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***State of the Art on Rural Road Transport Planning, Development and Management:
Standards and Specifications for Rural Accessibility***

**PAVING THE WAY FOR RURAL DEVELOPMENT & POVERTY
REDUCTION**

by

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ABSTRACT

Some of the tertiary road networks in developing countries are not yet developed to standards appropriate for their vital transport role. Governments and international agencies are also committed to alleviating poverty, which occurs mainly in the rural areas of these countries. Improving rural transport infrastructure will be an essential component of this strategy.

The cost of fully developing these networks will be substantial and the process is expected to extend over a time span measured in decades. With such a large commitment of resources in prospect, it will be essential that the policies, standards and arrangements for the development and maintenance of these networks make the most effective use of the available constrained resources.

Rural communities require sustainable year-round access for their basic social and economic needs. This is a fundamental requirement to support governments' efforts to reduce rural poverty. For many years gravel/laterite has been promoted as the principal surface for providing road access for rural communities. Recent research confirms the particular problems of gravel/laterite surfacing in some regions.

The paper presents the rationale for restricting the use of gravel/laterite as a road surfacing material in many circumstances. It also proposes a strategy for mainstreaming the application of more sustainable surface options for rural roads. The long term objective is the provision of year-round access to all rural communities at low cost and with manageable maintenance liabilities. Maintenance should be feasible with the realistic mobilisation of local funding and resources and arranged with the involvement of local communities and enterprises. The rural communities should benefit from both the provision and use of the improved infrastructure.

The paper is based on the work of research programmes funded by UK Department for International Development (DFID) with cooperation of the Governments of Cambodia and Vietnam, and other research on the use of gravel/laterite and low cost surfaces.

KEY WORDS: Sustainable Road Surface Maintenance Poverty

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1. The under-developed state of the tertiary road networks

In many developing countries, the main road network carries about 80 to 90 per cent of passenger and freight transport and it is, therefore, of key importance to the economy. Main road networks are understandably given high priority in the allocation of maintenance funds in recognition of their economic importance. Conversely, rural roads are given lower priority in the allocation of maintenance funding because they carry much lower volumes of motorised traffic. Unsealed rural roads with earth and gravel/laterite surfaces comprise the greater proportion of the length of public road in rural areas in developing regions. They account for almost 60 per cent of the main road network, or about 1.2 million kilometres. In addition, there exists an estimated 5 to 6 million kilometres of designated minor roads and motorable tracks, and an extensive network of undesignated tracks and paths, perhaps several times the extent of the designated network. Limited funding available for the maintenance, and other factors, have meant that much of the rural road network has fallen into disrepair.

In the South East Asian region two examples serve to illustrate the under-developed state of the rural road networks.

Cambodia

A recent report¹ on the Cambodian road network assessed that 75% of the 4,165 km of national (main and provincial) roads were not in a maintainable condition. A previous survey in 1999 assessed that of the approximately 28,000 km of rural road network, only about 6,000 km (21%) had been rehabilitated since the severe disruption of the Khmer Rouge regime. These roads were mostly rebuilt to gravel/laterite standards. However maintenance funding is only available for a small portion of the rehabilitated network. There is thus justifiable concern for the sustainability of a 'gravel-only' strategy for rural roads in Cambodia².

Vietnam

Vietnam has a road network of approximately 210,000 km, this represents a density that is twice that of Thailand or Malaysia. However, only 13.5% of the road network is considered to be in good condition, just 26% has two or more lanes, and 29% is bituminised. Over 10% of villages are inaccessible by road for at least one month of the year³.

Whilst funding is a major issue, questions are being raised regarding whether provision and maintenance of large unpaved networks is sustainable using the traditional strategies from a financial, resource management (gravels are a non-renewable natural resource) or environmental perspective.

2. The link between rural accessibility and poverty reduction

If rural roads are poorly maintained, this can have a large negative socio-economic impact on the livelihoods of local communities and the economy as a whole. Networks that deteriorate quickly put an untenable demand on the limited maintenance resources, reduce access to a level that severely restricts social and economic development and can put lives at risk in rural communities. It is the rural road network that serves this population and thus it has an important role in promoting the development of the rural economies and the livelihoods of the local people. Problems are often multiplied for vulnerable groups in society such as women, subsistence farmers, landless poor, the sick, disabled and elderly. Although all sectors of rural communities benefit from improvements in accessibility, women are often the greatest beneficiaries.

