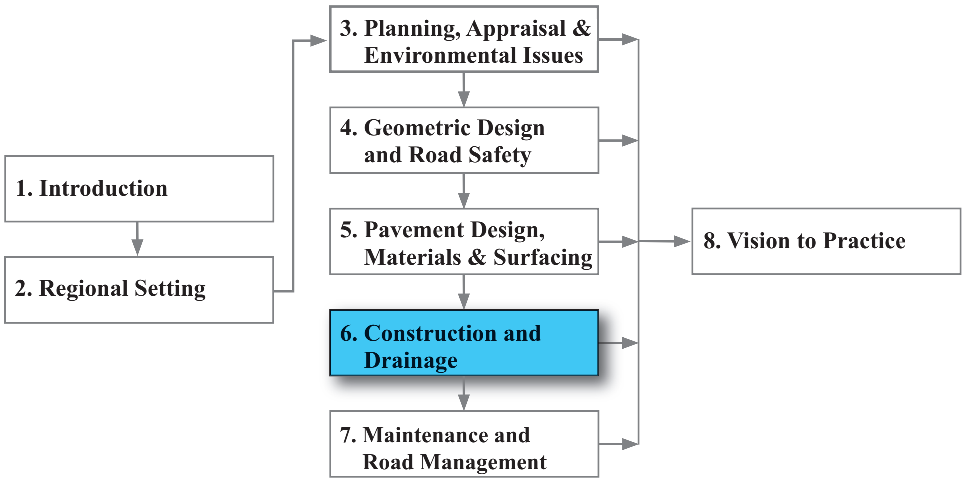
Chapter 6



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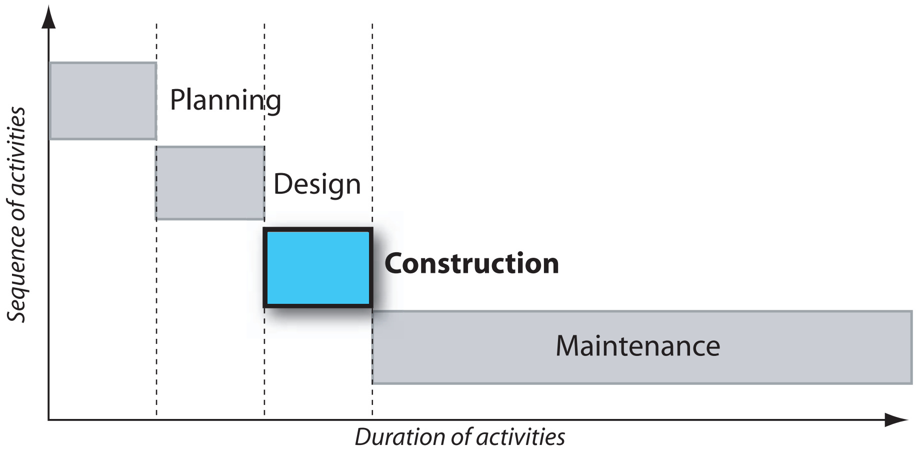
6.1 Introduction

6.1.1 Construction



Construction is a practical manifestation of the planning and design phases of LVSR provision in which the constructor faces the challenge of adopting a *construction strategy* that is appropriate to the prevailing social, economic, cultural and other needs of a particular country. In the SADC region, such a strategy should be aimed at optimising the use of limited funding by making maximum use of the relatively abundant resource of labour, indigenous materials and construction skills.

One of the secondary objectives and consequences of adopting an appropriate construction strategy is that it should reduce the demand for scarce foreign exchange, principally by reducing the need for plant-intensive operations, where feasible. This often requires modification of conventional construction management techniques, contract conditions, tender evaluation procedures, and the administration and financing procedures normally used for the construction of major, high-volume roads.

Irrespective of the construction strategy adopted, the quality of the construction process is critical as this can have a significant impact on the subsequent costs of maintaining the road. For example, *any initial savings made during construction through the inadequate provision of drainage or lax quality control are likely to paid for, many times over, during the life of the road through additional maintenance and road user costs.*

6.1.2 Drainage

Disruption of traffic and pedestrian movements due to flooding of rivers is a common problem in many rural areas.

Drainage is widely recognised as the single most important factor that controls the performance of any road, the more so a LVSR in which naturally occurring, often moisture sensitive, materials are used. The lack of good drainage can lead to ingress of water into the road structure, leading to structural damage and costly repairs and surface water can form a road safety hazard, especially on high-speed roads when it can cause aquaplaning. For these reasons, adequate attention to drainage is not only an important aspect of the preceding design process, but also of the construction and maintenance phases of road provision.

A clear distinction should be made between internal and external drainage. Internal drainage is concerned with controlling the movement of water within the road pavement or embankment, whereas external drainage is concerned with the control of surface water by various measures taken in the design and construction stages. In the final analysis, a balance has to be struck between the cost of the drainage measures and the function of the road as perceived by road users.

6.1.3 Purpose and Scope of Chapter

In view of the significance of labour-based methods in the construction of LVSRs, wherever this issue arises, it is indicated as follows: **LBM**

The main purpose of this chapter is to highlight the significant differences in approach to the construction of LVSRs by comparison with those of high volume, major highways. In view of the importance of utilising the most abundant resource in the region - labour - this chapter also seeks to raise awareness of the scope for utilising labour-based construction and of the type of equipment that is best suited to complement this approach. The importance of appropriate internal and external drainage is also highlighted as being of crucial importance in the performance of LVSRs.

6.2 Construction Issues

6.2.1 Characteristics of LVSRs

The construction *process* for LVSRs does not, in principle, differ from that used for other types of road. However, LVSRs are much more sensitive then other types of road to the social, economic and technical context in which they are built. Variations can be considerable with regard to the choice of construction method, type of resources available and type of construction materials being used. Moreover, aspects regarding social and environmental impacts, including the need for any resettlement action plan, require particular attention prior to the start of construction.

One aspect of the provision of LVSRs that is receiving increased attention is the use of labour-based construction. All the governments in the region recognise that economic growth and redistribution of wealth rely upon increased employment opportunities. Continuous efforts are therefore being made to create productive employment through the use of labour-based construction and maintenance, where these are technically and economically feasible.

6.2.2 Labour-Based Construction

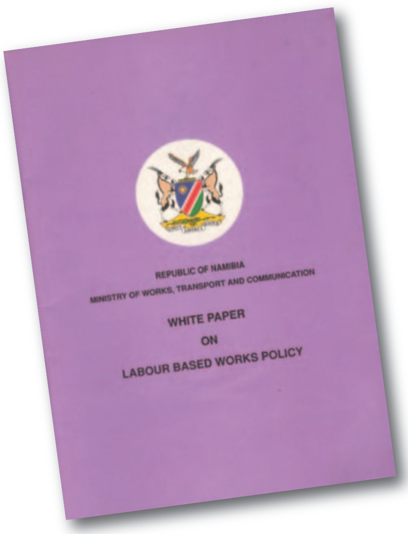
The objective of labour-based construction is to maximise the number of job opportunities per unit of expenditure. This approach involves using a combination of labour and light equipment rather than heavy plant, without compromising the quality of the end product. It optimises the use of labour and employs equipment only for those activities that are difficult for a labour force alone to undertake efficiently and cost-effectively. Unfortunately, despite the well-publicised and substantial potential benefits offered by labour-based construction, a number of myths and problems relating to this technology still persist in the minds of some practitioners.

Box 6.1 - Common misconceptions about the use of labour-based methods and small scale labour-based contractors[1]

Myths:
- standards should be lowered to allow for labour-based methods
- labour-based construction is out of date and incompatible with the modern world
- labour-based methods can be used for any construction activity
- labour-based construction is only intended for welfare relief schemes
- poorly educated contractors will never understand tender procedures
- voluntary labour can be used to keep costs down

Problems:
- lack of suitable documentation for the management of labour-based contracts
- many clients are still not open to even considering a labour-based approach for new projects
- many clients are unable to process payment for labour and materials fast enough to keep a labour-based contract operating smoothly

In order to overcome these problems, suitable forms of contract need to be more widely used; clients need to gain experience in awarding and managing labour-based contracts and small-scale contractors need to gain experience in managing such contracts efficiently. Government ministries also need to develop strategies that facilitate the implementation of pro-employment policies.



The development of a White Paper on Labour-based Works Policy is an example of a pro-active strategy by a SADC government to achieve increased utilization of abundant human resources in the roads sector[2].

Example of appropriate choice of technology

De-stumping of trees is an example of appropriate labour-based technology.

Screening of aggregate for road surfacing.

Before construction starts, all relevant environmental assessments should be completed to ensure that the project does not achieve its own goal at the expense of loss or inconvenience to non-beneficiaries or future generations [3].

Suitability of Construction Activities for Labour-Based Projects

Many activities are well suited to labour-based methods such as site clearance/bush clearing and ditch excavation wheneas activities, such as compaction of pavement layers or haulage of materials over long distances (typically > 5 km) are not. Quite apart from economic considerations, some construction activities (e.g. the manipulation of heavy precast sections) are just not possible without the help of the right machinery. However, these kinds of problem can be avoided if emphasis is given to those activities that can be undertaken effectively by labour-based methods, and design options selected that minimise the requirements for plant.

Labour-based projects usually employ a relatively large number of labourers. In such a situation, the site management staff should be particularly good "man-managers" with strong managerial and technical backgrounds. They should be familiar with local traditions and social structures in order to avoid serious disputes on site that could threaten the progress of construction and, ultimately, the sustainability of the project.

6.2.3 Environmental Considerations

Road construction can adversely affect the environment in a variety of ways. Assuming that the necessary mitigating measures have been incorporated in the contract documents, it is important that the contractor be made fully aware of his environmental responsibilities as part of his contractual obligations. Moreover, compliance with the environmental requirements of the project should be monitored throughout the construction process in order to correct problems before they occur (Section 3.4).

Box 6.2 - Typical best practice guidelines for environmental mitigation[3].

- **Construction process:** Ensure the existence of an Environmental Management Plan which sets out the specific undertakings for the necessary environmental protection responsibilities, measures, monitoring and auditing to be undertaken during construction in order to achieve the environmental requirements set out in the contract.

- **Construction procedures:** Ensure that procedures are adopted that:
  - minimise disturbance to flora and fauna
  - minimise sedimentation and erosion by implementing effective drainage/ stormwater control measures
  - minimise generation of dust and noise
  - progressively revegetate disturbed areas during road construction
  - minimise visual impacts and environmental disturbance at site camps
  - minimise environmental impacts of stockpiles and storage of materials
  - minimise construction wastes and dispose at an approved environmentally sustainable location
  - provide environmentally sound management for the handling, storage and disposal, if necessary, of fuel, oil, lubricants, bitumen and chemicals used in the road construction process

- **Auditing:** Ensure the existence of a documented environmental due diligence system to measure compliance with environmental management requirements throughout the construction process with the objective of correcting problems before adverse environmental impacts occur.

6.2.4 Mobilisation

Preliminary and General Items

LVSRs are often constructed in remote areas and establishment costs normally make up a substantial part of the total project cost. The cost of preliminary and general items, where establishment is included, is a larger proportion of total construction cost for LVSRs than that used on more heavily trafficked roads.

However, where labour-based methods are utilised, one can expect mobilisation costs to be considerably lower than these for large machine-based units. This favours the use of labour-based methods in remote locations, in circumstances where projects are relatively small or where larger projects can be split up into smaller contracts.

Health and Safety on Site

Road construction ranks among the most hazardous occupations in all countries of the world, particularly on projects where a large amount of labour is involved. The following typical LVSR site situations require that particular attention be paid to health and safety precautions on site:

- LVSRs are often constructed in remote areas where access to emergency medical care is limited, thereby aggravating the consequences in the case of accidents on site. Under these circumstances, greater awareness is needed of the risks attached to certain especially hazardous operations and appropriate measures should be taken to minimise these risks. For example, trained First Aid staff should be employed on site and an adequate stock of First Aid equipment and medicines should be kept in a secure clean place. This may, however, be a requirement under national employment law.
- Handling of hot bitumen is potentially harzardous due to the risk of burns and inhalation of fumes. The use of bitumen emulsion, which can be manufactured on site, is preferable[4].
- Traffic safety measures in remote areas with low traffic densities are often given less attention than they deserve. However, traffic moving through construction sites at high speed always poses a severe danger to construction staff.

Handling of bitumen is a hazard and requires suitable locations for storage, heating or blending.

HIV/AIDS

All governments in the SADC region are committed to combating HIV/AIDS. In this regard, construction operations are relevant on account of the following:

- Construction of roads requires the services of skilled personnel, depending on the type of operation and project. This leads to migration of labour and sometimes to the division of families, a situation that is widely considered to be a contributory factor in the spread of HIV/AIDS.
- LVSRs are often constructed in sparsely populated areas where the local communities are vulnerable to the transient effects of the influx of large numbers of workers. The establishment of a road camp may cause a rapid change in the local economy, which further exacerbates these effects.

Counselling ahead of project commencement is an important measure to combat the spread of HIV/AIDS as a result of construction activities.

Awareness and active involvement in taking measures to combat HIV/AIDS have become necessary requirements for sustainable operations and affect all responsible parties involved in road construction.

6.2.5 Contracts

Labour-Based works

The three main delivery mechanisms that may be adopted for expanding labour-based methods of construction and maintenance amongst small-scale contractors are shown in Figure 6.1 and are briefly described as follows[5]:

- *The Government-run Model:* In this model the responsibility for all aspects of contractor development (including small contract administration and payment) lies with the government roads agency.
- *The Agency Model:* Responsibility for all aspects of contractor development lies with an independent non-profit management agency or with a for-profit consulting firm.
- *The Development Team Model:* The responsibility is divided be between the employer, a construction manager and a materials manager.

