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Title: **Key Management Issues for Low Volume Rural Roads in Developing Countries**

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SYNOPSIS

The management of Low Volume Rural Roads (LVRRs) in developing countries presents a range of challenges to road designers and managers. In a number of countries, a substantial proportion of the rural road network is generally developed only to an earth or a gravel standard. Individual routes are often in poor condition and sometimes severed during the rains; causing high transport costs and unreliable access. In particular, the challenges are due to factors including high rainfall, in some cases flooding/seasonal high water table, road material quality, haulage and traffic issues, such as variable loading, and the inability to provide timely maintenance through financial, operational and other constraints. At the same time, there are substantial demands for improved access and mobility for the rural communities, to support the achievement of the National Development Goals, improve socio-economic conditions and to reduce poverty.

The paper discusses the key issues concerning the management of LVRRs in developing countries. It draws on experiences in Africa and Asia, but particularly on the experiences of the South East Asia Community Access Programme (SEACAP) in Cambodia, Lao PDR and Vietnam. Research on a number of projects has enabled recommendations to be made regarding provision of LVRRs, for basic access up to durable paved standards. Considerations include:

- appropriate policies;
- road classification and standards relevant to the road function, types of vehicle and flow volumes;
- road environment issues, such as the necessary drainage and anti-erosion measures;
- design based on Whole Life Costing assessment;
- optimal use of insitu and locally available materials, and other local resources;
- appropriate specifications and quality assurance regime;
- maintenance arrangements, capacity and funding.

The paper discusses strategies, such as Environmentally Optimised Design, which incorporates measures from spot improvement to whole link upgrades, in conjunction with a range of possible technology options carefully selected to match the investment and maintenance resources available. Opportunities for local enterprise and community involvement, as well as employment generation are also considered.

The paper summarizes key areas where there are significant knowledge gaps that require further research.

In summary, the paper indicates how the available resources may be more effectively managed to improve rural access and road network conditions, thereby making a significant contribution to socio-economic development and rural poverty reduction initiatives.

1. Background

The management of Low Volume Rural Roads (LVRRs) in developing countries presents a range of challenges to road designers and managers. In a number of countries, a substantial proportion of the rural road network is generally developed only to an earth or gravel standard. Individual routes are often in poor condition and sometimes severed during the rains; causing high transport costs and unreliable access. In particular, the challenges are due to factors including high rainfall, in some cases flooding or seasonal high water tables, material quality, traffic and haulage issues such as variable traffic loading, and the inability to provide timely maintenance through financial, operational and other constraints. At the same time there are substantial demands for improved access and mobility for the rural communities, to support the achievement of the National Development Goals, improve socio-economic conditions and to reduce poverty.

This paper synthesizes selected experiences and conclusions to date emerging from the South East Asia Community Access Programme (SEACAP) research work on rural roads in the countries of Cambodia, Lao PDR and Vietnam. The work is being funded by the UK Department for International Development and other agencies in partnership with the National Governments, the World Bank and the Asian Development Bank. The paper highlights aspects of provision and management of LVRR transport infrastructure, which deserve particular attention and indicates potential improvements in investment performance. Although this paper draws heavily on experiences in the South East Asian environment, many of the principles and lessons may be applicable elsewhere, though with due consideration of the local environment, and adaptation where appropriate.

2. Policy Framework

It is important that an appropriate national transport sector policy framework exists for the investment in and management of all roads, including LVRRs. This enhances coherence and consistency in developing and managing the LVRR assets leading to improved overall cost efficiency and performance.

The Policy framework should ideally include aspects of:-

- the role of the LVRR network and performance/service objectives
- the legal status and ownership of tertiary and access roads
- classification or categorisation of the road infrastructure assets
- quantification of the assets (development of road inventory)
- allocation of responsibilities for managing the assets, including government, community, private sector and other stakeholder roles
- financing arrangements for road improvements and maintenance
- technology and optimal use of available local resources
- setting and monitoring standards and specifications
- planning and prioritising construction and maintenance works
- implementing maintenance and construction works
- interface with inland water transport and other transport modes
- sector human resource development
- social, gender and vulnerable group issues
- environmental and sustainability issues
- road safety and health issues
- road use and traffic restriction (including loading) issues
- monitoring of performance of public assets and investments

The SEACAP website provides access to documentation that describes initiatives tackling many of the above issues in Cambodia, Lao PDR and Vietnam.

3. Rural Road Classification

The appropriate definition of road categories should be based on local conditions and priorities relating to transport policy, strategy, responsibilities, traffic characteristics, economic and social factors, and not least the financing available.

In a national network, roads are often categorised with terms such as Primary, Secondary, Tertiary and Access. Much of the knowledge researched and compiled by SEACAP relates to LVRRs which are variously classified as Tertiary or Access Roads. LVRRs present particular technical and management challenges. However, their actual existence and condition can significantly affect local social and economic development, and hence influence the impact of development initiatives.

The US Federal Highways Administration (FHWA) defines Low Volume Rural Roads (LVRRs) as carrying less than Annual Average Daily Traffic (AADT) 400, i.e. 400 motor vehicles per day. This is broadly the traffic level that is considered to be Tertiary in a wide range of countries.