¹ Cambodian Rural Transport Infrastructure Program, A Sub-Sector Overview, Ministry of Rural Development, December 2001.

² Seminar on 'Surface Options – Policy and Strategy for Sustainable Access', MRD, ILO, Phnom Penh, 11 – 13 December 2001.

³ Vietnam Country report 2001

Reliable rural road access improves:

- *Marketing opportunities for subsistence farmers. Impassable roads lead to loss of market opportunities, spoiling of crops, reduced or lost income. Agricultural input to the economy is often highest during or shortly after the rains and it is essential to move produce at this time.*
- *Rural community health through better access to health care. Maintaining wet season access is important because it is at this time that instances of malaria, dengue and other water borne diseases are at their peak.*
- *Education through better access to schools and shorter travel times.*
- *Social welfare. Maintaining inter-community access to family and friends has important social benefits, which help promote a better quality of life for the rural poor.*

Rural communities are often left isolated when their roads become impassable during the rains. Often it is only relatively short road sections that are affected. This is normally caused by poor maintenance, which has allowed roads and structures to fall into such a state of disrepair that they can no longer function.

Both the Cambodian and Vietnamese governments see lack of access to local transport infrastructure and services as one of the central features of poverty.

3. The previous focus on gravel roads and the associated problems in S. E. Asia

Natural gravel (or laterite) surfacing is generally used as a so-called “low-cost” solution to rural access problems in many developing and emerging economies. This material provides an intermediate surface between basic engineered earth and higher cost, usually bituminous paving. Gravel is appropriate where suitable material is available and laid to surfacing specifications, gravel haul distances are short (i.e. < about 10 km), road gradients are less than about 6%, rainfall is low or moderate (i.e. < about 700 mm/annum), traffic is relatively low (i.e. < about 200 motorised vpd), finance resources and management capacity are available for routine maintenance (including grading/reshaping), and periodic regravelling, and dry season dust generation is not severe.

Unfortunately, these conditions cannot be achieved in many locations, particularly in South East Asia. Naturally occurring lateritic and other suitable gravels are usually limited in occurrence; the good quality deposits still left unused are often located far from the roads requiring regravelling.

Gravel is a ‘wasting’ surface. Material is lost from the surface of the road due to the action of traffic and rainfall; gravel loss increasing approximately proportionate to both. Some regions of South East Asia experience particularly high volume and intense rainfall, which leads to severe erosion of gravel roads and often also impassable conditions. In the dry season the binding effect of the fines is reduced due to moisture loss and the material is ‘sucked’ out by traffic in the form of dust, leading to surface ravelling. Annual rates of gravel loss can exceed 5cm of surface thickness. Losses are higher if poor gravel is used, or if it is not properly constructed. Gradients are often steep on low volume roads to minimise earthworks and initial construction costs. Gravel loss increases on steep gradients. Gravel surfaces also disintegrate if they are subjected to flooding.

Maintenance of gravel is expensive, especially for periodic regravelling, which is typically required at 3 to 5 year intervals. Routine maintenance of a gravel road can be achieved for US\$250 - 650/km/year, depending on the methods used. However the need to replace the surface losses by periodic maintenance re-gravelling can cost a further US\$400 - 2,000/km/year. These levels of funding are difficult for governments or communities to provide. There is an inevitable increase in gravel haulage distances over time as deposits are worked out. Due to the foregoing, gravel roads are rarely maintained systematically and many revert eventually to earth road standard. The provision, and then deprivation of access to communities has serious social implications.