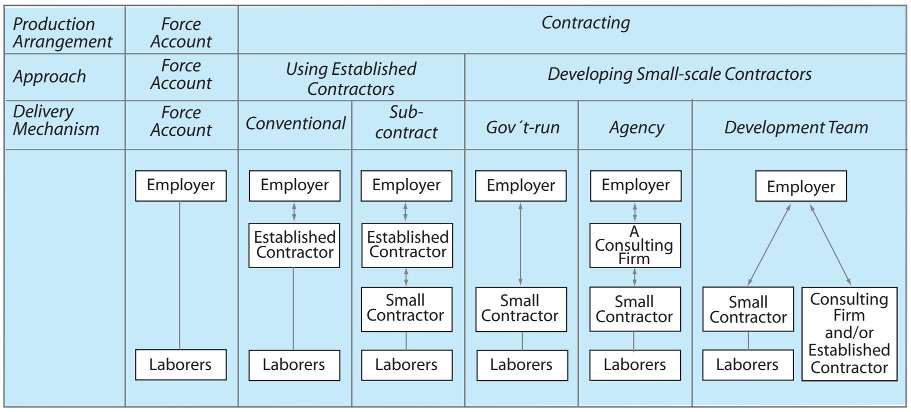


Figure 6.1 - Alternative arrangements for undertaking labour-based works

The type of model to be adopted will depend primarily on the country's contracting environment and on the extent to which the institutional reforms mentioned in Chapter 2 have been embraced. For example, if the roads agency is functioning well and reform can be facilitated, the Government run model may be the most appropriate. Conversely, if the roads agency is unable to effect the required reforms within a reasonable time, or would prefer to pass a portion of the risk of contractor development to the private sector, a Development Team Model may be the most suitable.

Risk Aspects

Wherever roads are constructed with innovative methods or marginal quality of materials, the aspect of risk inevitably plays a role in the process (Chapters: Pavement Design, Section 5.4.6). Risk needs to be carefully considered and managed in relation to the potential benefits offered. The roads agency is often in the best position to allocate risk as it sees fit as it is generally in control of the conditions that control the project.

The construction of LVSRs offers much scope for innovation and cost-savings as highlighted in every chapter of this Guideline. However, given the nature of the construction industry, the party most able to promote innovation is the roads agency. In so doing, *the agency cannot expect to reap the potential benefits of reduced construction cost that lie in the use of innovative methods unless it is also willing to carry a part of the any potential risks that may be perceived to be involved.*

A commercially operating contractor or consultant will have to price risk into a contract, involving insurance cost and potential losses in execution of the project if problems occur. This aspect is a common hindrance to innovations that would result in considerable benefits to society by providing LVSRs in rural areas using more cost-effective methods. It therefore appears reasonable that society, through the agency, also carries a large part of the calculated risk, bearing in mind that society is also the potential beneficiary in the use of innovative methods. Thus, the roads agency should carefully consider the merits of sharing some of the risk that normally lies with the contractor when allowing, encouraging or prescribing the use of methods or materials that are perceived to carry increased risk.

Planning and Design Stages

The key to ensuring optimal operations in construction with marginal materials and in a variety of different climatic conditions, lies in the preparation and planning/design of the contracts. Deriving maximum benefit from the use of marginal materials relies on the contractor's use of appropriate methods of winning the materials and subsequently processing them to meet the prescribed specification. The aim is to utilise the full potential of the material sources found in the project area once the appropriate standard has been set for the project. As illustrated in Box 6.3, incentives can be included in the conditions of contract to ensure that the contractor and the agency responsible for the project are both striving for the same end result.

Use of rock materials in bulk earthworks can speed up construction by:

- *Allowing thick layers to be constructed in a single lift.*
- *Eliminating the need for construction water and mixing in earthwork.*
- *Minimising the need for laboratory testing.*

Box 6.3 - Issues to consider during contract preparation

As contractors normally depend strongly on their cash flow to meet their financial obligations for the project, the following aspects should be given particular attention in the preparation of contracts for the construction of LVSRs:

- A contractor may be reluctant to stockpile materials well ahead of construction (an approach that improves the management of marginal materials), unless there is separate payment for borrow pit operations that secures his cash flow.
- Contractors are unlikely to select the better of two materials that both meet minimum quality requirements if they have to carry the entire amount of any additional cost incurred.
- The inclusion of haulage costs in the contract plays a key role in directing and creating incentives for the contractor to locate and use material sources of non-standard quality, the use of which is considered desirable and, ultimately, also of benefit to the roads agency.
- Although the specification should be written to cater for producing an acceptable end product with marginal, variable materials, there may be instances where exceeding the specification minimum may be beneficial to the project. However, a contractor is unlikely to use additional resources or time in processing in order to achieve a better than specified end result unless an appropriate reward scheme is in place.
- In the choice between use of machinery or manual labour, a contractor is likely to select the option that gives the best utilisation of *his own resources* and gives the better cash flow. This may not coincide with the optimal resources for the project from a national socio-economic perspective. Thus, where warranted, it may be necessary to specify certain operational methods in the conditions of the contract.

Construction Stage

The ultimate goal of all parties involed in a construction project is to make the optimal use of the available resources to meet the prescribed standards in the most efficient manner. However, after the project has started, it may not always be possible to make changes in itemisation and payment schedules without incurring a claims situation. Nonetheless, the supervisory staff can facilitate the attainment of optimal solutions in a number of ways which avoid claims. The following are typical examples:

- If available, the use of better quality materials can be promoted by pointing out to the contractor the potential for reducing the time needed for processing of the layer, the often reduced need for the addition of water and a greater likelihood of attaining the specifications more consistently.

- Consistently improving the workmanship/method can justify the increased use of method specifications, reduced frequency of control testing or use of simpler test methods. This will, in turn, benefit the contractor by increasing the speed of construction.

6.2.6 Earthworks Quantities and 'Design and Construct' Methods

The amount of earth-works is decided by:

- **the designer** *where pre-made geometric designs are used*
- **the site staff** *where design by eye methods are used*

The cost of earthworks in LVSR construction comprises a larger proportion of total costs than is the case with major highways where more expensive options for pavement structures and other installations are often used. Thus, a key factor in reducing total road costs is to maximise the use of fill materials in the road alignment and minimise haul distance or, preferably, to avoid it altogether, i.e. cut to fill by machine or to borrow from within the road reserve/side drain. The reduction of fill is a key factor in reducing the cost of earthworks.

"Design and construct" methods can provide benefits in the form of increased speed of construction and, in some cases, reduced earthworks quantities with associated cost savings. However, this approach is only viable where the field staff have the required skills and knowledge and if the appropriate measurement-for-payment procedure is in place.

Box 6.4 - Field staff requirements when using "design and construct" methods

Where "design and construct" methods are used, it is vital that field staff understand the consequences of the selection of alignment. This is important for:

- traffic safety
- internal and external drainage of the pavement
- measures required to deal with poor in-situ soils
- quantity measurement for payment

The horizontal alignment should always be given the highest priority when resources are allocated for alignment selection. This is because of the benefits that accrue from not having to change the road alignment if the road is subsequently upgraded. However, in fixing the alignment, careful attention should be given to a large variety of features within the road corridor, including dwellings, fields, graves, community access, drainage and irrigation channels, catchment areas, proximity of in situ material, avoidance of rock and unsuitable materials, preservation of flora and fauna, etc.

Supply of construction water may involve the construction of temporary pipelines.

LBM

Stabilisation with lime or cement can be successfully applied with basic methods and use of manual labour.

6.2.7 Working With Nature

Cost savings can be made where timing of the construction operations can be programmed to suit favourable weather conditions. However, a flexible approach is required for this. In contract work, such an approach may be difficult to achieve owing to contractual difficulties unless the contracts are tailored especially for the purpose. Force account construction offers more scope for flexibility to take advantage of local conditions that often change rapidly and are not easily foreseeable. They allow changes to be made and new procedures to be introduced on site without triggering contractual disputes.

An example of "working with nature" in a hot and dry climate is to minimise the use of water for compaction, thereby reducing associated cost and delays[6]. Such techniques may include:

- Removing overburden from borrow pits before the rainy season in order to allow water to penetrate deep into the gravel seam, thereby increasing the moisture content prior to stockpiling.
- Carrying out compaction of the subgrade during or just after the rainy season (i.e. in conditions nearer to the optimum for compaction).
- Adding and mixing in water at night in order to minimise loss by evaporation.

However, it is important to be aware that it can be more expensive to dry out gravel above the optimum moisture content than to import water for compaction.

6.2.8 Stabilisation

Not all natural gravels are suitable for use as road pavement materials in LVSRs and some form of improvement may be required to achieve adequate strength and to limit permeability. There are numerous types of stabilisers available for the purpose of achieving these improvements, of which the conventional ones - cement and lime - have had considerable success in the past within the region. Stabilisation with pozzolans can be expected to be similarly effective if applied correctly. Bitumen has become a viable option in recent years as a result of the development of emulsions and foaming technologies for use with natural materials.
In addition to the conventional and well proven stabilisers, the market now offers literally hundreds of brands of alternative chemical stabilisers. However, experience with the use of these stabilisers has generally been mixed and they should be used with extreme caution.

As a general rule, stabilisers of all kinds should only be used after careful consideration has been given to all other options including, in particular, screening of materials to improve their grading or mechanical stabilisation through blending of materials. Unless there is some previous experience of using the products, there is an inherent risk in adding substances to natural materials that may not work as expected and may result in increased construction costs. For example, there is the risk that failure of the stabilisation method could make reworking of the material difficult and costly because previously - stabilised gravel could require the addition of at least 40 per cent fresh gravel for the remedial works.

6.3 Construction Equipment

Traffic loading on newly constructed pavements by construction equipment is a concern on long duration projects where very heavy loading takes place after completion of the surfacing. In such cases, construction traffic should be included as part of the design traffic. Otherwise, work sequence/planning will be needed and measures applied to minimise the effects of construction traffic.

6.3.1 Introduction

The choice of the most appropriate type of equipment for a particular project is normally dependent on the following major factors:

- site condition
- type of operation
- size of the project
- soil conditions and type material used
- the extent to which manual labour is used in the operation

Equipment in current use for construction of LVSRs in the region varies from heavy equipment for major highways to the light plant used for labour-based methods. It will often not be appropriate to use high-capacity, heavy equipment on many LVSR sites because of the smaller quantities of materials and dimensions of the works. Such equipment is certainly not appropriate where labour-based methods are used to any significant extent. Use of manual labour for construction operations requires flexible solutions with many small units of equipment.

6.3.2 Equipment Used with Labour-Based Methods

LBM

Wheel barrows constitute part of the equipment used in LBM.

Fully labour-based methods usually require, in addition to hand tools, the provision of simple equipment such as wheel barrows and perhaps animal drawn carts, often supported by some mechanical transport. In addition, hand-operated compactors may be used for compaction. These require the use of specific methods to be effective, such as construction with a maximum layer thickness of 75 mm, and are unlikely to be effective in operations where pavement materials require compaction on a large scale. Compaction equipment heavier than the light equipment normally used on labour-based unsealed roads may be required for compaction of the pavement layers for sealed roads. Penetration macadam, emulsion-treated base and thin reinforced concrete pavement can all be constructed entirely by labour-based methods, whereas densely graded materials require the use of plant-based methods in order to be effective.

LBM

The concept of using labourers and small tractor-drawn buckets is a good example of labour-based methods.

Labour-Adapted Equipment - Tractor Units

Construction units with agricultural tractors[7] will provide flexibility in the use of the smaller items of equipment that suit operations where manual labour is a major component in carrying out the roadworks. The uses of agricultural tractors in key operations include:

Loading/transport: A small number of tractors can operate, intermittently, many small buckets or trailers, thereby giving labourers sufficient time to load these, whilst maximising the utilisation of the tractors. Buckets and trailers should be of such height that they can easily be loaded by hand. If this is not possible, the bench method can be used to facilitate hand loading.

Spreading/shaping: Graders suitable for towing by agricultural tractors are available in several sizes to undertake spreading and shaping operations. Alternatively, these operations can also be done by hand if some reduction in the regularity of the longitudinal profile can be tolerated.

Watering: Tractors can be used to tow water bowsers fitted with simple spray bars to spread the water evenly on sections prepared for compaction.

Mixing on the road: Agricultural disc harrows towed by large tractors are very effective for mixing, including mixing materials on the road with water and for stabilisation or blending.

Compaction: Towed vibrating, grid or tamping rollers. (For labour-based methods, rollers are often hand controlled).

Surface preparation: Towed mechanical brooms.

For scarification and stockpiling in borrow pits there is little practical use for tractors. Bulldozers and excavators are normally required. Labour can also do this work under favourable site conditions.

Bitumen operations: Towed bitumen sprayers can be used for priming and binder application in conjunction with suitable heating and pumping equipment. For labour-based methods, bitumen emulsions are generally preferred to avoid the need for heating to high temperatures.

Surfacing aggregate: Spreading aggregate by hand from towed trailers - also used for towing backchip units.

A typical tractor unit used in labour-based construction.

Box 6.5 - Advantages of using tractor units

Operationally, tractor-based units have the following advantages that are well suited for use by emerging contractors and for operations in remote areas:

- Plant operation: Fewer mechanical items are in use and units are simple to maintain with ordinary mechanical skills.
- Plant availability: It is often easy to find locally available plant outside the ploughing season, thereby offering flexibility in fleet management.
- Better utilisation of agricultural tractors.
- It is often easier to obtain spare parts for agricultural tractors then for heavy construction machinery.

Typical gravel loading operations.

6.3.3 Heavy Equipment Units

Construction units of various sizes based on conventional equipment, as opposed to tractor based units, have been widespread in the region. The components in typical units of this kind have the following features in the context of constructing LVSRs in remote areas, often by an emerging contracting industry:

Bulldozers for stockpiling: Large bulldozers (example>40 tonnes) are difficult to utilise economically where material sources are small, scattered and of very variable quality within each borrow pit. Smaller models are normally better suited for this operation. Bulldozers require regular preventive maintenance by skilled staff.

Front-end loaders for loading: Front-End Loaders are available in a variety of sizes. They are used mostly for loading gravel but use of this type of equipment is also dependent on the size of trucks available. For LBM, a Tractor Loader Backhoe is also suitable and can load a 6 cubic metre truck in 5 minutes.

Graders are versatile for processing materials on the road.

Excavators are convenient for various applications, including lifting.

Breaking down of any oversize fraction will benefit the grading and quality of the available material.

Grid roller.

Close-up of grid.

Scrapers: These are effective where earthworks quantities are large and where material quality is not critical. (The control of material quality is very difficult when using scrapers). The advantage of scrapers is that they can be used for cutting the roadway, excavation of drains, filling, spreading and, to some degree, compaction. However, motor scrapers incur very high investment and operational costs and consequently require high utilisation and mechanical skills for their maintenance. Thus, they are expensive to operate and currently tend to be replaced by a combination of other types of plant.