It is appropriate to further sub-divide the classification of these low traffic routes to facilitate their management. *Lebo and Schelling* (World Bank 2001) discuss Rural Transport infrastructure for Basic Access or Very Low Volume Rural Roads (VLVRRs) relating to routes carrying less than 50 motorized four-wheel vehicles per day (VPD) equivalent.

In many developing countries and transitional economies, both of these rural road categories relate to routes that are likely to be carrying substantial flows of intermediate means of transport such as bicycles and animal drawn carts, as well as motorcycles and locally made/adapted vehicles. However using appropriate equivalence factors for the various vehicle types will enable VPD/AADT to be calculated for local conditions.

The maintenance of LVRRs is typically the responsibility of local authorities (with or without the assistance of central government), whereas the maintenance of Basic Access roads (VLVRRs), by intention or default, often lies principally with communities, groups or individuals (again with or without external assistance). These fundamental characteristics influence the organisational arrangements and techniques that can be effectively applied to the financing and management of improvement and maintenance activities.

The indicative categories describes above are not definitive but serve to set the context of the rural transport knowledge discussed in this paper. The categorisation of roads should be based firmly on the road task, and the corresponding application of knowledge and good practice should consider local conditions and factors.

It is unfortunate that although these two categories of rural road (LVRRs and VLVRRs) are by far the most extensive in network length, they invariably receive the least financial (in many cases no regular) provision. Furthermore, environmental and physical factors, combined with scarce technical and management skills usually mean that the development and maintenance of these routes present a great challenge for communities, technical personnel and other stakeholders.

On the positive side, these lower category routes do not necessarily require overly sophisticated technology construction and maintenance approaches, and offer possibilities for traditional or ingenious techniques incorporating local resource use and community involvement to provide appropriate, low-cost and sustainable transport solutions.

4. Road Standards

Despite the widely recognised resourcing constraints for LVRRs, there are many examples of over-provision of road infrastructure on some routes. This is a waste of resources that could be more effectively deployed elsewhere. It is essential to set standards for road provision that match the transport requirements with the resources available.

Road standards should follow from their classification based upon the route task to allow for a consistent treatment of all similar roads within the infrastructure system in terms of their design, construction, maintenance requirements, users' expectations, and safety.

Figure 1, above left, shows an inappropriate over-provision of road width for a LVRR. This road will incur high maintenance costs. Figure 2, above right, shows a 1.4 metre wide concrete, all-weather, low maintenance VLVRR suitable for the predominant 2 wheeled vehicles using the route, allowing safe passing of loaded vehicles.

LVRR Standards should be appropriate for the local environment and accommodate the current road usage and the expected rural developments. They should be:

- Task based – they should suit the road function and its traffic (the people as well as the vehicles) which will pass along them.
- Local resource based – be compatible with the local road sector characteristics; the engineers and technicians who will design the roads; the contractors and labourers who will construct them; the villagers who maintain them; and, the construction materials that are available.
- Affordable – they must facilitate the construction of roads and associated structures with whole life asset costs that will not exhaust budgets or place excessive maintenance burdens on local communities.

LVRR Standards should accommodate technologies from engineered natural surfaces (ENS – Engineered earth roads) though various combinations of surfacing and paving upgrades to all-weather roads providing dependable year round access to villages and communities. Standards should allow Environmentally Optimised Design (EOD) and Spot improvement approaches (discussed later).
Table 1 is an example of road width standards recently developed for LVRRs in Lao PDR.

In Lao, SEACAP has assisted the Ministry of Public Works and Transport to elaborate standards and specifications that enable the utilization of Environmentally Optimised Design and optimal surfacing and paving technologies within a road length. These documents will be available on the SEACAP website in April 2008.

5. Road Environment Issues

The principal elements in the road design process are traditionally focussed on traffic and the choice of materials and their thickness within each pavement layer. Experience is increasingly indicating that in the case of LVRRs this traditional approach is inadequate.

Criteria	Decision (Shoulder + Carriageway + Shoulder)
If maximum vehicle width > 2.3m	Use Main Road design manual
It maximum plated (regulated) axle weight > 4.5T	Use Main Road Design Manual
If total 4-wheeled traffic AADT > 150	Use Main Road Design Manual
If maximum vehicle width > 1.8m and <2.3m	Use 1m+3.5m+1m, total 5.5m road width
If maximum vehicle width <1.8m and total AADT of non-motorized road users is <150	Use 1m+2.5m+1m total 4.5m road width
If maximum vehicle width <1.8m and total AADT of non-motorized road users is >150	Use 1.5m+2.5m+1.5m total 5.5m road width

Table 1, Example Criteria for Selecting Road Widths

It is now appreciated that additional road environment factors must be taken into account if the selected designs are to be cost-effective and sustainable. The design engineer needs to also understand all other non-traffic external impacts on the LVRR. In reality the performance of a LVRR depends on a whole range of factors that cumulatively can be described as the “road environment”. Factors important to the road environment can be broadly grouped as follows and illustrated in Figure 3:

- Available Materials – locally and within economic haulage
- Natural Environment factors – largely uncontrollable
- Road Task
- Operational Environment – largely controllable