4. The health and environmental issues of gravel

Numerous consequences are associated with gravel roads⁴. In dry conditions, dust generated by traffic, and to a lesser extent wind, results in increased gravel loss (40mm/annum vs 10mm/annum where dust control was practiced), safety hazard (fatalities on dry gravel roads are disproportionate to the number of vehicles using them) health hazard, discomfort and nuisance, air pollution, and reductions in agricultural yields and livestock health. Dust spread over people, villages, in homes and fields has many impacts and costs, many of which have

⁴ Doctorate Thesis, David Jones

yet to be quantified. Food stores and water resources can be polluted. Health risks associated with mineral airborne dust are well known. Particles finer than 10 microns are highly respirable and can result in bronchitis, emphysema, silicosis and pneumoconiosis, effects identified in various earlier research studies. There is also evidence of increased lung and skin cancer associated with high airborne dust concentrations. Dust enters machinery and electrical equipment, usually leading to substantially reduced life and/or greater servicing frequency and maintenance costs.

Research⁵ has shown that typically 30% of ambient particulate matter is attributed to road dust. One vehicle travelling one kilometre once a day every day of the year will typically generate between 0.2 and 0.6 tonnes of fines, this being lost from the road and causing the impacts described above. Put another way, in a dry season, vehicles and wind can remove of the order of 25 tonnes of dust per kilometre of unsealed road every year.

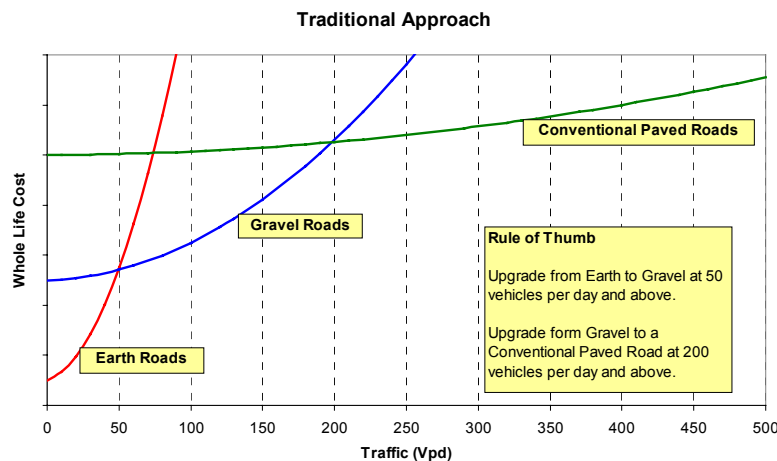
During rain periods, runoff of fines into streams has serious impacts on water quality. Runoff siltation causes a high maintenance requirement in the drainage system. Roads also become slippery leading to increased safety hazards.

Gravel pit excavations can eventually fill with water and become loci for disease. They are dangerous for children and livestock and inevitably become dumping sites for garbage, building rubble and scrap.

Perhaps the biggest environmental issue associated with gravel roads is that of sustainability of a non-renewable resource. Suitable gravel is becoming a scarce commodity and its injudicious use will eventually lead to there being no such material for any form of road construction.

5. New Strategies - A Paradigm Shift In Thinking

Despite the impact that the poor condition of rural roads can have on livelihoods, few countries are likely to be able to provide sufficient funding to fully improve and maintain networks to an acceptable paved standard in the foreseeable future. Rural Authorities, Non-Governmental Organisations and the local communities, need methods whereby all weather access can be maintained at reasonable cost. With very restricted resources and on very substantial networks this objective is impossible to achieve using current road provision and maintenance strategies.



About fifty years ago a ‘rule of thumb’ was established which stipulated that roads carrying more than 50 motorised vehicles per day merit upgrading from earth to gravel, and from gravel to a first generation bitumen surface at 200 vehicles per day. These rough and ready figures were based on assessments of whole life costs (the total of construction, maintenance, and road user costs). However, conditions have changed. Technology, research and knowledge have moved on apace. Unfortunately this outdated ‘rule of thumb’ still persists in the minds of many.

So what are the options?