Motor-graders are versatile and are typically used to level tipped heaps, spread gravel, break down oversize, mix in water, place gravel layers for compaction, cut levels, shape road prism, shape cut-off berms and cut mitres. Most operations carried out by the use of motor graders can be undertaken by labour-based methods. However, on more heavily trafficked roads, it may be preferable to cut the final levels with a motor grader for achieving good riding quality. This can be carried out as a one-off operation whenever a sufficient length (say 20 km) of base has been placed by hand.

Excavators: Large excavators can carry out the operations of both a bulldozer and a front-end loader for earth-moving in the roadway and in the borrow pits and is an economical option. Selection of material quality is very difficult and such operations can, therefore, be used only where material quality is uniform or can be mixed in situations where quality assurance is not critical (e.g. for bulk earthworks).

Articulated dump trucks: These incur high investment and operational costs with stringent requirements for mechanical skills in their maintenance. They can be efficient in high-capacity operations and provide both an off-road and an on-road driving capability wherever the units can legally use public roads.

Tipper trucks: Ordinary tipper trucks are often favoured by emerging contractors because they can be used for other transport purposes and are readily available on the second-hand market, generally with readily available spare parts. The skills required for their mechanical maintenance are moderate.

6.3.4 Compaction Equipment

In addition to conventional rollers for compaction there are other types of equipment that give particular benefits in the construction of earthworks and pavement layers for LVSRs. These includc:

Grid rollers: This is a static roller towed at a relatively high speed (approx.15 km/hour) for breaking down oversize and for compaction. In this manner the material is better utilised and problems arising from oversize particles are avoided. Good results are generally obtained with the use of this plant for the compaction of pavements constructed with natural gravel and of fill layers with marginal quality materials, which can sometimes be difficult to compact to the full layer depth.

The roller allows compaction of the layer to take place in several smaller lifts at the same time as the graders spread the material. This is achieved without forming laminations and shear planes within the layer, because of the pattern of the surface of the roller.

Pneumatic roller.

Close-up.

3-sided Impact compactor.

Very heavy towed pneumatic rollers: This type of roller can weigh up to 50 tonnes on one axle and has been used successfully for compaction and proof-rolling of the roadbed, especially in thick layers of single-size sand. Its advantage is it provides a uniform and sound foundation for the pavement, achieved by collapsing and densifying any soft areas.

Impact compactors: These are non-circular, relatively high-energy ‘rollers’, typically three-, four - or five - sided. Large-wheeled tractors are used for pulling the compactors at operational speeds of 12 - 15 km/hr producing a series of high amplitude/high impact blows delivered to the soil at a relatively low frequency (90 - 130 blows per minute) with the energy per blow varying between 10 and 25 kilojoules, depending on the mass and amplitude of the compactor.

Owing to their very high *energy density* per blow, their main advantage over conventional compaction plant is their depth-effectiveness, typically of the, order of one metre of fill or in situ layers, thereby producing deep, well-balanced, relatively stiff pavement layers. These rollers are well suited for densifying collapsible soils. They have been successfully used in low-cost road systems and, when appropriately specified, offer a cost-effective option for LVSR construction.

Selection of Compaction Plant

Figure 6.2 provides a broad guide to the selection of compaction equipment. Each roller has been positioned in its economic zone of application. However, it is not uncommon to find them working out of their zones. Moreover, the exact positioning of the zones can vary with differing material conditions.

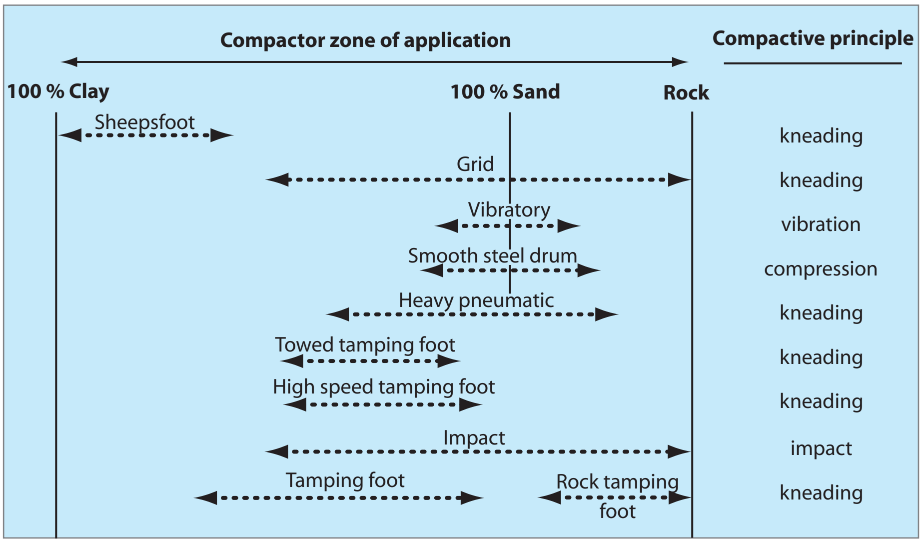


Figure 6.2 - Compaction equipment selection guide[9]

The degree to which soils and natural gravels can be utilized in LVSR construction, instead of more expensive processed materials, will determine the success of the project in terms of economy in both construction and maintenance.

6.3 Utilising Soils and Natural Gravels

6.4.1 General Considerations

Natural Gravel Resources

In areas where natural gravel and soils are available for road building purposes, these materials constitute the most valuable resource in the construction of LVSRs, hence, every effort should be made to use them in a creative manner - a challenge that has met with significant success in the SADC region. However, this has required that particular attention be paid to construction methods.

Large thickness of overburden does sometimes exclude labour-based methods for winning gravel materials. (The example shown in the picture is from construction of LVSRs where the thickness of the overburden is in excess of 2 m).

LBM

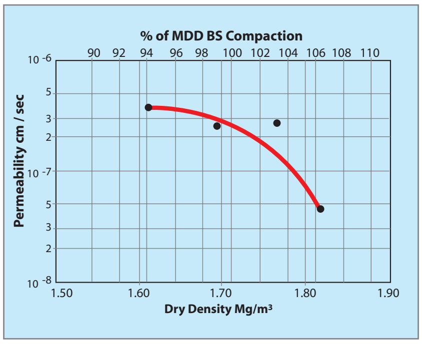
Box 6.6 - Labour-based methods in borrow pit operations

Labour-based methods in borrow pit operations may be utilised for combined stockpiling/loading in pits without overburden and where the ground does not require ripping. Labour-based operations may also be viable in combined operations where heavy plant is used for removal of overburden, while loading is carried out with manual labour. Where bulldozers have removed overburden, it is advantageous to let the same machines scarify the gravel and perhaps undertake stockpiling before manual loading.

Compaction

Compaction is a vital, integral aspect of LVSR construction that results in all-round improvements of soil properties and its performance as a pavement supporting layer. A well compacted subgrade possesses enhanced strength, stiffness and bearing capacity, is more resistant to moisture penetration and less susceptible to differential settlement.

One of the critical aspects of using natural gravels is to maximise their strength and increase their stiffness and bearing capacity through effective compaction. This can be achieved, not necessarily by compacting to a pre-determined relative compaction level as is traditionally done, but by compacting to the highest uniform level of density possible without significant strength degradation of the particles ("compaction to refusal"). In so doing, there is a significant gain in density, strength and stiffness, the benefits of which generally outweigh the costs of the additional passes of the roller.



Permeability-dry density relationship for a lateritic gravel (Kenya).

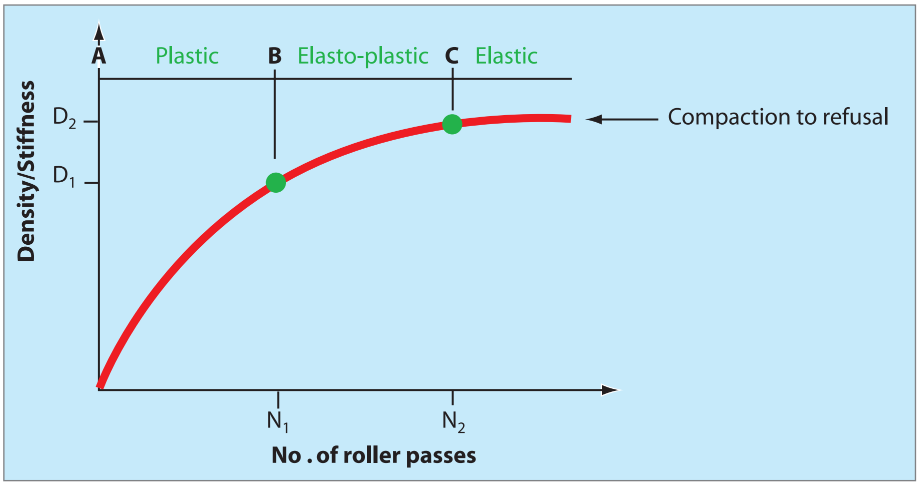


Figure 6.3 - Illustration of concept of "compaction to refusal"

Compaction to refusal ensures that the soil has been compacted to its near elastic state as shown in Figure 6.3 with the significant benefit of reduced permeability and, hence, susceptibility to moisture ingress.

In general, the effectiveness of the compaction process depends on three important, inter-related factors, namely:

- soil moisture content during compaction
- soil type
- type and level of the compactive effort

A maximum allowable moisture content during construction should be specified and proper precautions for surface and sub-surface drainage (where required) should be taken on all road-building projects to ensure optimal performance of the road.

Different types of soils respond to compactive effort in different ways. Thus, it is important to ensure that the compaction plant being used is appropriate for the type of soil being compacted and the purpose intended. For example, sand or sandy soils are most efficiently compacted with high frequency vibrating rollers, whereas cohesive soils are most efficiently compacted by static pressure, high-amplitude compaction plant. In addition, if the requirement is to compact and to produce a good riding quality of base course, this is unlikely to be achieved with a very heavy roller that compacts to a great depth and, in the process, disturbs the surface.

Good management procedures that prevent rejection of material on the road create confidence in the quality assurance system and greatly reduce the risk of shortcuts and poor practice.

6.4.2 Materials Management[10]

Proper management of the material sources is essential to ensure that the best qualities of available material are used in the top layers of the pavement structure. The efforts made to locate the best quality of locally available and often scarce materials for road base are of no avail if this material ends up in earthworks layers. Good management of materials resources is, therefore, a critical operation in LVSR construction.

Box 6.7 - Procedure for materials management

Stockpiling forms an important part of materials management by promoting appropriate selection of materials as well as providing opportunities for blending materials and for testing materials before transportation to the road. The biggest threat to good materials management is when borrow pit operations are not kept sufficiently ahead of the construction.

There is considerable experience to show that the following sequence of procedures will ensure good management of the material resources:

- Initial investigation of material sources by trial holes.
- Stockpiles to be clearly marked.
- Allocation of materials for specific layers on specific sections of the road after stockpiles are completed.
- Laboratory testing should be conducted if possible.
- Loading from stockpiles according to allocation for transportation to site.

It is important to ensure that rejection or acceptance of materials is carried out at the source and not after the material has been transported to the road.

The procedure set out in Box 6.7 requires sufficient plant for opening of borrow pits to avoid construction demands exceeding the materials supply from the borrow pits. In cases where the opening of borrow pits cannot keep ahead of construction, there is a considerable risk that materials selected for basecourse, will end up in the lower layers of the pavement, causing pressure on the supply of material when base course materials are needed at a later time.

6.4.3 Borrow Pits and the Community

Operations in borrow pits will always put a strain on surrounding areas and the environment as a whole. Work in borrow pits has environmental disadvantages, such as temporary noise and dust pollution, and creates traffic safety problems and other hazards to livestock and humans. Some of the effects may remain after construction is completed, such as permanent changes to the topography and disturbance of the soil cover. The Environmental Management Plan, which should be developed in conjunction with the community, will indicate the agreed procedures for the opening and re-instatement of borrow pits.

Wishes of the Community

The wishes of the community will vary according to their needs in the particular area and may include one or more of the following:

- provision of future access to borrow materials for utilisation by the community
- use of the depression for water collection, sometimes requiring fencing or sloping of sides to at least 1:3 for the safety of people as well as to protect livestock from drowning
- levelling of the area in order to prevent collection of water that may lead to mosquito breeding and water-borne diseases
- use of the depression for landfill (rubbish) deposits, always requiring special precautions to prevent pollution
- reinstatement of the area for farming purposes, requiring fertile topsoil replacement, which must be self-draining
- reinstatement and landscaping of the area for building or recreational purposes

It should be noted that the public perception of benefits in leaving borrow pits open is often exaggerated and, as a rule, borrow pits should be reinstated. Before decisions on the future use of a borrow area are finalised, the community should be made aware of the disadvantages of leaving borrow pits open.

Backfilling of borrow pits, i.e. replacement of the material from the pit, is only viable where the material for backfilling is either:

- *spoil material, or*
- *originates from a source where excavtions give considerably less disadvantages than in the borrow area. The cost of this method is likely to be very high.*

Reinstatement of Borrow Pits

The extent of the work required to comply with the wishes of the community will depend entirely on the requirements in each individual case. In the cases where no particular standard for reinstatement has been established, one should routinely carry out reinstatement as described in Box 6.8. The condition of all areas used for access roads should be assessed in the same manner as for the borrow areas.

Reinstatement operations in a borrow pit.

Box 6.8 - General procedure for borrow pit re-instatement.

The following simple procedure will minimise the limitations that the construction activity has placed on future use of the land:

- Shape mounds and steep banks down to a slope (steepest 1:3) that is naturally found in the landscape.
- Spread the topsoil evenly back into the pit in order to promote growth of vegetation.
- Ensure the area is self-draining.

Before reinstating a borrow pit, one should assess the need for materials in future road maintenance and then stockpile appropriate quantities of gravel for this purpose.

6.4.4 Clearing, Grubbing and Removal of Topsoil

Burrowing animals such as termites can cause damage to pavement layers unless nests are removed properly and poisoned with an approved pesticide during clearing and grubbing.

It is particularly important to take account of environmental aspects at the early stages of construction so that sensitive operations such as clearing and grubbing are conducted as carefully as possible. It is important that damage to the vegetation cover is minimized, shifting of soil and associated damage due to erosion is avoided and that any mitigation measures set out in the Environmental Impact Assessment are observed, (Section 3.4). All topsoil that is stripped should be stockpiled for use in areas that are being reinstated for farming purposes or to promote vegetation. Any vegetation being removed should be disposed of in a manner that is to the benefit of the community, e.g. for fuel wood.

