically justified

- Recent developments combining the concepts of “environmentally optimized design” with the use of in situ environmental and material conditions have led to the increasing use of the **DCP method of design**.
- The engineer must be familiar with the fundamental principles and assumptions that this technique depends on eg, good in situ testing, an effective and well-maintained drainage system and relatively good construction and maintenance practice.

Bituminous Surfacing Options

Menu of surfacing options for consideration

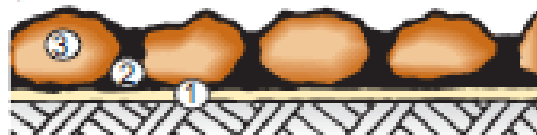
SAND SEAL

- 1 Prime
- 2 Binder
- 3 Sand



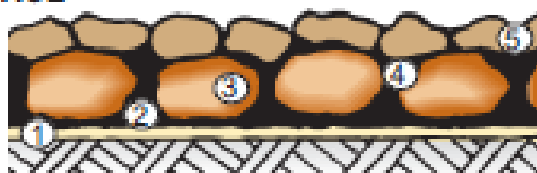
SINGLE SURFACE DRESSING

- 1 Prime
- 2 Binder
- 3 Stone



DOUBLE SURFACE DRESSING

- 1 Prime
- 2 Binder
- 3 Large Stone
- 4 Binder
- 5 Small Stone



CAPE SEAL

- 1 Prime
- 2 Binder
- 3 Stone
- 4 Slurry



SINGLE OTTA SEAL

- No Prime
- 1 Binder
- 2 Graded aggregate



DOUBLE OTTA SEAL

- No Prime
- 1 Binder
- 2 Graded aggregate



COLD MIX ASPHALT

- 1 Tack
- 2 Asphalt Premix



Examples of Non-Bituminous Surfacing



Alternative Context-Sensitive Surfacing

Pavement Type	Local Materials	Flat Terrain	Steep Terrain	Populated Areas	Marshy Areas	Low Strength Sub-Grade	Small Contractor Suitability	Likely Cost Advantage	Maintenance Reduction
Gravel pavement	+	+	-	-	-	+	+	+	-
Unreinforced concrete	-	+	+	+	+	-	+	+	+
Reinforced concrete	-	+	+	+	+	+	+	+	+
Concrete geocells	-	+	+	+	+	+	+	+	+
Concrete strips	-	+	+	+	+	+	+	+	+
Concrete paving blocks	-	+	+	+	+	-	+	-	+
Hand-packed stone	+	+	+	-	+	+	+	+	-
Single Otta seal with a sand seal	-	+	-	+	+	-	+	-	+
Double Otta seal	-	+	+	+	+	-	+	-	+
Double Sand seal	-	+	-	+	-	-	+	-	+
Slurry seal	-	+	-	+	+	-	+	-	-
Double surface dressing	-	+	+	+	+	-	+	-	+
Bitumen penetration macadam	-	+	+	+	+	-	+	-	+
Engineered natural surface	+	+	-	-	-	-	+	+	-

NOTES: Green (+) indicates a positive advantage; red (-) indicates a possible disadvantage.

Benefits of Adopting New Approaches

- Application of locally derived, appropriate technology
- Reduced life cycle costs of LVSR provision
- Facilitating socio-economic growth and development and poverty alleviation