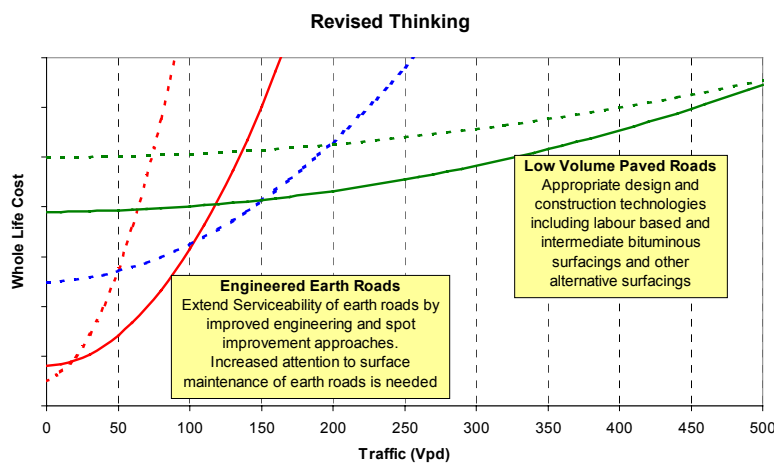
- *Adopting a flexible, realistic and innovative approach to access needs, provision and maintenance,*
- *Maximising the use of earth (provision of good camber, drainage and traffic control can often extend the serviceability of earth roads) where in-situ soils are suitable,*

⁵ US Environmental Protection Agency

- *Spot improvements where limited available resources are targeted toward appropriate improvement measures at strategic points on the route to ensure an optimal level of access. These would include:*
 - *Judicious use of gravel (if nearby resources are scarce)*
 - *Provision of short section of bituminous or non-bituminous surfacings.*

By promoting innovation, using labour-based and light equipment technologies and developing design approaches and maintenance strategies that work with the environment, both the initial construction costs and longer term maintenance demand can be significantly reduced (see Figure below).

Recent research⁶ has shown that in some circumstances bitumen sealing of gravel roads is economically justified at traffic levels as low as 40 to 70 vpd, and well engineered earth roads on good subgrade soils can provide adequate service at traffic levels of between 70 to 100 vpd and beyond. Situations requiring a gravel surfacing need careful consideration particularly as better engineering approaches, including increased attention to surface maintenance (often maximising use of labour and light equipment), can increase the serviceability of earth roads. Localised 'spot improvements' such as improving drainage or providing gravel or other paving options over key short lengths can enhance the utility of earth roads by extending their ability to carry traffic in wet weather conditions.



Aside from current economic considerations, concerns are being voiced regarding the dwindling availability of suitable gravel resources and the increasing cost of longer haul distances. The local capacity to achieve re-gravelling targets, the continuous maintenance burden, and socio-environmental issues, notably the adverse effect on air quality of dust raised by vehicles using gravel roads, are all providing impetus to promoting policy change and provision of alternative surfacing technologies.

6. The proven alternatives to gravel

It is necessary to be more rigorous in evaluating the options for rural and access road surfacing. Gravel will probably be found to be suitable in fewer locations than previously thought. The foregoing diagrams illustrate the typical reduced 'window of suitability' of gravel. In certain locations the combination of site factors (refer to section 3) will mean that gravel should not be used at any traffic level, i.e. the 'window' is closed.

Poor people often rely on non-motorised transport, motorcycles and simple trucks for their transport needs. On many soils, an engineered earth road is sufficient to provide basic access for these vehicle types, provided that specific, limited constraints such as watercourse crossings and steep gradients are adequately engineered with spot improvements. The camber and drainage must of course be maintained.

However in some circumstances the in-situ soils are just too weak to support any traffic in the wet, and must be covered. Fortunately, there is a range of alternative surfacing and paving options already proven in various countries that could provide appropriate, economical and sustainable alternatives to gravel. Suitability will depend on local circumstances. These alternatives, involving the appropriate use of available materials, may be cheaper in whole-life-cost terms. Many can be carried out by small local enterprises using low-capital, labour based and light equipment methods. They could have lower maintenance requirements than gravel, not only in terms of cost but also by reducing the need for (imported) heavy equipment to transport and compact. Their environmental impact could be substantially less.

⁶ Secondary and Feeder Road Development Programme Final report, Department of State Roads, Ministry of Transport and Energy, Government of Zimbabwe. November 1995.

The options for roadbases and surfacing are summarised in Table 1⁷. Guidelines on the use of these alternative surfaces and pavement layers have been compiled and successfully implemented in a number of African and South Asian countries. Similar documents are currently being compiled for South East Asia.