Box 6.9 - Clearing and grubbing using manual labour **LBM**

Clearing and grubbing is eminently suitable for labour-based operations where the required speed of construction and availability of labour makes it possible. Labourers may experience problems in achieving the required result as described in specifications due to the need for ripping, depth of grubbing, size of roots, etc. In such cases it is advisable to review specifications in the light of the requirements of a low-volume road and to ascertain whether there is actually a realistic risk of damage to the pavement resulting from reduced standards of grubbing by comparison with current specifications.

6.4.5 Construction of Earthworks

Research has been carried out to establish whether it is possible to compact fills in dry regions without costly addition of water. Although possible, such practice could result in the compacted layer having a high void content and the risk of settlement at a later time if water enters the fill materials.

The optimal techniques and methods for undertaking earthworks operations are largely dependent on available equipment in addition to the operational skills and experience of the field staff. Section 6.4 gives an indication of the advantages and disadvantages of the various types of equipment available for earthworks operations.

When compacting earthworks it may be difficult to adjust in situ moisture content before compaction, especially when using clayey material types where a good distribution of water in the material is difficult to achieve. To mix water into such materials requires much effort and is not very effective. The possibility of adjusting moisture contents of earthworks is particularly difficult in wet climatic regions, whereas in dryer areas it is possible to dry out materials that are too wet. Careful timing of earthworks, where possible, can, to some extent, alleviate the problem.

Box 6.10 - Labour-based methods in earthworks **LBM**

The use of labour-based methods in earthworks is only appropriate where the quantities are moderate or where there is a large source of labour available for the work.

There is evidence to show that the performance of well constructed base courses of natural gravel can be equal to or better than base courses constructed of highly refined, but less well constructed, crushed materials.

6.4.6 Construction of Pavement Layers

Use of Natural Gravel Materials

Optimal use of natural materials is a constant challenge that is faced in the construction of pavement layers for LVSRs. However, depending on local conditions, it may sometimes be necessary to resort to processing of these natural gravels by crushing/ screening, or stabilisation. Natural gravel materials offer levels of performance that are directly related to successful construction methods and workmanship. Aspects of construction that require particular attention are:

In the case of natural gravel with high fines contents, the required density to the full depth of the layer is often far more difficult to achieve then that of well graded granular pavement materials. This often requires special techniques, such as the use of grid rollers, to obtain a good result - see Section 6.3.4.

- Natural gravels with high contents of fines or clay particles gain their strength as a result of suction following drying back, rather than from friction between particles. This means that the in-service moisture regime of the pavement, achieved through appropriate internal drainage measures, is of vital importance for the performance of the layer.
- Correct moisture content (material dependent, however just below optimum moisture content) and achievement of the specified density for the different layers, is essential.
- Depending on the construction plant used, a good surface finish is sometimes difficult to attain. It is essential that the base has a smooth dense surface finish before sealing to ensure that a good bond is obtained between the base course and the bituminous seal and for subsequent good pavement performance.
- Natural materials often include some weak larger particles and, when such materials are compared, these larger particles may break down, hence changing the properties of the material as a whole. An assessment of the consequences of this processing action is therefore required in order to establish whether or not the material meets the specification requirements following construction.

Close up.

The use of mixing equipment, such as ploughs or large disc harrows, greatly reduces the time required for mixing water into the material, by comparison with blade mixing with a grader, particularly where relatively poorly graded gravels with high fines contents are used.

Moisture for Compaction of Pavement Layers

Experience with materials in the region has shown that thorough mixing of water with soil or gravel over the full width and depth of the layer at the optimum moisture content is essential for achieving the required density and an even surface finish. The optimum moisture content for the appropriate level of compaction determined in the laboratory is a good guide to the amount of water required in the field compaction process, although modern compaction plant normally requires a lower moisture content than the optimum indicated from laboratory compaction methods.

Box 6.11 - Effective mixing of water into the material

It is often far more difficult to achieve the required density to the full depth of the layer in natural gravels with a high fines content than in well-graded granular materials. Effective mixing with water is, therefore, of particular importance when these materials are used.

Much as natural gravels may need to be brought near to saturation moisture content for efficient compaction, it is also good practice to allow a significant amount of drying back to occur before sealing takes place. This is particularly beneficial for fine-grained materials that rely on suction and cohesion as their predominant source of shear strength.

Experience has shown that the rapid premature failure of the uppermost layer of the base course can be linked to poor finishing of this layer with subsequent loss of bond to the surfacing.

Finishing of Base Courses

If the operation of mixing, spreading and compaction is not completed before drying out of the surface takes place, then a loose upper layer (biscuit layer) will result. If this happens, the bituminous surfacing will not have a hard surface on which to bond resulting in base course failures resulting from shearing by wheel loads. Such failures may appear to be the result of insufficient material strength, but studies of construction records, and evidence of good performance under similar conditions in base course layers of poorer material qualities, indicate that finishing of the base course layers is vital and decisive for the good performance of LVSRs.

Box 6.12 - Cutting final levels of natural gravel base courses

A critical operation affecting the future performance of LVSR pavements is the cutting of final base levels. Attempts to make minor adjustments to the surface should not be allowed. The cutting of final levels should be confined to the cutting off of high areas and not the filling in of low areas. Thus, it is much better to make corrections to geometric levels at subbase level where surface finish is not critical. Thereafter, construction of the base course can be carried out 'by eye' and with normal control of layer thickness. It is strongly advisable to *cut final levels of natural base courses by eye* rather than by following geometric levels set out in the field.

Figure 6.4 illustrates a recommended procedure for finishing off base courses made of natural gravel. The advantage of this method is the speeding up of the processing of the base course to prevent drying out of the surface whilst ensuring that full attention is given to achieving a good surface finish rather then to dealing with minor irregularities in geometric levels. Trimming of the surface should be confined to the action only of cutting off gravel to side spoil or be off loaded for use in subsequent sections. Spreading loose material over the surface in a thin layer is unacceptable because this is likely to prevent a firm finish of the layer which will inhibit the bond with the bituminous surfacing.

LBM

In most cases, the removal of oversize material is best carried out by the use of manual labour.

LBM

Box 6.13 - Pavement construction with labour-based methods

Labour-based methods for construction of pavement layers have varying potential depending on the type of layer being constructed. Certain types of road pavement and surfacing are more "labour-friendly" than others as far as their construction is concerned.

- Penetration macadam may be constructed entirely by labour-based methods, including production of materials at hard rock sources.
- Granular materials, including natural gravel, may be spread, mixed and levelled by labour. Compaction can be done effectively by labour-based methods as long as the method is appropriate to meet the requirements of a sealed road.
- Improved riding quality is obtained if a motor grader is used to cut the final level.

When trimming off the pattern from grid rollers in the surface of the base, it is important to ensure that any dragging marks from stones is filled in immediately and before smooth rollers are applied.

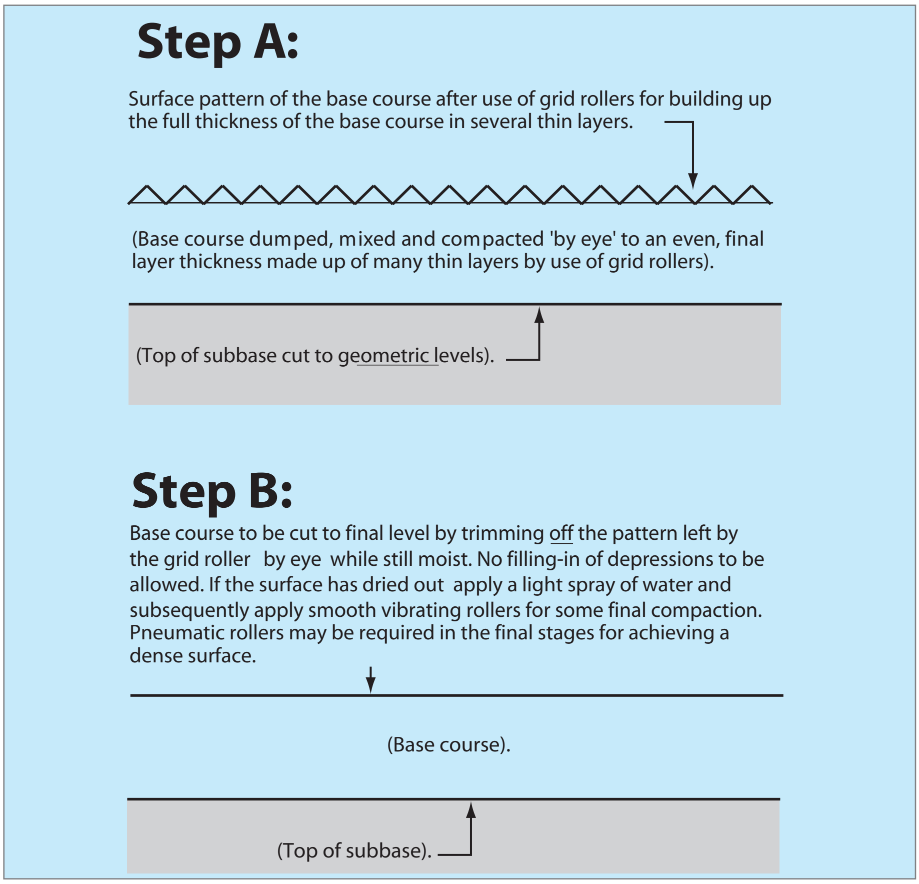


Figure 6.4 - Illustration of procedure to finish off base courses made of natural gravel

Admixture of Kalahari sand to calcrete can potentially improve the material properties by reducing plasticity and improving stability, reducing the damaging effect of soluble salt contents in the calcrete and improving workability to achieve the required density.

6.4.7 Dealing with Variability

Utilisation of Local Material Sources

The mixing of two different materials to achieve a quality that exceeds that of either of the two individual materials is the most common and probably one of the best methods of improving the engineering properties of natural gravels. Mixing fine-graded materials with those that lack fines, such as some volcanic tuffs, can create a material with less potential for breaking down under compaction, with a higher density through improved grading and improved stability and workability.

Mixing of sand in proportions up to a third of the total material quantity has shown benefits without adverse effects. However, the optimal proportion varies depending on material properties. Simple laboratory investigations and field trials (test sections) are required in each individual case.

Box 6.14 - Optimal use of natural gravel

Optimal use of local materials requires innovative engineering solutions to obtain the best performance from available resources. Mechanical blending is often the best option for increasing the quantity of an acceptable material quality or improving the quality of the final material.

When materials are mixed in a borrow pit the proportions will normally be less accurate than when mixed on the road. This method of blending is not recommended.

Separate stockpiling in advance is necessary to control the properties of the individual materials being mixed and the quality of the final material mixture.

Some mixing during stockpiling is a good option when this process can be carried out by digging through two gravel seams of the materials to be mixed. Bulldozers are not well suited for this purpose nor will heaping the borrow materials in high cones give satisfactory results. Building up stockpiles in layers and subsequently loading from them in a special manner or sequence is feasible but requires very close control of borrow pit operations. Best results are obtained by mixing on the road.

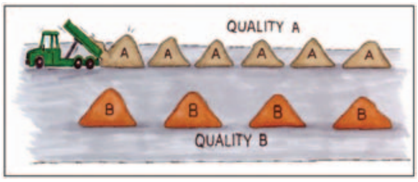
Mixing Technique on the Road

When mixing two types of gravel on the road, motor graders should be used in combination with disc harrows, if available, to achieve a homogeneous mix. The method should be to dump gravel A on the road in the required quantity, then to flatten the heaps and to spread the gravel over half the width of the base course. Then gravel B should be dumped on top of the spread material A and spread over the same half width. Mixing should proceed as normal with the blading of both materials A and B. (See figure 6.5.).

Mixing of different material types requires particular attention to be paid to blending the full thickness of the dumped layer of material on to the road, mixing it properly and adding water at the same time.

Step A: Separate stockpiling

Step B: Controlled dumping on the road



Step B (Alt.) Controlled dumping on the road

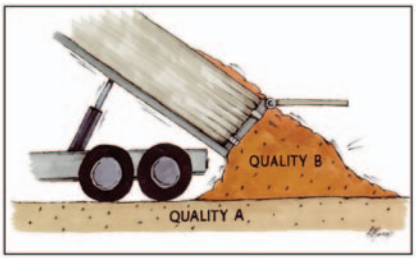


Figure 6.5 - Illustration of two alternative mixing techniques on the road

Mixing by labour-based methods normally gives effective mixing. Where quantities are moderate this method may be a viable alternative to plant mixing.

6.4.8 Shoulder Construction

General

Besides the maintenance and traffic safety benefits gained by sealing of shoulders, there are benefits related to the load bearing strength of the pavement. Sealed shoulders reduce the risk of water penetrating into the pavement layers, resulting in a drier road environment, especially near and under the outer edge of the running surface.

Unsealed shoulders place particular demands on the type of gravel materials being used as they need to be durable when exposed. This design may therefore complicate operations by requiring separate construction of shoulders and carriageway.

Box 6.15 - Simplified construction with sealed shoulders

The construction of sealed shoulders with the same material as that in the base course is the preferred option. Generally there has to be a considerable difference in material cost for carriageway and shoulders to justify the use of different materials in these two components. It may be justified where highly refined base course materials are used but this is unlikely in LVSRs.

An increasing number of countries in the SADC region are embarking on the sealing of shoulders on roads that were originally constructed with gravel shoulders. This is operationally difficult and there are critical aspects with regard to construction technique that are likely to determine the success of such programmes. The following should be given particular attention:

- Materials in the paved shoulder should be at least as permeable as the materials in the adjacent base. If this cannot achieved, then suitable filters should be incorporated in the shoulder in order to prevent the collection of water in the base.
- A well-compacted joint can only be achieved if the joint between the surfacing and the new shoulder is initially cut straight and clean before shoulder materials are placed.
- The shoulders have to be at least 2.5 m wide to enable a motor grader to mix and place the shoulder gravel as well as to accommodate the width of water trucks and compaction equipment. Excess width can, if required, be cut off on completion of shoulder layer works.
- Shoulders should be finished off and compacted at least 10mm higher than the adjacent base, and subsequently cut to level, as shown in Figure 6.6. Proper compaction and a firm surface for shoulder surfacing is otherwise impossible to achieve.
- Where widening of the road prism is necessary, earthwork fills should be benched and compacted in order to prevent pavement damage resulting from differential settlement.