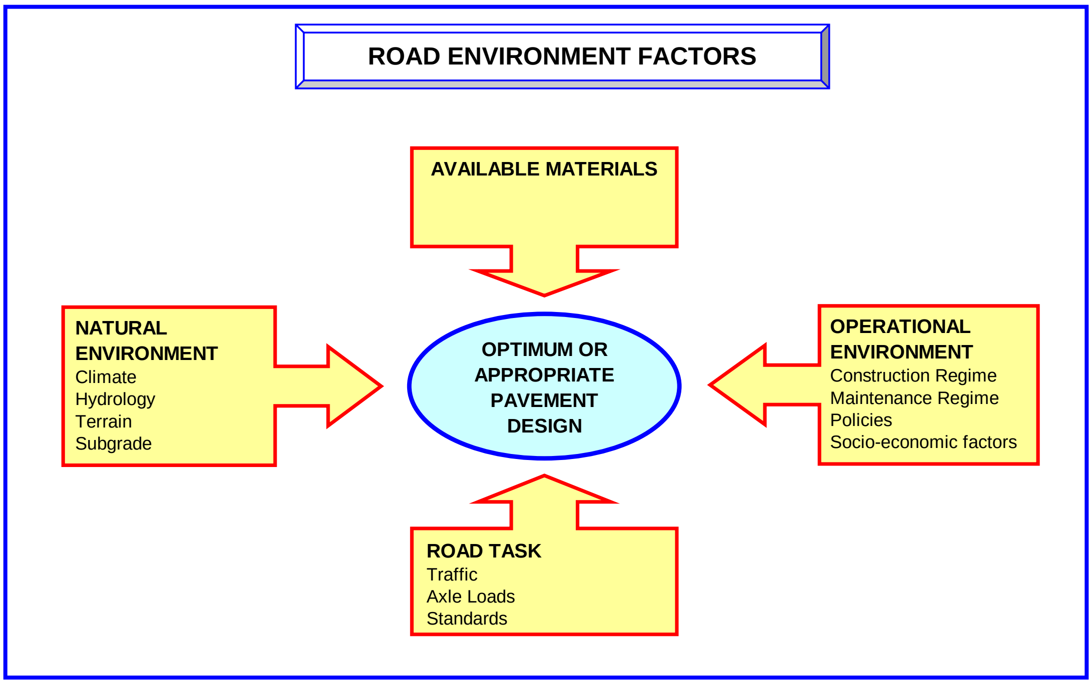


Figure 3: The Road Environment, Natural and Project Related Factors

Appropriate LVRR design should take into account the impacts and influences of the various road environment factors and their effect on:

- Earthworks,
- Drainage,
- Structures,
- Pavement.

There clearly has to be an upper limit to the traffic for the LVRR approach to design and construction. Above this limit, the traditional traffic related factors will be the predominant influence on deterioration. This limit is illustrated on Figure 4. This is a general conceptual figure which needs to be interpreted and adapted for specific regions bearing in mind their particular characteristics.

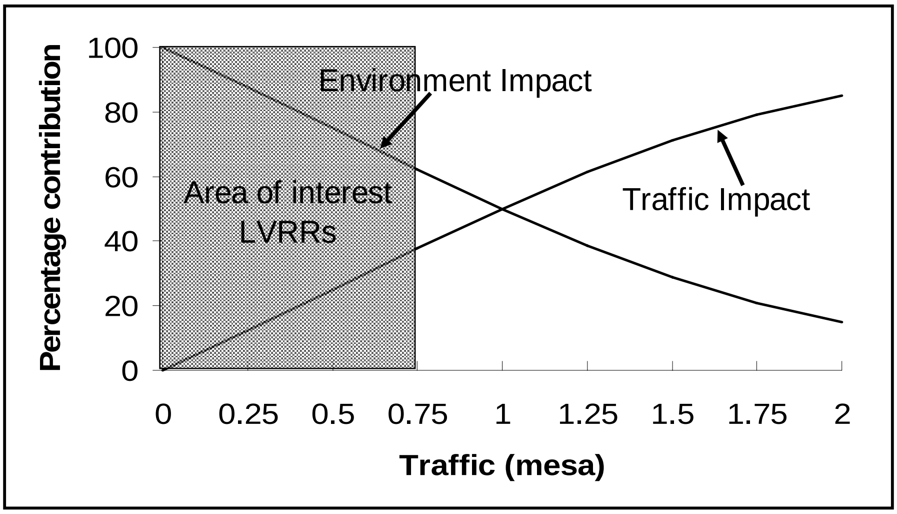


Figure 4: Conceptual - Relative Impacts of Traffic and other Road Environment Factors

This paper does not discuss general environmental issues relating to sustainable use of materials, energy or pollution issues.

6. Environmentally Optimised Design

During the past 20 years or so, DFID and other development agencies have supported research on various aspects of LVRRs with the aim of improving their affordability and sustainability. Some of this research has led to innovative and unconventional LVRR solutions and approaches that are highly beneficial and cost effective, for example, the use of alternative pavements and surfaces.

Key to successful solutions is recognition that conventional assumptions regarding road design criteria need to be challenged. One emerging design concept is for the Environmentally Optimised Design (EOD) approach. LVRR standards and designs need to support the function that the road is providing as well as recognising the important influences of the deterioration mechanisms.

The principle of EOD implies a spectrum of practical and affordable actions for improving or creating rural access – from dealing with individual critical areas on a road link (Spot Improvements) to providing a whole length design, which, in the latter case, could comprise different design and surfacing/paving options along its length.