7. The experiences of Southern Africa

Comprehensive research into low-cost surfacing as an alternative to gravel roads has been undertaken in southern Africa in recent years^{8 9}. Research has included justification for upgrading (considering issues other than traffic alone), material specifications (layers and surfacing), surfacing types (dust palliatives, sand seals, single seals, graded seals, thin concrete and block paving), construction methods (including labour-based) and life-cycle costs. The research has shown that, provided traffic characteristics and growths are understood, sound construction practices are followed and adequate maintenance is carried out, major improvements in access can be achieved and significant savings in whole-life costs are recorded. Small contractors, using labour-based methods throughout the construction process, have produced good quality work meeting all the necessary specifications. Improved roads have resulted in notable developments in the communities, including increased tourist traffic, commercial agriculture and forestry and small manufacturing businesses. As part of the research, training courses and appropriate documentation (including contractual documentation) has been developed to facilitate the development of small contractors.

There are a number of low-cost surfacing types that lend themselves to both labour-based, simple equipment operations¹⁰. These include:

- Sand seals
- Chip seals
- Slurry seals
- Otta seals

TRL in collaboration with ANE in Mozambique recently constructed a range of bituminous seals to demonstrate the feasibility, applicability and potential for construction of bitumenised seals (Otta seal, premix, penetration macadam, and single/double surface dressing and sand seal) using labour. Emulsions, applied at ambient temperature were used instead of hot bitumens.

8. Spot Improvement Strategies

Earth and gravel roads are particularly susceptible to environmental damage. Often, just short sections of road are affected but these can have a serious impact on passability, especially during the wet season, thus reducing the benefits for rural communities, which they were designed to provide. In response to these conditions, spot improvements targeted at problem sections of rural road networks can give large benefit/cost ratios. The focus on road provision in rural areas is moving away from the conventional concept of benefits from reduced vehicle operating costs to that of providing all weather access for the modes of transport used. When access is treated as a priority (i.e. to schools, clinics, markets etc), it is likely that there will be an increased focus on localised improvement options. If these 'spot improvement' works are to be carried out, then the conventional large contractor-equipment based approach can become prohibitively expensive and cumbersome for the small sections of road to be tackled. However, this can create opportunities for locally based small contractors using labour-based or intermediate technologies.

These spot improvements can take many forms, including the surfacing of sections of road that are likely to require excessive recurrent maintenance. Low-cost sealing as an option for spot improvement works can be carried out by labour-based methods utilising a range of relatively low-cost equipment. Much of the equipment

⁷ Low Cost Surfacing, Working Paper No 1 - Rationale for the compilation of international guidelines on low-cost, labour-based, alternative & sustainable road surfacings, R C Petts, March 2002.

⁸ Performance of low-volume sealed roads: Results and recommendations from studies in southern Africa. TRL Project Report PR/OSC/167/99. Transport Research Laboratory, Crowthorne, Berkshire, UK, CS Gourley and PAK Greening, November 1999.

⁹ New approaches for the provision of low volume sealed roads. 20th Annual South African Transport Conference. Pretoria, South Africa, PAK Greening and CS Gourley, July 2001.

¹⁰ Increasing skills of labour-based contractors through transfer of appropriate road surfacing technology, 7th Conference on Asphalt Pavement for Southern Africa (CAPSA), Zimbabwe, PAK Greening, CS Gourley & JM Tournee, July 1999.

required for the bituminous surfacing is part of the standard plant used by small contractors in the construction of rural roads. Many small contractors are using tractor-based or local vehicle/equipment technology and this raises the opportunity to use relatively low-cost equipment and attachments for sealing works. Purchase of hand-lances and tractor attachments should be within the range of the capital investment expected by small-scale contractors or local equipment hire enterprises.

Labour-based or intermediate approaches are seen as an important route to allow the entry of emerging contractors into the road sector. The main reason for the success of this approach is that a much lower level of investment is required by labour-based contractors than for more equipment intensive operations. This has enabled contractors to enter the roads sector at different levels ranging from petty contracting for routine maintenance to periodic maintenance, rehabilitation and even larger construction projects.