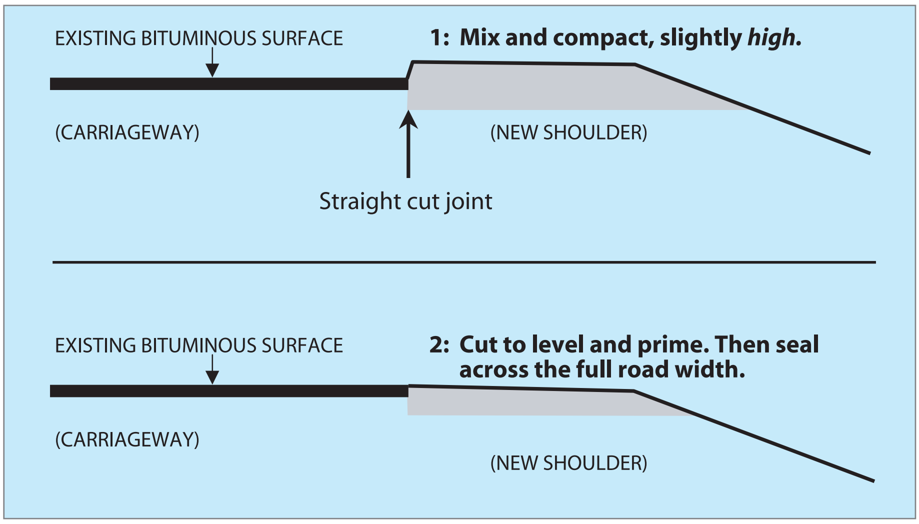


Figure 6.6 - Construction of sealed shoulders to existing bitumenised roads initially having unsealed shoulders

Shoulder Seals

Seals on shoulders should have a higher bitumen content than those on the carriageway, unless the shoulders are expected to be regularly trafficked, e.g. in built-up areas. This can be achieved without higher binder spray rates by using a smaller size aggregate than in the carriageway.

Blinding off shoulder seals with a bituminous ***sand seal*** *is often an appropriate method to:*

- *arrest loss of aggregate*
- *provide a good surface for pedestrians and bicycles*
- *give a desired visual contrast to the carriageway*

Edge marking of the running surface with a paint line is also desirable if the resources to do this are available.

6.5 Construction of Seals

6.5.1 Selection of Seal Type and Materials

Design of seals and selection of appropriate type of seal is fully covered under Chapter 5 - Pavement Design, Materials and Surfacing.

Decisions on utilisation of aggregate sources for bituminous surfacing often require revision at the construction stage as a result of increased knowledge about available material sources as construction proceeds[10]. This is of particular relevance to LVSRs because:

- A wide range of aggregate types and qualities can be used for the bituminous surfacing.
- Site investigations at the design stage tend to be focussed on identifying bulk materials for the pavement layers. As construction proceeds and materials are excavated for the pavement layers, sources of better quality surfacing materials are sometimes revealed that were not discovered at the design stage.

LBM

Sand seals require lower levels of skill, material quality and equipment than chip seals or Cape seals. If applied over an Otta seal, locally available sand along the roadside may be of adequate quality for the sand seal.

Box 6.16 - Utilisation of local material sources for bituminous seals

Site staff should become familiar with the wide range of seal types and suitable aggregates for LVSRs and with the scope for applying labour-based methods in the production of aggregate and construction of the seal. The inability to fully utilize locally available resources in the construction of low-cost but durable seals results in lost opportunities for achieving construction cost savings.

6.5.2 Resources Required on Site

As indicated in Table 6.1, each of the various types of surfacing has different requirements as regards the necessary resources on site to achieve a satisfactory end result. It is important to observe these requirements when deciding on an appropriate choice of seal for a LVSR.

Table 6.1 - Required input for achievement of a good bituminous seal

	Required input for achievement of a good result (Low - Moderate - High)				
	Surface dressing	**Otta seal**	**Sand seal**	**Slurry**	**AC 4)**
Skills	Moderate	Moderate	Low	Moderate 3)	Un-suitable
Equipment, Spreading	Moderate	Moderate	Low	Low	Un-suitable
Equipment, Bitumen Application 1)	Moderate	Moderate	Low	Low	Un-suitable
Materials quality	High	Moderate	Low 2)	Moderate/ High	Un-suitable

1) A bitumen distributor is required for most sprayed seals. Hand sprayers are an alternative, especially when using emulsions, but spray rates need to be controlled. Mixing slurry in concrete mixers is preferred, even when laying by hand. Self-propelled slurry machines increase efficiency but at much higher cost.

2) Coarse sand, sometimes available by screening, can increase the material quality to "moderate" where sand seals are used alone as permanent seals. Where sand seals are used as cover seals, the material quality requirements can be reduced to "low".

3) The selection and handling of bitumen emulsions, including proportioning and adjustment of consistency, increases the need for handling skills. Training is usually required.

4) Although included for comparison with other seal types, surfacing with AC is usually confined to areas with wet climates and/or steep terrain.

LBM

A small, simple crushing/ screening plant can be combined with labour-adapted tractor operations.

Applying aggregate for surface dressing using mechanical chip spreaders.

High contents of dust and fines in the aggregate are more critical for the good performance of a surface dressing than for that of an Otta seal.

Drag brooming is sometimes applied in order to improve distribution of aggregate.

Rolling of sand seal.

6.5.3 Aggregate Production

Table 6.2 outlines the operations required to win and produce aggregate for each type of surfacing that may be used with a LVSR.

Table 6.2 - Production of aggregate for bituminous surfacing

Type of seal	Type of aggregate	Winning and processing of materials
Surface dressing	Crushed stone or rock.	Crushing and screening.
Otta seal	Gravel, natural or crushed.	Stockpiling. Normally screening is also required.
Sand seal (used alone)	River sand (crusher dust may be used, but can be expensive).	Stockpiling (while river is dry). Screening out pebbles.
Sand cover seal (over Otta seals)	Any non-plastic sand.	Stockpiling if sand is not available along the roadside.
Slurry	Crusher dust.	Crushing and screening.

6.5.4 Construction Procedure

All types of sprayed surfacing, such as surface dressings, Otta seals and sand seals, follow a similar construction procedure:

1. Priming of the base (may sometimes be omitted).
2. Base repair (chip and spray by hand using emulsion) to even out the occasional rut caused by a stone under the motor grader blade.
3. Spraying of bituminous binder.
4. Spreading of aggregate.
5. Chip spreading requires uniform aggregate cover. A drag broom can assist this process on large areas.
6. Rolling is preferably carried out with pneumatic rollers but can also be done by trafficking.
7. Repeat steps 2 to 6, if a double layer is applied.
8. An emulsion "fog spray" is sometimes applied to chip seals after they have been laid to enhance adhesion of the chippings.

In slurry seals, crusher dust, bitumen emulsion, water and cement filler are premixed with either a specialised "mix and spread" machine or in a concrete mixer for spreading by hand with squeegees. Mixing by hand is possible but is not recommended.

6.5.5 Labour Friendliness

The various types of bituminous surfacing appropriate for LVSRs offer different degrees of suitability for labour-based application. Table 6.3 provides an assessment of the suitability of each surfacing type for the use of manual labour in the production of aggregate and construction respectively.

LBM

Screening aggregate by labour-based methods (Otta seal is shown, sand seals would be similar).

LBM

Spreading gravel using labour-based methods. (Otta seal), from heaps placed along the road.

Table 6.3 - Labour friendliness of various surfacing types LBM

Activity		'Friendliness' for labour-based methods (*Good – Moderate – Poor*)				
		Surface dressing 1)	**Otta seal** 2)	**Sand seal**	**Slurry** 3)	**AC** 4)
Production of aggregate	Quality	Poor	Good	Good	Good	Poor
	Output	Poor	Good	Good	Poor	Poor
Construction of surfacing	Quality	Moderate	Good	Good	Good	Poor
	Output	Good	Good	Good	Moderate	Poor

1) Hand-crushing of aggregate for surface dressing tends to produce flaky chippings with some rock types.

2) Oversize and fines can be removed by hand screening of natural gravel aggregate for use with Otta seals.

3) Output of aggregate production for slurry (crusher dust) depends entirely on availability on the commercial market.

4) Although included for comparison with other seal types, AC would not normally be used on a LVSR.

LBM

Box 6.17 - Labour-based methods in surfacing operations

- The ease of application of labour-based methods for construction of seals varies with seal type. However, in general, all seal types offer good scope for labour-based operations, both as regards production of aggregate as well as construction on site. However, the uniform binder spray rates required for chip seals are more difficult to achieve with labour-based methods.
- Where labour-based methods are desirable, seal types that are most suited for this type of construction should be given the preferential consideration. It may be necessary to provide training to ensure that the final product will be of the desired standard.
- All seals, except the slurry seal, need rolling and therefore require some form of machine-based equipment for this purpose. Where traffic volumes are sufficiently high, it may be possible to rely on traffic for rolling, but at the risk of an inferior result and speed will need to be strictly controlled.

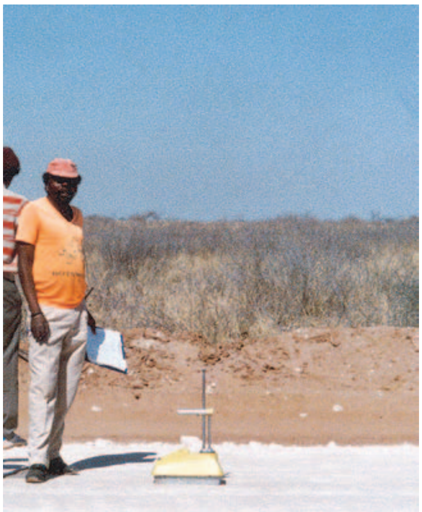
6.6 Quality Assurance and Control

6.6.1 Introduction

Quality control does not in itself create higher quality, but is one of several tools that are used to ensure that a product of the desired quality is produced.

Quality assurance in road construction includes the total system within the construction site that ensures correct quality of the final road and associated structures. Besides conventional site control, quality assurance also includes the measures that contractors themselves apply for this purpose during operations.

Quality control includes laboratory and field testing of materials and construction and forms part of the overall quality assurance system. It is applied in various ways, depending on the type of contract. Conventional contract relations with a supervising body - often a consultant - carrying out control of the works is a common system used in the region. Under these circumstances, end-product quality control is routinely included in elaborate systems and is applied with great effect on projects where roads are constructed. It is commonly considered necessary to establish full laboratory services on site for control of workmanship and material quality. The resources one can afford for such control during the construction of LVSRs are often less, for the following reasons:



Effective quality control for LVSRs does not necessarily require a full-scale programme of laboratory testing.

- The cost of quality control measures that are applied to more highly trafficked roads would represent a much larger proportion of the construction costs of LVSRs.
- Contractors and consultants involved in the construction of LVSRs are often smaller and have less resources available than those routinely constructing larger projects.
- LVSRs are often executed as small projects where the establishment of full site-testing facilities is often not viable. Distances to central laboratory services may also render this option impractical.

This section sets out a conceptual approach to ensure the best possible quality assurance with a reasonable level of control in constructing LVSRs. The inherent compromise in this approach will often require innovative solutions and focus on the overall quality assurance system to achieve optimal results.

6.6.2 Methodology

General

As the resources available for quality control in construction of LVSRs are often limited, it is important to utilise whatever means are available as efficiently as possible and to combine conventional control methods with other quality assurance methods.

Density control is important in 'calibration' of method specifications, but full-scale test programmes are not always viable on LVSRs owing to lack of resources.

Quality Assurance with Reduced Resources

Quality assurance procedures where control systems are applied at reduced levels include the following:

- **stockpiling** as a means of selecting qualities and ensuring known quality of the materials being used
- good **management** procedures to ensure that materials are used to their full potential and to prevent rejection of material after transportation to the road

Having spray cans with bitumen emulsion available at all times during surfacing operations for repairing minor faults is part of good quality assurance.

Direct strength measurement can assist but cannot replace materials management and observation of the work procedures as the most powerful means of quality assurance.

- systematic use of **method specifications**
- **control by observation** of construction procedures by an experienced practitioner
- **proof rolling** (e.g. with loaded trucks) to test the stability of layers before proceeding with construction
- use of methods for **direct strength measurements** by correlation with known parameters (e.g. probing methods such as DCP and others)[11]
- laboratory testing for **'calibration'** of method specifications
- laboratory testing of typical material sources for **'calibration'** of visual observations

Priority in Quality Control

Box 6.18 - Optimum priority for quality control

The resources put into quality assurance should be applied where there is a maximum benefit from the efforts, i.e. where the benefits, in terms of structural life or surface life, are greatest in relation to efforts made in the control.

LVSRs typically utilise natural gravel in the base course, followed by a thin bituminous seal. This pavement structure is sensitive to any irregularities in the seal, in the interface between seal and base course and in the base course itself. Conceptually, the priority when allocating resources to quality assurance should therefore be as shown in Table 6.4. The table sets out the priority on the basis of what is possible from a technical point of view in relation to the input of resources for control. It does not take account of contractual and institutional issues. These aspects will vary considerably and require varying measures for optimal quality assurance.

Visual control of the bitumen distributor and continuous inspection of the work on site are important parts of the quality control procedures and can reduce flaws in thin seal that could lead to premature failure of the surfacing.

Continuous visual control by skilled staff through the entire operation when processing the base course for LVSRs is essential. Inadequate compaction of natural gravel is often caused by poor mixing, insufficient moisture content or poor final spreading and compaction of the layer.