7. Surface and Paving Options

Until recently, the commonly applied solution for improving rural access in developing countries was to provide gravel roads. Superficially, the attractions looked convincing; low initial road cost, all-weather passage and technology so simple that even communities could often be organised to build the roads themselves. However the shortcomings associated with gravel roads are increasingly becoming acknowledged.

There are still many situations where gravel is still an appropriate and affordable LVRR surface option. However, in recent years research in Africa and South East Asia has identified some limits to the sensible use of gravel and also highlighted a range of proven alternatives that can provide more sustainable access; each option's suitability depending on the local circumstances and environment.

The old 'rule of thumb' used to be *"For flows up to 50 (motor) vehicles per day (vpd) use earth surface, 50 – 200 vehicles per day use gravel, and above that seal."*. This approach does not account for local environmental factors, local materials, haul distances, alignment gradient and other highly localized issues that are the controls for the relative costs and deterioration of the road and hence must influence the technology choice.

On any given road alignment there maybe some natural soils that are unable to tolerate any sort of traffic, especially when wet. Other in situ soils may be found with strength and performance characteristics that are very easily able to carry quite substantial volumes of traffic in their natural state if adequately shaped and drained. Therefore the local materials, site characteristics and environment have greater influence on appropriate design, not traffic volumes such as the deceptive 50 vpd earth-gravel transition benchmark indicated.

Research in the Southern Africa region has also shown that sealing can be justified at motor vehicle flows of as low as 70VPD or less. In some extreme combinations of adverse rainfall, gradient, materials or other factors, a durable pavement will be required for any regular vehicle passage. Furthermore, the range of surface options at the disposal of the engineer or community makes bitumen 'sealing' only one of the many upgrading techniques to be considered.

Anticipated traffic generated benefits are also not the only possible justification for improving access to poor rural communities. The above old 'rule of thumb' is therefore no longer appropriate.

The first weapon in the engineer's armoury that is often neglected is the 'Engineered Natural Surface (ENS)' or earth road. This uses the in-situ natural material of the road, shaped up to form a camber and drainage provided to ensure that rainwater flows off and away from the road. In the early 1990s a pilot project in Kenya showed that many sections of a LVRR alignment could provide satisfactory access if the earth was shaped up, side drainage and cross drains were provided, and difficult sections such as poor soils or steep gradients were provided with an improved pavement/surface. Soils with year-round in situ CBRs of about 15 or more are likely to be quite adequate for low traffic flows and even moderate axle loadings. In situ measurements of CBR can be measured quickly and cheaply using the Dynamic Cone Penetrometer (DCP). The recent document *Behaviour of Engineered Natural Surfaced Roads* discusses the considerable potential for the use of this widely under-rated technique.

Concerns about the performance of gravel roads led to the preliminary work on surface options under a DFID-funded Knowledge and Research project and the publication of the Low Cost Surfacing *Working Paper No 1.* This set out the rationale for restricting the application of gravel as a surfacing material and the investigation and the promotion of alternative technologies and solutions.

A paper by *Johnston and Salter* in 2001 highlighted the sustainability problem regarding continued investment in gravel road networks without the necessary maintenance capability being in place to preserve the considerable investment.