One of the identified risks for ensuring the long-term viability of small contractors is that they have a relatively narrow skills base and are therefore extremely vulnerable to any discontinuities in the funding for road works. Opportunities for work are also likely to be restricted if contractors have limited skills. If these contractors are to remain viable, it is arguable that they must widen their skills and client base so that they can diversify their operations when particular types of work are scarce and also be able to compete with the more well established contractors for paved road work. There must also be opportunities for some diversification into other activities. Typical examples would be small paved areas in schools, clinics, roads in small municipalities, rural district roads, roads in villages, car and bus parking areas, and other surfacing techniques in the roads, buildings, agriculture and water sectors.

It is also important that the urban and rural authorities have access to contracting capacity that can operate at the local level without incurring large mobilisation costs for relatively small road works that would be necessarily incurred by larger scale contractors. This is particularly relevant to the construction and maintenance of the relatively short lengths of surfaced roads for which many of these local authorities are becoming responsible.

The development of locally based (district and province level) contractors can assist in spreading the employment opportunities into all areas of the country, and also provide capacity at the local level for the implementation of road maintenance and improvement works.

9. Current initiatives in Cambodia and Vietnam

In Cambodia, the excessive rates of gravel loss experienced on rural roads and generally long haul distances for gravel contribute to the very high maintenance burden for this type of surface. It is assessed that the typical cost of maintaining a gravel/laterite rural road in Cambodia is US\$1,625/km/year¹¹. There are also significant dust problems associated with the locally available materials in the long dry season; this is particularly evident due to the tendency for the population to construct their housing immediately adjacent to the road alignments.

Costs and sustainability concerns regarding gravel roads led to an initiative to arrange trials of alternative surfaces for rural roads in Kampong Cham and Siem Reap provinces. These trials have been arranged by Ministry of Rural Development and ILO Upstream Project in cooperation with Intech Associates under the DFID funded Low Cost Surfacing for Poor Communities research programme. Techniques being investigated include hand placed and packed stone, dressed stone, water-bound macadam, sand-aggregate, aggregate stabilised laterite, armoured laterite, bitumen emulsion chip and sand seals, and bamboo reinforced concrete paving¹². A surfacing policy and strategy workshop in December 2001 led to the inclusion of a more rigorous approach to evaluation of surfacing options in the revised Cambodian national rural roads policy.

Vietnam also experiences considerable variability in natural gravel quality and extremely long material haul distances in some provinces. Rainfall intensity and volume also causes high rates of surface gravel loss. In some delta areas gravel or hard stone materials have to be hauled up to 200km. The concerns for the maintenance liabilities and sustainability of gravel/laterite surfacing in some locations led to a national workshop on rural road surfacing options¹³. Surfacing trials are being planned in a number of provinces with World Bank and DFID support to test and demonstrate alternative surface options for rural roads.

¹¹ Rural Road Investment, Maintenance and Sustainability, A Cases Study on the Experience in the Cambodian Province of Battambang, D Johnston and D Salter, May 2001.

¹² Bamboo Reinforced Concrete Pavement, Mustafa I. Azam, Samer Al-Fayadh, Fergus Gleeson, 2002.

¹³ Rural Road Surfacing Workshop, Hanoi, September 2001, Ministry of Transport (MOT)

10. A proposed strategy for providing basic access for the poor

An engineered earth road will provide adequate access throughout the year for a rural community in many situations, IF it is adequately maintained. The suitability of this standard of access will depend on:-

- The characteristics of the in-situ soil (type and strength)
- Gradient, crossfall, and drainage arrangements
- The rainfall characteristics
- The types and loading of traffic in the critical season (usually the wet season)
- Feasible arrangements for maintenance

The limiting circumstances for the use of engineered earth road surfaces need to be determined based on the above parameters. Preliminary work has already been carried out by TRL, Intech Associates (*Roads 2000*) in Kenya and the CSIR in South Africa in areas of medium rainfall and conventional traffic. This work requires to be verified and extended to the high rainfall regions of South East Asia where a range of Intermediate Means of Transport (IMT) is the prevalent transport mode for the rural poor.

International Guidelines on the application of Engineered Earth Roads are required. This is a high priority for research, recently confirmed by the Greater Mekong Sub-Region Academic Research Network (GMSARN) Rural Transport Workshop in Cambodia (May 2002).