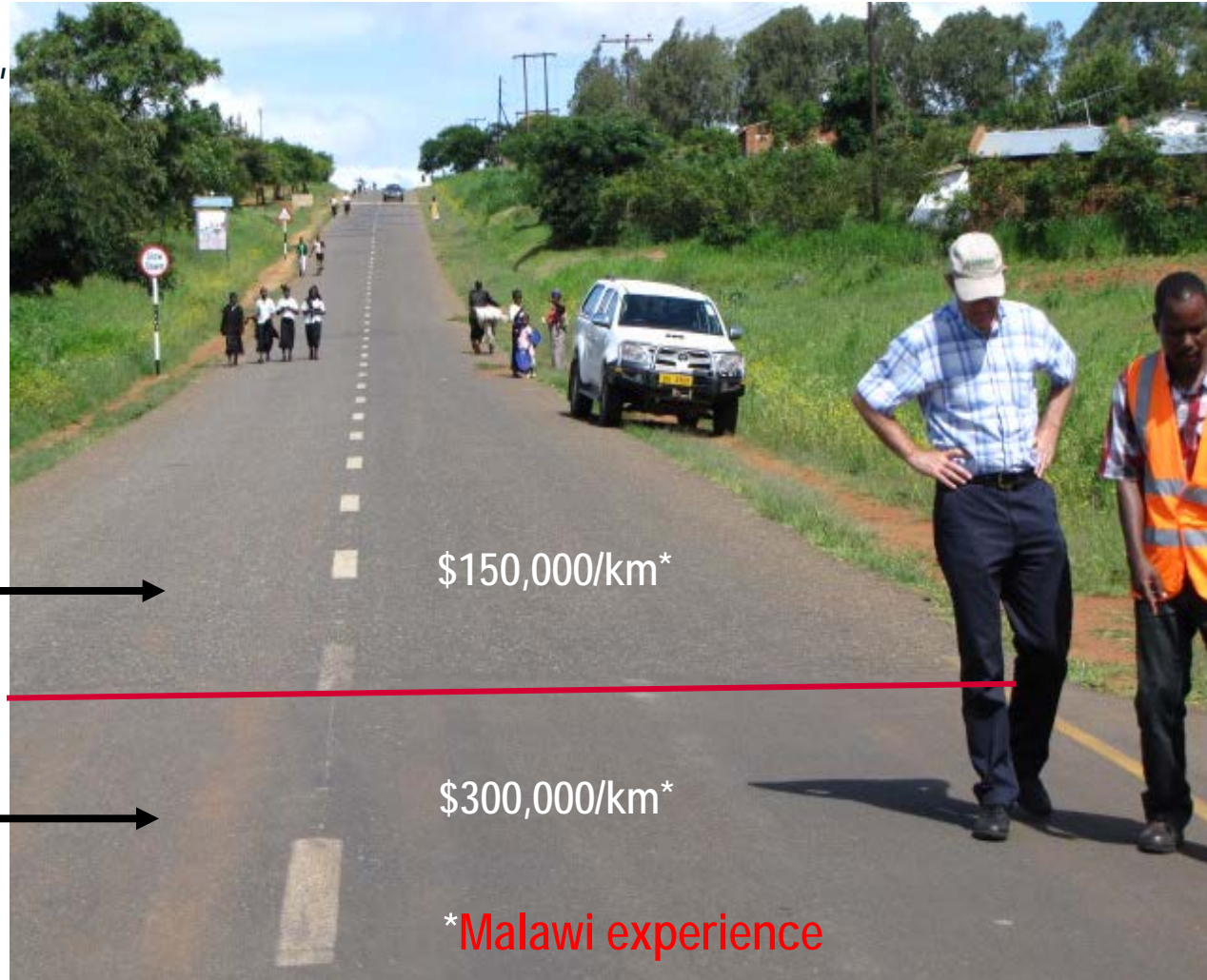
LVR construction →

\$150,000/km*

Standard construction →

\$300,000/km*

* Malawi experience



Pavement Structure Comparisons

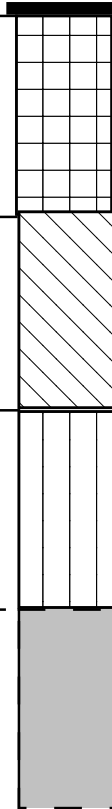
Bituminous surface treatment

Base: 150mm natural gravel
 CBR >80% soaked @ 98% MDD
 PI < 6
 Grading envelope: Yes

Subbase: 150mm natural gravel
 CBR > 30% (at emc) @ 95% MDD
 PI: 6-20 (climate dependent)

Subgrade: 150mm natural gravel
 CBR: > 15% (at emc) @ 93% MDD
 PI: N/A

In situ material

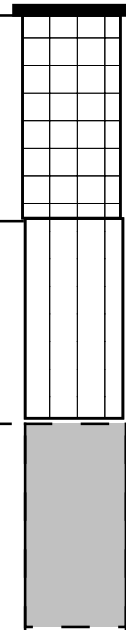


Bituminous surface treatment

Base: 150mm natural gravel
 CBR >50% soaked @ 98% MDD
 PI < 16
 Grading envelope: No

Subbase/subgrade (original surface)
 CBR > 30% at EMC after proof rolling
 PI: N/S)

In situ subgrade material



Typical 2-layer LVR pavement structure : Ntchisi (school) road

Typical traditional 3-layer pavement structure (left) and 2-layer LVR structure (right)

LVSR Philosophy



The successful engineering of a low volume sealed road requires ingenuity, imagination and innovation. It entails “working with nature” and using locally available, non-standard materials and other resources in an optimal and environmentally sustainable manner.

It will rely on planning, design, construction and maintenance techniques that maximize the involvement of local communities and contractors.

When properly engineered to an appropriate standard, a LVR will reduce transport costs and facilitate socio-economic growth and development and reduce poverty in West Africa

Thank you