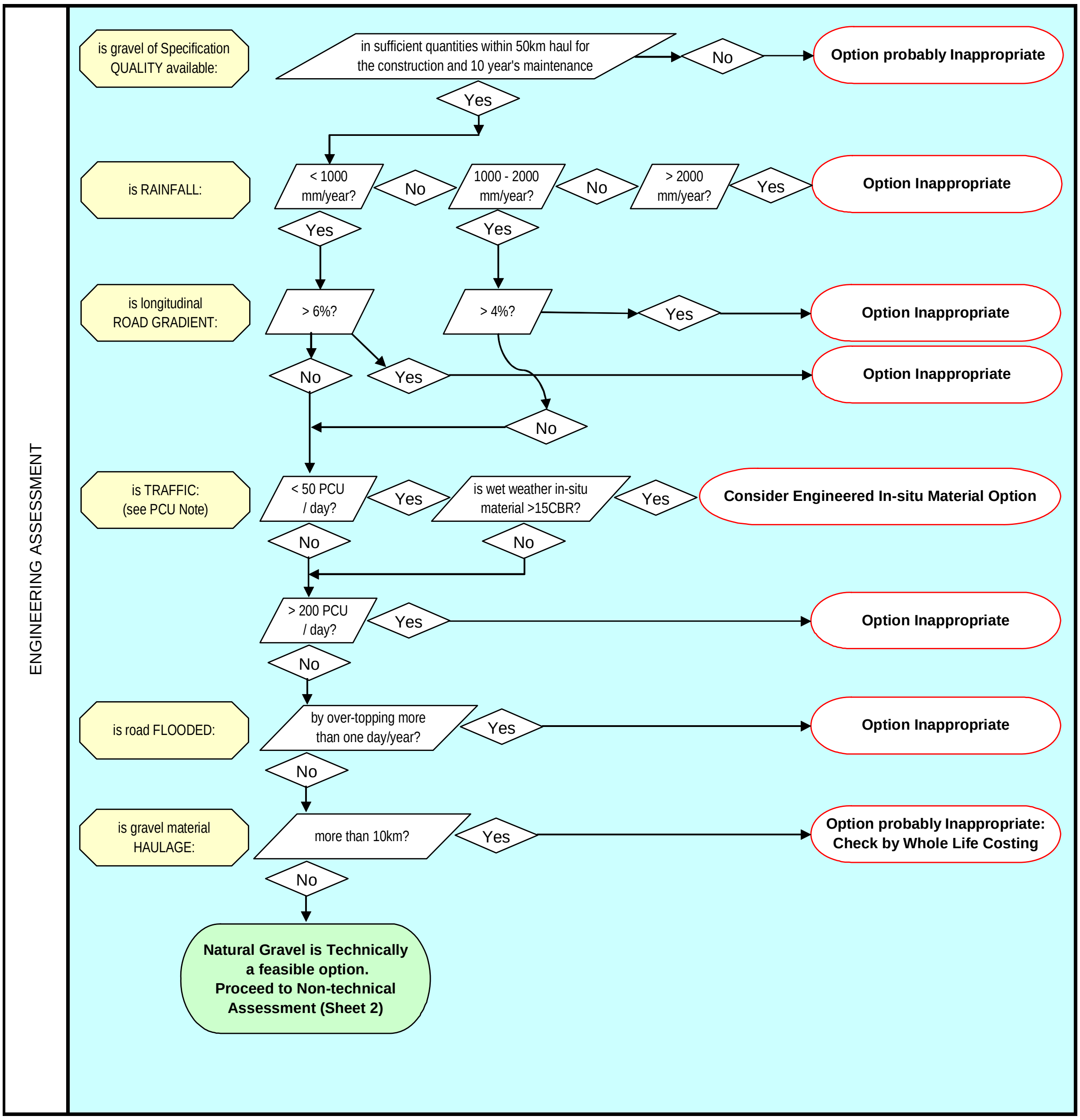
In Southern Africa the SADC *Low-Volume Sealed Roads Guideline* has made a very strong case for the sealing of roads at quite low traffic volumes. The paper by *Hongve and Paige-Green* describes the experience with Labour Orientated use of the guideline and also provides indications of the expected lives of various surface options.

The *SEACAP 4* project in Vietnam studied over 700 road sites where gravel surfacing had been used in current and previous rural road projects throughout the country. The study led to recommendations on the restriction of the use of gravel, particularly for locations with adverse factors of material haul distance, traffic, rainfall or flooding, gradient, material quality and maintenance capability. Some of the recommendations are incorporated in Figure 5.

Figure 5

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

The *SEACAP 1* project has been a major complementary programme of research and trials into alternative rural road pavements and surfaces in Vietnam. It drew on local experiences and earlier surfacing trials in Cambodia to develop recommendations on a range of surfacing and paving techniques, many of which are suitable for construction by local contractors and communities themselves, thus creating new employment opportunities as well as the economic benefits of improved access.

LVRR surfacing trials programmes have now extended to Lao PDR, Sri Lanka and other countries.

Figure 6 lists the range of surfacing and paving options being investigated and compiled under various research initiatives. A range of base and sub-base options is also being investigated and compiled.

SURFACES

Reference	Surface/Paving Technique
S 01	Engineered Natural Surface
S 02	Stone Chipping Blinding
S 03	Gravel/laterite Surface
S 04	Stabilised Soil Surface
S 05	Telford Paving
S 06	Waterbound/Drybound Macadam
S 07	Hand Packed Stone
S 08	Irregular Cobble Stone Paving
S 09	Stone Setts or Pavé
S 10	Mortared Stone
S 11	Dressed Stone/Cobble Stone
S 12	Bituminous Surface Dressing Chip Seal
S 13	Bituminous Emulsion – Surface Dressing Chip seal
S 14	Bituminous Sand Seal
S 15	Bituminous Emulsion – Sand Seal
S 16	Bituminous Slurry Seal
S 17	Graded Gravel Bituminous Seal
S 18	Ottaseal
S 19	Penetration macadam
S 20	Bituminous premix macadam
S 21	Fired Clay Brick Pavement – Un-mortared Joints
S 22	Fired Clay Brick Pavement – Mortared Joints
S 23	Cement Brick Pavement – Un-mortared Joints
S 24	Cement Brick Pavement – Mortared Joints
S 25	Geo-cell Paving
S 26	Bamboo Reinforced Concrete
S 27	Steel Reinforced Concrete
S 28	Non-Reinforced Concrete

Figure 6: Surfacing and Paving Options

Figure 7 shows a recommended surfacing/paving selection approach.

A two phase selection approach is proposed (Figure 7) as follows:

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.