With the successful application of such guidelines, the majority of funds currently wasted on gravel/laterite roads in unsuitable circumstances could be saved by the provision of engineered earth roads in appropriate conditions. These substantial savings could be re-deployed to provide better, low cost and low maintenance paving in those circumstances not suitable for engineered earth surfaces, using spot improvement strategies where appropriate. In practice, **the same overall funding currently deployed would produce more sustainable access to more poor people on a global basis.**

Research work is currently progressing on low cost surfacing by CSIR, TRL and Intech Associates which will lead to improved recommendations on the use of stone, brick, bitumen and concrete based surfaces. Draft guidelines are already available for the use of gravel/laterite¹⁴.

To provide essential basic access to poor communities, it is envisaged that surface selection will in future consider engineered earth road as the first option in the circumstances where they are appropriate¹⁵. It will be necessary to ensure that they can be maintained using labour and simple equipment and the financial resources available. For higher grade surfacing, gravel/laterite would be just one of the options evaluated using technical feasibility, whole life costing, socio-economic and environmental evaluations. As with engineered earth roads, a realistic assessment of maintenance funding and capacity must be an integral part of the evaluation and decision process to ensure a sustainable solution.

The above research initiatives need to be coordinated and coupled to dissemination and mainstreaming strategies which will ensure that policy makers, practising engineers, national and international agencies and the education system adopt appropriate rural road surfacing strategies that will be meet the rural access and transport needs of the poor and will be sustainable within the financial and management resources available.

The target institutions are those organisations that will be better able to advise on, educate and disseminate for, plan or implement road investments, hence the initiatives will contribute to improved governance. The main beneficiaries will be those communities who are currently affected by the adverse economic, social and environmental effects of unreliable access, dust, erosion, and high transport costs, and which have high proportions of poor, isolated and vulnerable people.

¹⁴ DFID Transport Links website: www.transport-links.org, Research, R7782.

¹⁵ Design and Appraisal of Rural Transport Infrastructure. Ensuring basic access for rural communities. World Bank Technical Paper No. 496, Lebo J and Schelling D, 2001.