Table 6.4 - Priority in quality control

Priority	Layer	Comments
1	Bituminous surfacing	• Choice of equipment, choice of material type, visual assessment and measurement of application rates is of greatest importance. • Only basic laboratory equipment is essential for effective control during operation.
2	Surface finish of the base course	• Biscuit layers are the most common reason for an unacceptable product. A geological hammer/pick can be used to identify such flaws. • Visual assessment, plus choice of equipment and working method is of greatest importance. • Laboratory equipment is not essential for effective control during operation.
3	Material quality of the base course	• Laboratory tests in advance and after construction, combined with indicative tests or observations during construction, are essential.
4	Compaction control of the base course	• Method specifications, appropriate choice of method and equipment, visual assessment and proof rolling, in combination with regular testing for 'calibration'. • The extent of testing required for 'calibration' purposes should be adapted to site conditions and available resources.
5	Subbase and earthworks	• Visual assessment and laboratory tests ahead of construction give improved confidence in material quality. • Method specifications, visual control, proof rolling and appropriate choice of method and equipment are sufficient for site control of workmanship.

6.7 Drainage

6.7.1 Introduction

Drainage is probably the most dominant factor affecting the performance of a LVSR. When such roads fail it is often because of inadequacies in drainage resulting in the ingress of water into the road structure, structural damage and costly repairs. In addition, surface water can form a road safety hazard by causing aquaplaning of vehicles.

Unfortunately, many LVSRs have evolved with inadequate initial engineering and drainage design. Even with properly engineered LVSRs, on-site inspection is often necessary to correct any unforeseen conditions during construction. Such an approach is more cost-effective than maintaining or correcting deficiencies after the road has been in service for several years.

Two inter-related aspects of drainage require careful consideration during construction, namely:

- *Internal drainage* of the pavement which seeks to avoid the entrapment of water by allowing it to permeate through and drain out of the pavement structure.
- *External drainage* which seeks to divert water away from, and prevent its ingress into, the pavement structure through measures such as the construction of sealed shoulders, side drains, etc.

6.7.2 Internal Drainage

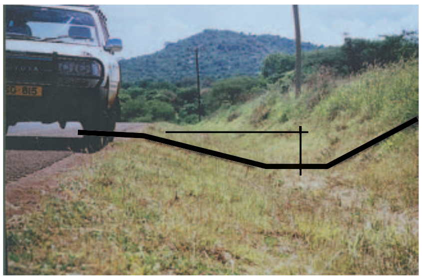
General

Internal drainage involves measures to minimise moisture contents in the embankment and pavement layers and importantly to prevent unwanted movement of water within the structure. Internal drainage is vital for the satisfactory performance of earthworks and pavement layers made of natural soils and gravel, especially those that utilise fine grained and plastic materials such as those commonly used for LVSRs[12]. (Refer to Chapter 5 for more details).

It is important to create an awareness amongst the public so that actions that lead to impaired drainage of the pavement can be prevented.

Permeability of pavement layers

Wherever possible, each layer in pavement and earthworks should be more permeable than the overlying layer in order to prevent any water entering the structure from being trapped. It is often not possible to meet this requirement consistently and the provision of cross-fall in all earthworks and layer works for water to escape from the pavement structure can alleviate the problem (see also Section 5.4.3 and Box 5.7). Under severe conditions, especially where there is risk of water seepging into the pavement structure, consideration should be given to installing subsurface drainage systems or, better still, to increase the height of the road in such areas.



Research in the region has shown that a minimum crown height is a critical parameter that correlates well with the actual service life of pavements made of fine grained and/or slightly plastic materials. A minimum crown height of 0.75 m is recommended. See Chapter 5 - Pavement Design, Materials and Surfacing, Section 5.3.4.

Crown Height

Crown height is the vertical distance from the bottom of the side drain to the finished road level at centre line and needs to be sufficiently great to allow proper internal drainage of the pavement layers. Economical ways to achieve sufficient crown height include the use of material from the side drain and road reserve a common procedure where scrapers/motor graders are used for construction. Maintaining sufficient crown height through cuttings is of particular importance, owing to the unfavourable drainage conditions in such areas. However, this may result in a considerable increase in the quantity of earthworks cut. Alternatives, such as subsurface filter drains, should be considered as a last resort because of cost and maintenance implications. The traffic safety aspects of large crown heights should be taken into account by moving the side drain further away from the shoulder break point.

In areas where in situ soils are considered to be self-draining, such as in sandy areas and desert-type areas, priority should be given to providing good side support within a low embankment profile and shallow side slopes (typically 1:6 or 1:8) rather than a large crown height and relatively steep side slopes.

Seepage and subsurface drains

Unfortunately, inadequate surface and subsurface drainage are typical deficiencies associated with cut-and-fill pavement sections for LVSRs, as shown in Figure 6.7. Such deficiencies can affect the pavement by erosion, decreasing soil support or initiating creep or failure of the downhill fill or slope. They should be addressed during construction rather than waiting until failures occur because it is much more expensive to undertake remedial works.

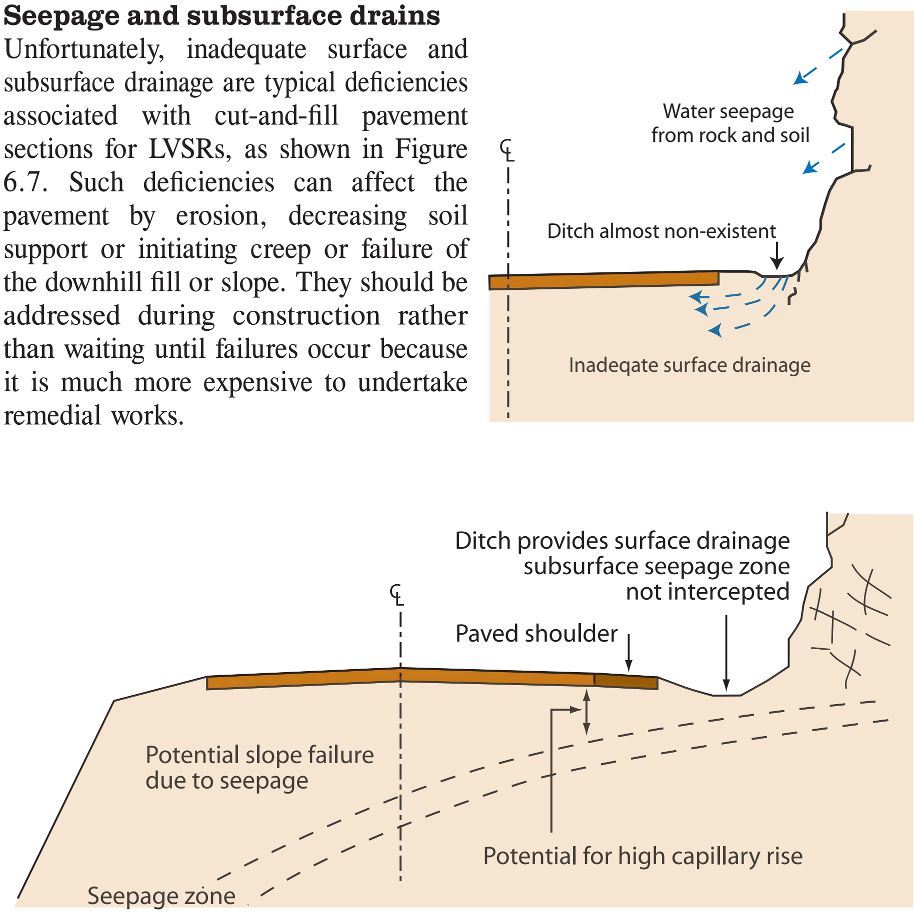


Figure 6.7 - Typical drainage deficiencies associated with cut-and-fill pavement sections[13]

Blocked side drains may lead to surfacing failures.

In the design of the vertical alignment of LVSRs, it is advisable to try to avoid cutting into the ground to reduce the risk of encountering subsurface water. Thus, the "depressed pavement construction" shown in Figure 6.8 should be avoided except where soil moisture conditions are suitable or the drainage systems effectively eliminate water-related problems.

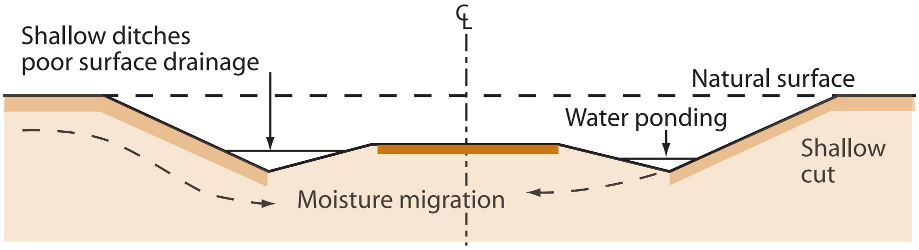


Figure 6.8 - Potential drainage problems associated with depressed pavement construction

Localised seepage can be corrected in various ways but seepage along pervious layers combined with changes in road elevation (grades) may require sub-surface drains as well as ditches, as shown in Figure 6.9.

Subsurface drains can be made of geo-textiles wrapped around aggregate, with or without pipes installed, but various specialised systems are also marketed. Such drains have commonly been made out of aggregate surrounded by filter sand instead of geotextiles, depending on the grading of the in-situ soils.

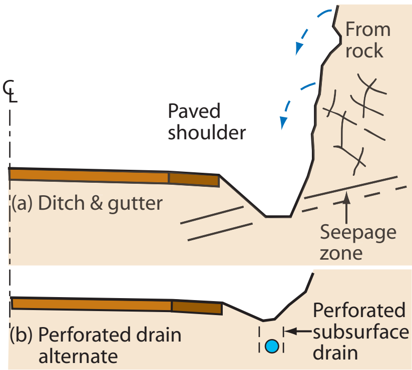
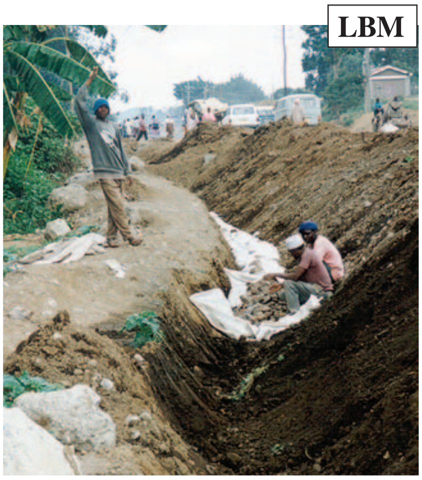


Figure 6.9 - Beneficial interception of surface runoff and sub-surface seepage[13].

LBM



Construction of filter drains is well suited for labour-based methods. Geotextiles used for filter drains should be of a type that does not get blocked by fines from surrounding soils.

As subsurface drainage systems usually incur relatively high installation costs and there is the risk of blocking of buried systems, alternative options are preferred.

Shoulders

Construction of shoulders needs to be undertaken carefully if typical drainage problems are to be avoided. Preferably, the granular base should extend to the embankment slope with sufficient height above the ditch to prevent water intrusion. Trench, canal or "bathtub" construction, in which the pavement layers are confined between continuous impervious shoulders, should be avoided as this has the undesirable feature of trapping water at the pavement/ shoulder interface and inhibiting flow into the drainage ditch.

Shoulder materials should be selected which have a permeability similar to that of the base course, so that water does not get trapped within the pavement. However, the material properties for unsealed shoulders may well be different from those required for the base for reasons of durability. Unsealed shoulders are similar to a gravel wearing course and require material with some plasticity, which is a property that might be considered less desirable for road base material.

A common problem is water infiltration into the base and subbase, which occurs for a number of reasons as, illustrated in Figure 6.10. These include:

- rutting adacent to the sealed surface
- build up of deposits of grass and debris
- poor joint between base and shoulder (more common when a paved shoulder has been added after initial construction)

Water infiltration in shoulder and rut leading to edge failures.

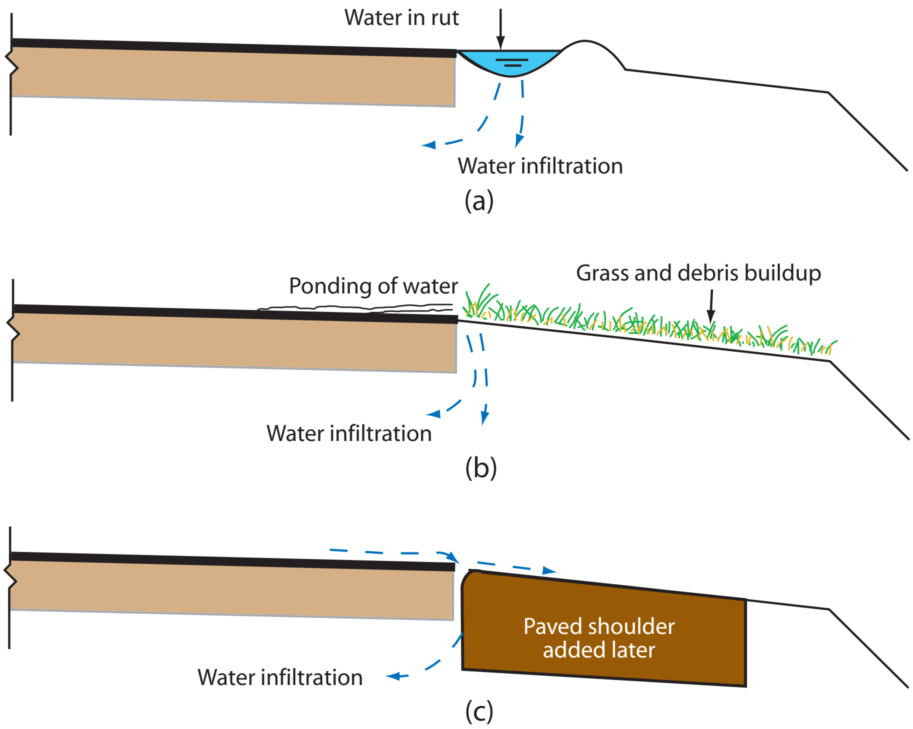


Figure 6.10 - Typical drainage deficiencies associated with pavement shoulder construction[13]

Ideally, as illustrated in Figure 6.11, the base and subbase layers should be extended outwards to form the shoulders, which should preferably be sealed.

Use of different materials in the shoulder and the carriageway is often uneconomical because of disruption in the construction procedures. Use of the same material in the carriageway and the shoulder eliminates the risk of trapping water.