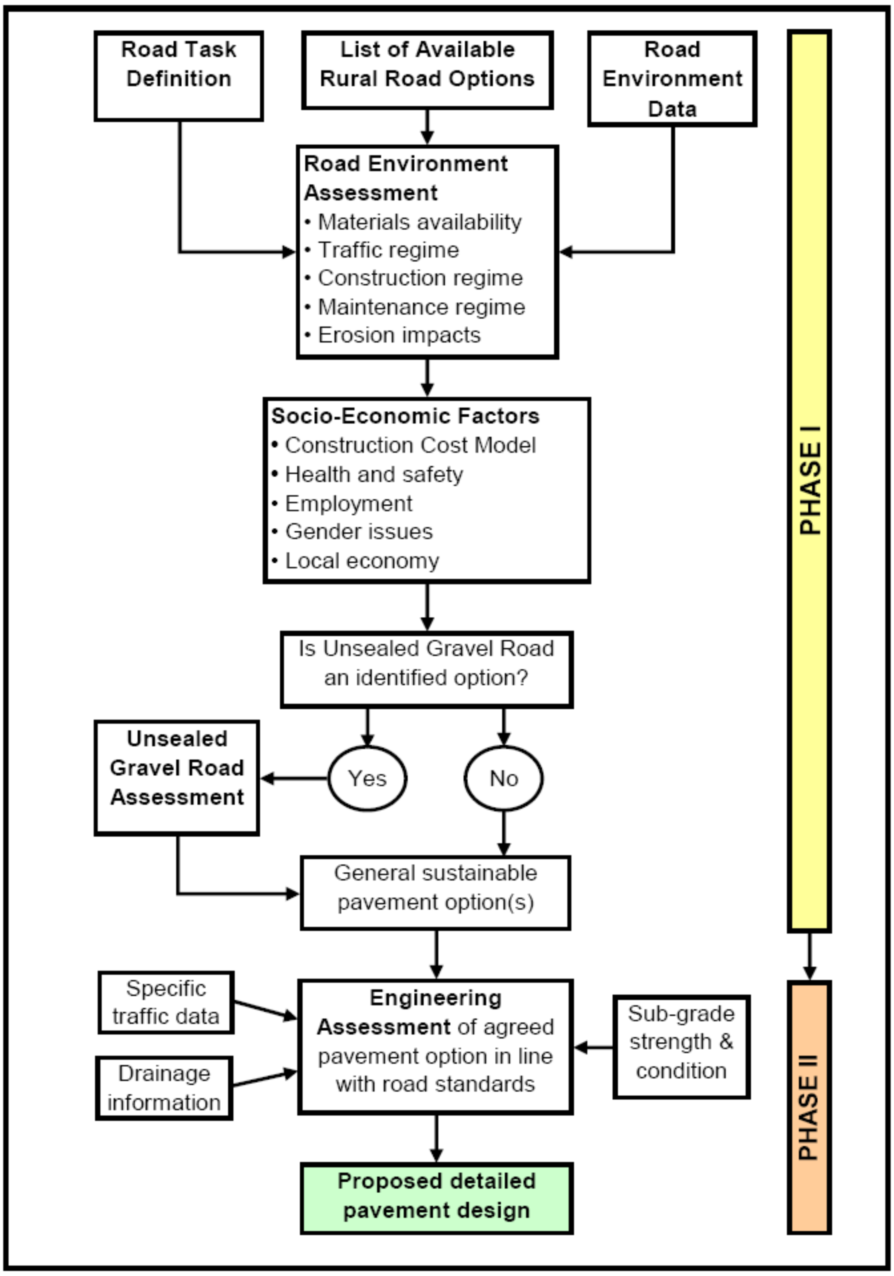


Figure 7: General Surfacing/Paving Selection Process

8. Whole Life Costing

There are a number of accepted and documented techniques to assess the comparative costs and effectiveness of alternative types of road investments. Some methods require substantial amounts of data that may not be readily available, would be costly to collect for routine management decisions, would be difficult to analyze with confidence, and may not justify the levels of resourcing required in comparison to the investment funding available, especially for LVRRs.

Whole Life Costing is preferable to considering only the initial design and construction costs. The consideration of all present and expected future costs involved with an investment in rural road infrastructure should be an integral part of the design process, especially maintenance aspects.

There are two basic assessments of whole life costs for LVRRs, which may result in somewhat different conclusions depending on the local circumstances. These can be characterized as:-

a) **Whole Life Road Asset Costs** to the owner and manager
b) **Whole Life** Transport **Costs to the local economy**

Using Whole Life Road **Asset** Cost assessments aims to minimize the costs of **Construction** and **Maintenance** of a particular road and pavement over a selected period of time. This assessment is of interest to the road owner and to the asset manager, such as a local engineer, as a key management tool. Minimization of Whole Life Road Asset Costs steers the manager towards the best use of available construction and maintenance budgets and best preserves the value of investments in the road infrastructure.

Another application of Whole Life Road Asset Costing is the analysis of various ‘stage construction’ scenarios. In a stage construction strategy resources are invested in accordance with the development of the road use and likely future availability of resources. Initial low cost construction would be followed by improvements and upgrading as traffic grows and as additional resources become available. It should be appreciated that the actual, as opposed to the planned, availability and timing of construction and maintenance funding often necessitates compromise solutions and trade offs.

A Whole Life **Transport** Cost assessment has a wider view and includes the impact of the road condition on the local economy. This assessment relies heavily on the estimation of **Vehicle Operating Costs (VOCs)** of the road users and the potential VOC savings from various construction-maintenance strategy options. It may also include other estimations of other economic or socio-economic impacts (e.g. user time savings, community, environmental or even local employment generation). This assessment is of more interest to, for example, community representatives, national policy makers, planners and development agencies. Such an assessment aims to minimize the total costs of transport in economic terms over the selected assessment period. This is a more complete appraisal of the road condition impact and is preferable, however, there are currently constraints to the effective application in many LVRR situations.