Table 1 - SCHEDULE OF ALTERNATIVE ROAD SURFACE IMPROVEMENTS

	Road Surface Improvement Options	Description (A roadbase option may need to be used in combination with the selected surface improvement)
C1	Dragging Road Surface	Smoothing out minor defects on an earth or gravel road surface and redistributing loose material on the surface, using tyre or blade drag.
C2	Light Grading/Reshaping of Surface	Minor reshaping of an earth or gravel surface to restore correct camber using labour or light/heavy grading equipment.
C3	Natural Gravel Surface	A layer of compacted natural gravel wearing course (typically 15 – 20cm thick)
C4	Lime Stabilization of Existing Surface	Addition of and mixing of quicklime or hydrated lime to a soil or surface material, watering and compaction to increase its strength and reduce its susceptibility to the weakening effect of increasing moisture content. This is achieved by chemical reaction of the lime with the clay particles. Mixing and compaction by light or heavy equipment.
C5	Stone Chippings Surface	A layer of single sized (typically 20mm) crushed stone chippings.
C6	Hand Packed Stone Surface	A layer (typically 20 – 30cm thick) of large broken stone pieces, tightly packed and wedged in place with stone chips rammed by hand into joints, with remaining voids filled with sand. The Hand Packed Stone is normally bedded on a thin layer of sand/gravel.
C7	Dressed Stone Surface	A layer (typically 15 – 20cm thick) of stone blocks cut (dressed) to a cubic shape by hand, laid by hand. Joints mortared/sealed or tightly packed and wedged with stone chips rammed into place with remaining voids filled with sand. The Dressed Stone is normally bedded on a thin layer of sand/gravel.
C8	Stone Sett Surface (Pavé)	As dressed stone, however stone blocks are smaller; typically about 10cm x 10cm x 10cm with mortared joints.
C9	Concrete Block Surface	A layer of concrete blocks (typically each 10cm x 20cm and 7 – 10cm thick) laid by hand on a thin (3 – 5cm) sand bed with joints also filled with sand and lightly compacted.
C10	Clay Brick Surface	A layer of high quality clay bricks (typically each 10cm x 20cm and 7 – 10cm thick) laid by hand on a thin sand bed with joints also filled with sand and lightly compacted, or bedded & jointed with cement mortar.
C11	Bamboo Reinforced Concrete Surface	Jointed slabs of structural quality concrete reinforced with a split bamboo rod grid. Joints with steel weight transfer dowels and bitumen seal.
C12	Steel Reinforced Concrete Surface	Jointed slabs of structural quality concrete reinforced with a mild steel rod grid. Joints with steel weight transfer dowels and bitumen seal.
C13	Bituminous/Tar Sand Seal Surface	A seal consisting of a hand or machine applied film of bitumen (straight run, cutback or emulsion) or road tar followed by the application of excess angular sand or fine crushed stone, lightly rolled into the bitumen/tar.
C14	Ottaseal Surface	A layer consisting of a hand or machine applied film of relatively soft bitumen (usually straight run or cutback) followed by the application of graded natural gravel or crushed stone aggregate (typically 16mm downwards), rolled into the bitumen using heavy pneumatic tyred rollers.
C15	Bitumen/Tar Surface Dressing Surface	A seal consisting of a hand or machine applied film of bitumen (straight run, cutback or emulsion) or road tar followed by the application of a single layer of single sized (6 – 20mm) stone chippings, lightly rolled into the bitumen/tar.
C16	Bitumen Slurry Seal Surface (and "Cape" Seals)	A seal consisting of fine graded aggregates (typically 10mm downwards), water, bitumen emulsion, cement, and sometimes an additive, mixed in a concrete mixer or other machine and spread on the road surface by hand or machine. Cape seals are combinations of Surface Dressing and Slurry Seal.
C17	Bituminous Premix Macadam Surface	Graded crushed stone material (typically 28mm downwards) usually derived from fresh sound quarried rock, boulders or granular material and mixed with a bituminous binder (straight run, cutback or emulsion) and laid and compacted. Material may be hand or machine mixed and laid. Compaction by light or heavy equipment.
C18	Penetration Macadam Surface	Two or three layers of single size crushed stone (of decreasing nominal aggregate size, e.g. 63 mm downwards) each compacted and with bitumen (straight run, cutback or emulsion) or road tar sprayed between each stone application.
C19	Water Bound Macadam Roadbase	A layer of nominal single sized (typically up to 50mm) crushed stone compacted and fully blinded with well graded fine aggregate which is watered into the voids and compacted to produce a dense stable material. Layer thickness up to twice the nominal stone size. Material may be hand or machine crushed and laid.
C20	Dry Bound Macadam Roadbase	A layer of nominal single sized (typically up to 50mm) crushed stone compacted and fully blinded with angular sand or fine crushed stone material which is then vibro-compacted to produce a dense stable material. Layer thickness up to twice the nominal stone size. Material may be hand or machine crushed and laid. Suitable in areas short of water.
C21	Slurry Bound Macadam Roadbase	A layer (about 7cm thick) of single size aggregate (typically 50mm) blinded with smaller aggregate (typically 25mm), plate compacted and grouted with bitumen emulsion slurry before final compaction.
C22	Crushed Stone Roadbase	A layer (usually up to 20cm thick) of graded crushed stone material (typically 50mm downwards) usually derived from fresh sound quarried rock, boulders or granular material. The angular material derives its strength primarily from mechanical interlock. Material may be hand or machine crushed.
C23	Mechanically Stabilised Roadbase	Addition and mixing of granular material such as crushed stone or sand to a material to increase its strength and achieve the properties required of a roadbase.
C24	Chemical or Emulsion Stabilized Roadbase	Addition and mixing of a stabilizer such as lime, cement, or ion exchange chemicals, to a material to increase its strength and achieve the properties required of a roadbase. Mixing and compaction by light or heavy equipment.
C25	Improvement using Recycled Materials	Use of recycled road pavement materials, brick kiln waste, broken brick, demolition materials, industrial slags, etc.

C1 & C2 are maintenance/surface improvements, C3 – C18 are surface options, C19 – C25 are lower pavement layer options.