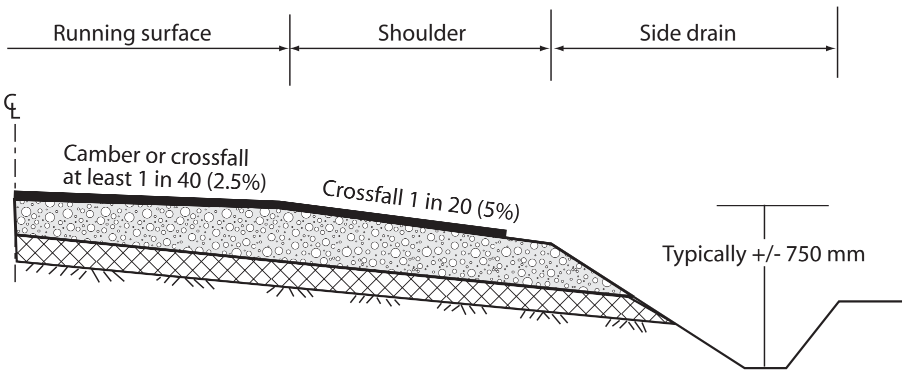


Figure 6.11 - Ideal shoulder construction/drainage arrangements

6.7.3 External Drainage

Caution is required in undertaking drainage work as interference with the natural drainage pattern can lead to major environmental damage in sensitive areas.

Introduction

External drainage involves methods of crossing of watercourses, measures to divert water away from the road and prevention of damage caused by erosion. In the construction of LVSRs there is often wide scope for the use of various measures to improve external drainage, such as low-level structures, drifts etc. where 100% passability to traffic throughout the year may not be required.

It is not within the scope of this Section to provide a *detailed* description of all the various measures that make up a good drainage system. Conditions on site will vary tremendously in respect of in-situ soils, topography, vegetation, climate, human settlement patterns, environmental concerns, etc. The skills of site personnel and knowledge about local conditions are critical for successful installation of mitre drains, catch-water drains, side drains, berms, channels, cut-off drains and crossings along the road [14].

6.7.4 Hydrology and Hydraulic Calculations

Introduction

The use of sophisticated methods to estimate run-off and for the calculation of the size of waterway structures is not always appropriate for LVSR because either the data and/or the resources required are not available. Thus, alternative methods, which also rely on visual observations and historical evidence from consultations with the local populations are often more appropriate. Furthermore, financial constraints also mean that a compromise is often required between structures that provide all-weather access and those that can be constructed with the available resources.

Method

The capacity of drainage structures should ideally be calculated on the basis of local experience gathered over a long period of time and should be updated to cater for any recent changes in rainfall pattern and climate. However, such information is often not readily available in many countries, prompting a need to develop standards for drainage design and calculations. In all cases it is advisable to combine calculations with observations on site, in addition to information from reliable local sources.

With the ever-increasing cost of maintenance, it is desirable to increase the size of drainage structures to a minimum of a 600 mm opening so that they can be easily maintained.

Overtopping on LVSRs, although undesirable, has less impact on the economy than if it occurs on HVRs.

Return Period

The return period for a given flow of water is related to the estimated statistical risk of overtopping of drainage structures. It is part of the hydraulic calculations required for each type of structure for each project on the basis of policy and anticipated consequences to the road or the public. The return period is therefore a critical parameter in the design of LVSRs because it controls the level of risk in relation to cost of construction and the type of structure that is appropriate. As a broad guide, the following return periods can be considered for LVSRs:

- Bridges: 10 - 50 years.
- Culverts: 5 - 10 years.
- Drifts or well-protected culverts: 0 - 5 years.

6.7.5 Drainage Structures

Introduction

This chapter gives some examples of the range of solutions available to designers and constructors of LVSRs. The techniques shown are the results of innovative methods tried out and applied in many countries in the region over a number of years. A basic requirement in the construction of structures for crossing water courses is to assess the need for protection of the structure against erosion during the construction period as well as assessing the risk that structures that are not designed to withstand flooding will actually experience overtopping, so that additional protection measures can be taken. Construction of low, “sacrificial” points for overtopping should be considered where available resources do not allow for the provision of structures with adequate capacity [15].

LBM

Inadequate culvert capacity, particularly in combination with high embankments can result in severe damage and expensive remedial works.

Low-level structures

A low-level structure is designed to accept overtopping without damage, and is ideally suited for LVSRs in locations where less than full all-weather passability is acceptable to the community. The two basic types listed below have been used with success in the region. Various alternative names are sometimes used to describe these structures.

Low-level drift.

- **Drifts** are designed to provide a firm driving surface in the riverbed, where traffic can pass when water levels are moderate.
- **Vented drift** sometimes named fords, causeways or Irish bridges, larger structures are called low level bridges) allow water to pass through openings, but can withstand overtopping without damage. Openings in vented drifts should, like culverts, be made large enough, preferably not less than 0.9 m so that cleaning during future maintenance is made easier and the risk of blockage is minimised.

Vented drift.

A common feature of all low level structures is that they require proper foundations and anchoring, as well as scour protection to the road prism.

Culverts

Types: Culverts are constructed on LVSRs using a variety of methods and materials. Examples include corrugated plastic pipes, steel pipes or arches, pre-cast or fresh concrete pipes, boxes, arches or half arches (“shelverts”), reinforced concrete slabs resting on blockwork in a box culvert profile and wooden culverts in a box or circular profile.

Banks of pipe profiles culverts are prone to blockage by trees even when large sizes are used.

As indicated in Box 6.19, there are many innovative ways of producing inexpensive culverts.

LBM

Inflatable rubber balloons have been used successfully as formwork for construction of concrete pipe culverts on site. Concrete is poured directly against the side of the trench, which is protected with plastic sheets.

Upstream protection against blockage by trees can be successfully constructed from old railway steel sleepers well-anchored into the riverbed.

LBM

Concrete culverts are only practical for use in labour-based methods if each section is not too heavy for handling by labour or by mechanical equipment available on site.

LBM

Box 6.19 - Innovative construction of culverts

Innovative methods are in use in the region for simple and efficient construction of culverts that are particularly well suited for application in LVSRs, especially where labour-based methods are used. Examples of such techniques include:

- use of locally produced treated planks (pine) for yard production of pipe culverts, strapped with steel bands (Tanzania)
- use of inflatable rubber balloons as formwork for site casting of concrete pipe culverts in a large variety of dimensions (Tanzania) up to several metres in diameter
- use of drums as formwork for standardised yard production of concrete modules for pipe culverts (Zimbabwe)
- use of drums as formwork (left behind) for site casting of concrete pipe culverts (Tanzania)
- use of timber for site construction of square profile culverts
- use of blockwork for site construction of square profile culverts (Botswana)
- shelverts are pre-casts concrete half-arches that require less skill for construction than culverts
- masonry vertical brick walls with concrete slabs cast on site

Location: Wherever possible, culverts should be located in the original stream bed with the invert following the grade of the natural channel. Stream bed realignment may be undertaken in exceptional cases.

Skew culverts: Water courses intercepting the road at an angle of skew of less than 20 degrees can generally be accommodated by a culvert placed at right angles to the road centre line. In such cases, the culvert inlet should be positioned at the point where the channel meets the road, and any modification to the channel made downstream of the outlet. Water crossings with a skew angle greater than 20 degrees should be provided with a skew culvert.

Inlets: To avoid silting, culvert inverts should be placed at a grade of not less than 1.25 per cent for pipes, and 0.5 per cent for box culverts. Invert gradients should be increased by one per cent in the case of culverts provided with drop inlets.

Outlets: The invert level at the outlet of a culvert should coincide with ground level. Where culverts are unavoidably constructed on a steep slope, the energy generated must be dissipated to avoid serious erosion at the discharge end of the culvert. A stilling box and widening at the outlet are effective methods of reducing the velocity of the water.

Foundation: Ideally, culverts should be located on sound foundations such as rock. Soft, saturated and expansive clayey soils may cause settlements or seasonal movements of the culvert. Removal of poor soils or stabilisation of the foundation should be considered.

Use of Labour-Based Methods

Labour-based methods are very well suited for the construction of drainage structures, excavation of drainage channels, construction of soil berms, stone pitching, scour protection, etc. Pre-cast concrete culverts are not well suited for LBM if the weight of each element is too great for manual handling.

6.7.6 Erosion

Blockwork has been used successfully for simplified construction of headwalls on small culverts and for the support of concrete slabs to make a box culvert.

Introduction

Any disruption to the natural flow of water carries a risk of erosion that may lead to environmental degradation, silting, damage to roads, damage to buildings and services, destruction of farming land and loss of fertile soil. Thus, there is a responsibility to ensure that the construction of the drainage system for a LVSR receives the same attention to good practice as the construction of other roads. Indeed, avoidance of erosion can be more critical in the case of LVSRs because of the greater challenges faced in maintaining the drainage system in remote areas where these roads are often located.

Erosion in outlet channels can cause considerable environmental damage in sensitive areas.

Scour Checks

There are many examples in the region of inexpensive and effective methods that are used to protect drainage channels and side drains by the use of scour checks that are easily constructed by labour-based methods. The scour checks can be made of wooden sticks, rocks, concrete or other materials depending on the most economical source of materials. The frequency of scour checks needs to be properly adjusted according to slope gradient in order to prevent erosion between the checks causing damage to the system. The following can be used as a guide:

Gradient of the ditch	Scour check spacing (m)
4% or less	(not required)
5%	20 m
8%	10 m
10%	5 m

Concrete scour checks in side drain.

Erosion of Culverts

Short culverts requiring high headwalls and wingwalls are prone to erosion around both inlets and outlets, especially along the wingwalls. Constructing culverts that are sufficiently long to reach the toe of the embankment will minimise necessary protection measures, future maintenance and the risk of damage to the embankment around the openings. It is necessary to carefully assess the additional cost of lengthening culverts against these benefits, especially in the case of LVSRs that are often located in remote areas where regular maintenance is a challenge.

Slope Protection

If required, placing of topsoil and planting of vegetation on the slopes of embankments should take place in order to minimise erosion before indigenous vegetations can establish roots.

When there is a risk of erosion at outlets, suitable aprons and other protective measures are required.

Box 6.20 - Planting of vegetation for protection of slopes against erosion

Where grass or other vegetation is planted for protection of slopes, it is absolutely vital that professional advice to be obtained from a botanist. Failure to do this could lead to intrusion of non-indigenous species that could threaten the environment or cause damage to local farming.

6.8 Summary

The key points raised in this chapter are:

1. The characteristics of LVSRs are such that the methods employed for their construction may be different from those for more highly trafficked roads. In some circumstances labour-based methods can be effectively employed for many, if not all, of the construction activities.

2. Construction of LVSRs are often carried out in remote rural areas. These circumstances can give rise to special problems relating to health, safety and the environment and appropriate measures need to be taken to ameliorate any detrimental effects of the road construction processes on local populations and the environment.

3. A higher degree of awareness of the properties and use of materials is required in the construction of LVSRs so the use of the (often) scarce resources of good quality road-building material can be well managed.

4. The nature of LVSRs construction provides a range of both technology choice and equipment use. The selection of equipment must be matched to the chosen technology in order that the the highest quality of construction is attained with the resources available.

5. Compaction of natural gravels is an essential component for the good performance of LVSRs. Where the materials are suitable, compaction to refusal during construction adds relatively little to construction costs but is likely to produce significant benefits from improved road performance. Conversely, poor compaction is likely to lead to lower density, moisture ingress, deformation and increased maintenance.

6. Good quality control during construction is important in the construction of all roads but is particularly important on LVSRs, where greater use is made of locally available resources. It is important that these roads provide a good quality riding surface and pavement performance so that unexpected maintenance inputs do not occur.

7. Many of the natural gravels used in the construction of LVSRs provide high strengths when dry but are also moisture sensitive. Keeping the pavement dry through good drainage is, therefore, a critical factor in the performance of LVSRs and it is important that measures that reduce moisture ingress are applied at the construction stage rather than later, when they are generally much more expensive to carry out.

8. Perceived risks associated with the use of unconventional approaches, technology and materials can be sensibly managed through relatively low-cost measures that ensure good performance.

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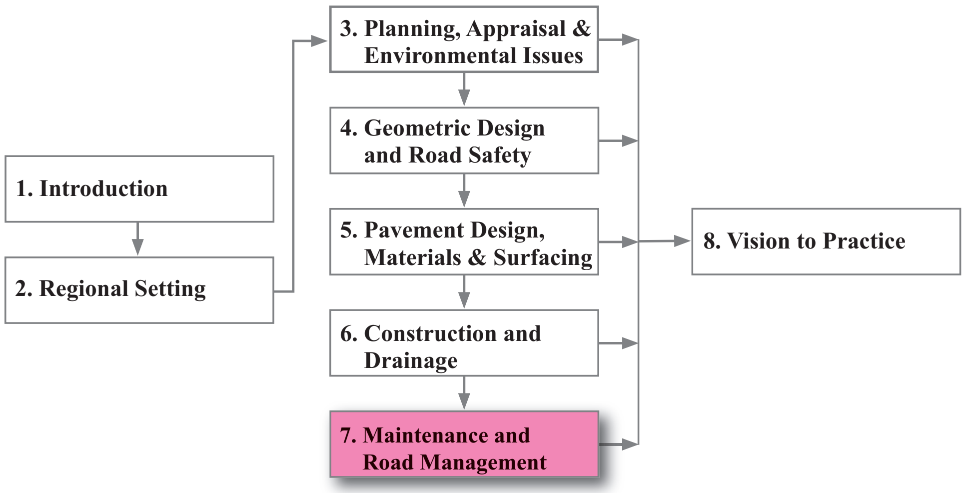
Chapter 7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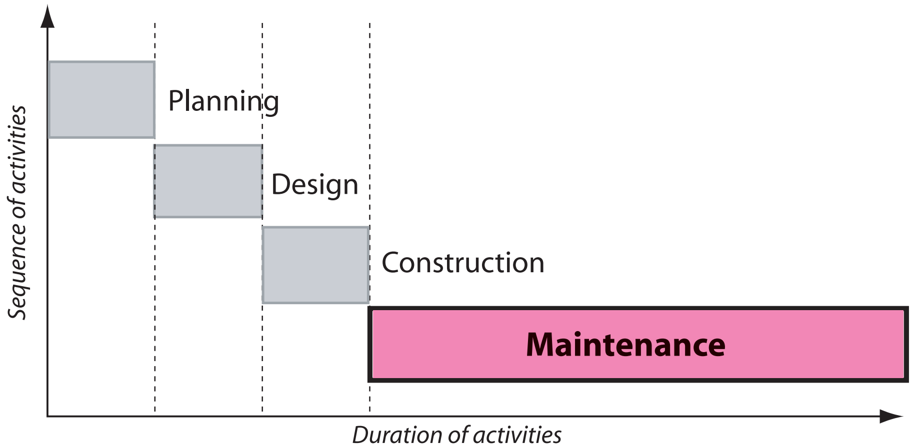
Maintenance and Road Management

7

7.1 Introduction

7.1.1 Maintenance



Definition of road maintenance

"To conserve as nearly as possible, the original designed condition of paved and unpaved roadways, and of traffic signs, signals and markings, in a manner most likely to minimize the total cost to society of vehicle operation and accident cost, plus the cost of providing the maintenance itself, under the constraints of severe resource limitations, in respect of skilled manpower, equipment and money, both local and foreign." (PIARC).