Any assessment will only be as good as the data and knowledge used in the relationships incorporated in the evaluation. It is evident that for many LVRR situations, the confidence in the cost data is usually good for the construction inputs. However, the knowledge and confidence are generally poor for both maintenance cost inputs of various road technology options (and their likelihood of being financed and implemented in a timely manner) and road user VOCs. Similarly the knowledge and confidence in the accuracy of other, and often equally important, social and environmental factors is weak. However, as traffic flows on a particular route increase, the potential VOC savings should be more influential in the selection of optimal technology-construction-maintenance strategy.

Various economic models have been developed to help decision makers assess the balance of road construction and maintenance investments and road user costs, including HDM4 and the World Bank’s RED model.

There are a number of constraints to be considered for the application of these models for the situation of LVRRs in many countries, particularly with regard to the evaluation of VOCs:

- HDM4 is primarily motor vehicle and roughness driven and is more appropriate for assessment of the higher category routes,
- VOC relationships for HDM4 and RED have been developed primarily from experience in Africa and South America, but not yet in South East Asia, where there are climatic, traffic, environmental, operational and cultural differences.
- "The models are limited in their ability to deal with the problems of very basic access; Many of the key road deterioration and VOC cost relationships tend to break down for rough earth roads and tracks and very poorly maintained roads"[1].
- The models do not have VOC relationships for motorcycles and bicycles, which account for most of the traffic on many LVRRs.
- There often is a substantial component of pedestrian traffic on LVRRs.
- The "commercial" vehicles commonly used on LVRRs in many Asian counties are mainly light and slow moving (often locally made) trucks and agricultural vehicles, for which VOC-road condition relationships are not well researched.
- Robust VOC versus road condition knowledge is not available for many LVRR conditions[2].
- VOC-road condition relationships can vary by substantial factors[3]. It is likely that the fundamental factors of the local environment regarding **vehicle life and depreciation, repair capability and culture, spare parts availability and refurbishment, value of time** and **load carrying and personal/commercial decision making** will vary substantially compared to previously researched regions, thereby influencing VOC relationships.
- The issue of seasonal passability is particularly relevant in the instances of roads that become flooded for short or long periods, and gravel roads on weak subgrades that can become impassable to motorized traffic when severely deteriorated, or routes liable to landslips.

In conclusion Whole Life Costing must be carried out with extreme care, taking into account all design, construction and maintenance costs and with utilisation of the local knowledge available. Incorporation of VOC savings and other social benefits is often difficult but highly desirable. It is a priority area that requires further research. The deterioration and maintenance requirements of the various surface/paving options in the range of environments also justifies further research.

9 Materials

The materials used in road construction and maintenance are an important and expensive resource that are not limitless and are largely non-renewable. Their nature, engineering character and location are essential aspects of any LVRR assessment. The need for the management of scarce financial resources means that widespread use of local materials is essential for Low Volume Rural Roads (LVRRs). Their appropriate usage is a priority if reserves are limited, or of marginal quality.

A fundamental principle, or message, that needs to be carried forward from current research is that appropriate road construction materials need to be selected on a "<u>fitness for purpose</u>" basis; that this is related to their actual service performance. There is need to ensure that materials used are neither sub-standard nor wastefully above the standards demanded by their engineering task.

Materials testing programmes vary greatly in size and scope depending on the type of the road project and associated works. However, even for limited scope LVRR projects, materials testing should not be

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1 Source: TRL documentation.

2 Regional data - Analysis of Vehicle Operating Costs on Rural Roads, Rural Transport Strategy Study, Vietnam, I T Transport, 1999.

3 Research by TRL found that unit road freight transport costs varied by factors of 4 to 6 between some African countries and Pakistan. Rizet, C and J L Hine, 1993.

commissioned on an arbitrary basis, but should be rationally programmed and at the very least 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).

Where genuine material problems or shortages exist, it is the responsibility of the road designers to overcome the issue by a combination of:

- Adapting the specification and road design to suit local materials (e.g. thickening pavement layers, raising compaction levels, sealing shoulders),
- Adapting or modifying the materials to suit a realistic specification (e.g. mechanical or chemical stabilisation).

10. Specifications and Supervision

The ability of the material to perform its function in the road is normally assessed by its compliance, or non-compliance, with construction material specifications. These specifications are applied to control the impacts of excavation, transportation, processing, compaction and placing, and the in-service impacts of both the traffic and environment depending on the nature and position of the materials in the pavement structure.

The direct application of traditional evaluation criteria and standards when selecting pavement materials for LVRRs is questionable. By necessity, general specifications must cover a very wide range of material types and cater for extreme climatic environments. As a consequence they are likely to contain significant in-built factors-of-safety. By implication, this means that proven specifications drawn-up for specific materials for particular environments need not be so conservative in approach and hence may allow the use of previously non-conforming or marginal materials.

It is not realistic to attempt to force contractors to meet inappropriate or unobtainable standards, and for overall cost-effectiveness and minimization of environmental impact, LVRR specifications should where possible take into account the nature of locally available materials. Hence the use of flexible material specifications that acknowledge local material variations is recommended.

It must be recognised that the consequence of using more focussed specifications may be a greater need to ensure that the materials actually comply the requirements and that the material approval for use needs to be accompanied by clear guidelines laying out the limits within which the approval is valid.

Quality control in construction has a significant affect on the performance and life of any LVRR pavement surface and a greater awareness of this is required to be imparted to political, administrative and engineering personnel through improved awareness creation, training and project management. Essentially, poor quality control results in poor return on road asset investment. This issue is of substantial importance even for gravel road investments, and will be increasingly significant as the rate of investment per km increases with the adoption of the more expensive more durable surfaces.

Quality Control should not be an onerous administrative burden within the rural road sector, but rather it should comprise a few simple straightforward procedures as set out in the following Table 2.

Ref.	Quality Control Procedure	Comment
1	Assessment of proposed material sources combined with control on as-delivered materials	Quality control research has demonstrated problems with contractors changing materials between original approvals and actual construction. The principle of testing of construction materials as delivered and as placed on site must be adhered to.
2	Use of simple on-site observational and testing procedures to control construction quality	The combination of simple standard sheets, on-site measurements and simple tests such as DCP and the concrete slump test will assist good quality control, as will annotated and dated site photographs.
3	Survey of final as-built quality including use of random inspection pitting	Research has demonstrated the effectiveness of this approach. Superficial "drive-over" surveys cannot be considered an alternative if Quality Assurance is to be taken seriously as part of the contractual signing-off procedure.

Table 2: Quality control procedures

11. Maintenance arrangements and funding

The South East Asia regional experiences have shown that the capacity and delivery of maintenance on LVRRs is generally far from adequate. This is due to a complex and interactive range of factors, however these can be briefly characterized as:-

- Insufficient and unstable flow of funds,
- Unclear institutional arrangements and responsibilities,
- Insufficient appreciation of the vital importance of maintenance (and economic and social consequences of the lack of maintenance),
- Insufficient capacity to implement, report on and monitor maintenance activities,
- Absence of quantified needs, productivity and cost Norms for LVRR maintenance,
- Technical and management guidance for LVRR maintenance not mainstreamed,
- Lack of compiled knowledge and guidance to justify needs for proper maintenance of LVRRs,
- Lack of motivation and cooperation of the principal stakeholders to address and solve the maintenance challenges.

These factors result in an inadequate provision of routine maintenance on nearly all LVRRs in the SEACAP participating countries, and in addition a serious inability to make adequate provisions and arrangements for the (expensive, extensive and vital) periodic maintenance re-gravelling required of the considerable network of gravel roads.

It would be beneficial to develop initiatives to address the foregoing maintenance constraints. In the meantime when Whole Life Costing is carried out, a pragmatic assessment of the expected maintenance resources and capacity should be carried out to achieve a realistic WLC assessment.

Alternative pavements and surfaces to gravel generally have lower maintenance requirements (Table 3). In the Table, BASIC Maintenance includes all off-surface items such as shoulder repairs, vegetation control and drainage system cleaning and erosion repairs, which will be of similar quantity for all surfaces on LVRRs. There will however be more drainage cleaning required on unsealed sections of road as surface materials will be washed into the side drains.

Pavement Option	**Maintenance Needs Rating**	**Expected Routine Maintenance**	**Expected Periodic Maintenance**
Engineered Natural Surface (baseline comparison)	High	BASIC plus pothole repairs and camber reshaping (1 – 6 times per year). More frequent on weaker soils and with higher traffic and rainfall. Camber reshaping can be achieved manually or by simple grading equipment.	Raising embankment or camber when worn down, using local material.
Unsealed Gravel	Very High	BASIC plus pothole repairs and camber reshaping (1 – 3 times per year). Camber reshaping can be achieved manually or by simple grading equipment.	High-cost re-gravelling to replace material lost due to traffic and weather. Typically from 2 to >5cm of surface material loss per year depending on the road environment The timing of re-gravelling is critical, otherwise the surface may quickly revert to an earth standard.
Sealed Natural Gravel	Moderate	BASIC plus pothole repairs	Reseal of the surface after maybe 8 – 12 years (depending on various road environment factors).
Sealed Armoured Gravel	Moderate		
Sealed Macadam	Moderate		
Non Reinforced Concrete	Low	BASIC only	Crack sealing and joint repairs

Table 3: Provisional LVRR Maintenance Assessment

Ongoing SEACAP research is monitoring the performance of the various trial roads and will enable the maintenance requirements to be quantified in more detail.

12. Issues for further investigation

The foregoing discussion identifies a number of issues that justify further research, compilation and dissemination. Particular needs are relating to the topics of road maintenance and vehicle operating cost relationships for local vehicles and road conditions. The experience of the range of alternative LVRR surfaces also needs to be extended.

While there is a relatively large volume of documentation relating to LVRR management theory, there are few examples of where this theory is actually working in practice. Certain projects are cited as successful during or soon after implementation, but not many actually seem to sustain their promise very far into the future. There is a need to identify and document good practice in reality and investigate the reasons for success, or otherwise.

In the meantime the past and on-going research knowledge is being compiled and disseminated through the SEACAP and gTKP initiatives on the following websites, where some of the References may be accessed:

www.gtkp.com

www.seacap-info.org

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