Road maintenance is an integral component of the LVSR provision process, the type and cost of which are influenced significantly by decisions made during the preceding planning, design and construction phases. Proper maintenance contributes to the preservation of the road asset and to prolonging the road's life to its intended service duration. Without adequate maintenance, roads deteriorate rapidly, become dangerous and costly to use and, ultimately, the costs to the economy are substantial.

Whereas design and construction of LVSRs are dominated by engineering issues, maintenance is essentially a multi-dimensional issue in which the management and technical aspects are influenced by political, social and institutional issues. For example, the use of maintenance works as a poverty alleviation tool through appropriate community involvement is assuming increasing importance.

Maintenance currently constitutes one of the major preoccupations of roads agencies in the SADC region. In the early stages of road development, most of the road expenditure was spent on construction. However, as these networks have become more developed, the expenditure required for adequate maintenance and rehabilitation has increased relative to that required for new construction.

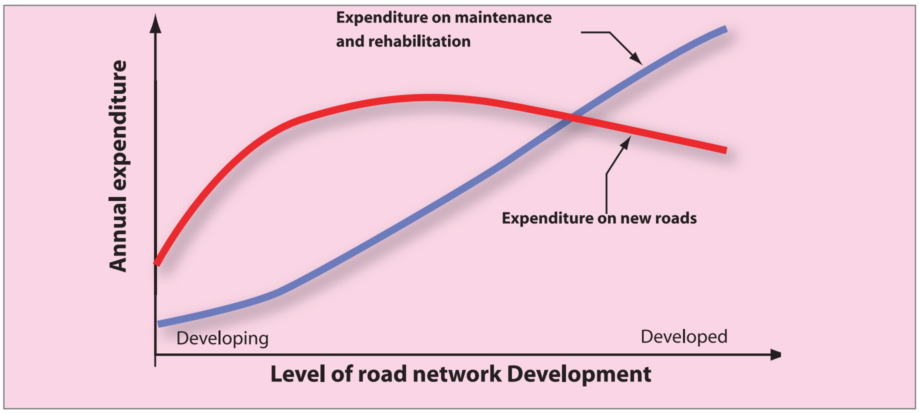


Figure 7.1 - Pattern of road expenditure in the SADC region

Example of a badly deteriorated road that has received little, if any, maintenance since it was first constructed? Result? Very high vehicle operating costs and loss of most of the original investment.

Unfortunately, for a variety of reasons, including lack of adequate funding, provision of satisfactory road maintenance still remains an elusive goal for a number of SADC countries. As a result, these countries, and the region as a whole, have paid a high price in terms of deteriorating road networks, very high transport costs and the reluctance of donors to assist with the funding of new or rehabilitation projects. Fortunately, however, roads agencies are beginning to tackle the maintenance challenges in a more holistic manner to improve efficiency and effectiveness and to achieve sustainability.

7.1.2 Road Management

The SADC road system represents a major investment and is one of the region's largest public sector assets, with a replacement cost of more than $50 billion (2000). Indeed, the asset value of the road system often exceeds the combined value of all the other surface transport systems. Therefore, it is extremely important that this asset be preserved through effective and efficient management. In the absence of this, the investment can be eroded quite quickly because roads that are not maintained deteriorate very rapidly.

Even for relatively low-trafficked road networks, reliable information has become essential for effective management. This has led to the development of management tools, including various types of road management systems, that assist roads agencies in allocating resources in a manner that achieves the best value for money. However, to be sustainable, such systems should be carefully chosen to match the available resources - both technical and financial - of the roads agency. Unfortunately, there are a number of examples of systems which have failed to work satisfactorily.

7.1.3 Purpose and Scope of Chapter

The main purpose of this chapter is to provide guidance on how to improve the maintenance and management of LVSRs through the adoption of appropriate institutional arrangements, management strategies and technical standards. Guidance is also given on criteria for establishing road management systems to assist roads agencies in the overall management of their road networks. Aspects of maintenance operations are not covered in detail because sufficient reference texts on this topic already exist.

7.2 Maintenance Issues

7.2.1 Maintenance Setting

Why Maintenance?

The case for maintenance is compelling. Having spent time, effort and money in planning, designing and constructing a road, it is vital to ensure that the asset is preserved by timely and effective maintenance. Such maintenance has three principal purposes:

- it prolongs the life of the road and postpones the day when renewal will be required
- it reduces the cost of operating vehicles on the roads
- it helps to keep roads open and ensures greater regularity, punctuality and safety of road transport services

The first purpose corresponds most directly to the interest of the roads agency, the second to that of operators of vehicles, and the third, more generally, to that of the inhabitants of the area traversed by the road.

__Routine maintenance:__ Fixed cost activities that are carried out irrespective of the engineering characteristics of the road or the density of traffic (e.g. grass cutting) and cleaning of drains.

__Recurrent maintenance:__ Activities required throughout the year but whose frequencies vary with traffic, topography and climate (e.g. road marking).

__Periodic maintenance:__ Those recurrent activities that are required at intervals of several years (e.g. resealing).

__Lengthman:__ A man engaged on a contract basis responsible for routine maintenance on a fixed length of road adjacent to his own home. He is paid a fixed sum per day or month to keep drainage ditches clear, fill in potholes, cut grass, repair minor erosion to shoulders, etc.

Typical Maintenance Activities

Maintenance activities are either *cyclic* or *reactive* and can be of a *routine* or *periodic* nature. Cyclic activities are those that are carried out at regular intervals. Reactive activities are those that are carried out in response to an occurrence e.g. erosion, drainage repairs or a condition defect exceeding values dictated by maintenance standards, e.g. rutting greater than a given value.

Table 7.1 - Maintenance activities

Works Category	Maintenance Activity	Type	
		Cyclic	Reactive
Routine Maintenance	*General:*		
	Grass cutting	x	
	Removal of obstacles		x
	Culvert clearing/repair		x
	Bridge clearing/repair	x	
	Drain clearing	x	
	Erosion control/repair		x
	Carriageway markings		x
	Repairing road signs		x
	Pavement:		
	Pothole repairs		x
	Surface patching (local sealing)		x
	Crack sealing		x
	Edge repairs		x
Periodic Maintenance	Rejuvenation seal		x
	Resealing		x
	Shoulder regravelling/reshaping		x

Grass cutting - a typical, labour-based, routine maintenance activity.

Many of the activities in Table 7.1 can be carried out cost-effectively using labour-based methods. If some of the routine maintenance work is contracted on a "lengthman contract" basis, for example, there would be little or no requirement for maintenance labour camps for transport to and from the work site, thereby saving money. Some periodic maintenance work may still require specialised equipment, e.g. bitumen sealing operations, but labour-based methods can be used for many activities.

Lack of attention to simple maintenance tasks can impose a multitude of problems for road users, society and the national economy, as illustrated in Table 7.2.

Table 7.2 - Maintenance problems, effects and solutions

Road Safety		
Issue/Problem	**Effect**	**Solution**
Vegetation growth	Impairs driver visibility	Ensure safety standards are established and maintained. Carry out routine inspections to identify deterioration likely to lead to a reduction in road safety. Record and analyse accident data to provide clues to maintenance deficiencies .
Potholes	Danger to motorists	
Flooding (blocked culverts)	Reduces pavement strength	
Dirty, damaged or missing traffic signs	Increases likelihood of traffic accidents	
Faint road markings		
Damaged bridges and guard-rails		
Scoured highway shoulders	Impairs integrity of road pavement	
↓	↓	↓
Increases safety hazards to road users	**Causes more road traffic accidents**	**Need for effective and timely road maintenance**
Road User Costs		
Issue/Problem	**Effect**	**Solution**
Clear link established between pavement condition and vehicle operating costs and embodied in transport investment models (e.g. HDM-4).	An increase in surface roughness causes vehicle operating costs to increase Significant additional costs incurred by road users when maintenance requirements are overlooked.	Identify, programme and control maintenance operations.
↓	↓	↓
Rate of pavement deterioration is often not contained, causing surface roughness to increase at an accelerating rate	**Additional costs to highway users**	**Use of an appropriate maintenance management system**
Life-Cycle Costs		
Issue/Problem	**Effect**	**Solution**
Feasibility and design strategies assume: that: (a) regular pavement strengthening will be carried out to arrest deterioration, (b) care will be taken to deal with localised imperfections as they arise (e.g. crack sealing).	Failure to control deterioration results either in an earlier requirement for strengthening or substantially increased costs of reconstruction.	Optimise investment by judiciously applying maintenance interventions to arrest rate of deterioration and to preserve structural integrity of each road link in the network.
↓	↓	↓
Assumptions often not realised in practice.	Economic penalties incurred which result in a need for premature reconstruction.	Use of an appropriate pavement management system.

7.2.2 Deterioration Characteristics

All roads deteriorate with time. However, LVSRs are particularly sensitive to the vagaries of the physical environment so that timely and effective control of their deterioration becomes the key challenge to the management of road maintenance.

Even with strict adherence to proper standards of construction, roads deteriorate with the passage of time. The rate of deterioration may vary greatly depending on the climate, the strength of the pavement and underlying subgrade, the traffic volume and axle loads. The wear and tear of road surfaces by traffic is aggravated by rainwater and by changes in temperature. Cracking occurs in the bituminous surfacing which, together with the ingress of rainwater, often leads to pavement failures.

Figure 7.2 illustrates how road condition deteriorates with time and how road life may be extended by controlled maintenance.

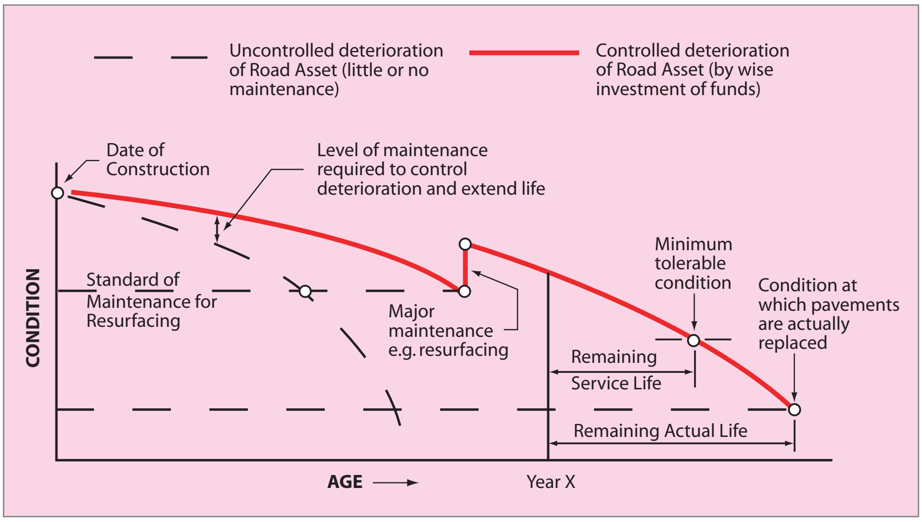


Figure 7.2 - Typical road condition deterioration with time

In Zimbabwe, the environmental component of roughness progression varied by a factor of almost 4, with low-volume roads built to lower cross sectional standards having the highest rate of progression and higher volume roads with standard designs having the lowest rate of progression. Corresponding crack initiation times and rates of crack progression were almost half and double those of standard designs respectively[1].

Of particular significance in responding to the maintenance requirements of LVSRs is the fact that, in contrast to more heavily trafficked roads, the proportion of total distress resulting from environmentally-related influences is very high, as illustrated in Figure 7.3[1].

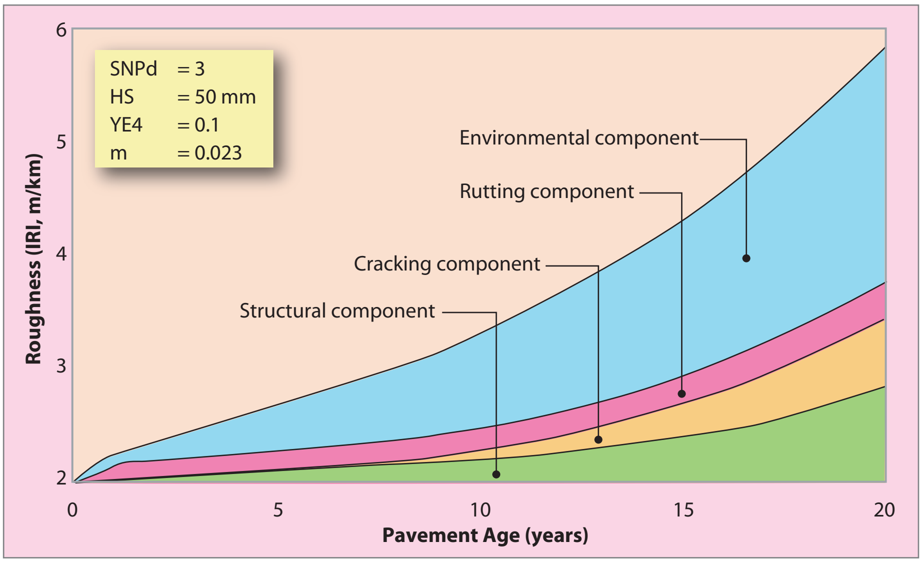


Figure 7.3 - Contribution to total predicted road roughness of different components for a low-medium volume paved road[1]

Whether the increased risk of deterioration is important in any locality will ultimately depend on the local climatic, traffic, pavement design, construction, workmanship and maintenance factors. Consequently, knowledge of local rates of deterioration will be vital. On the other hand, higher levels of deterioration and consequent reduced service standards can be tolerated from both an economic and user perspective. The lesson, therefore, is to appreciate the risks and manage these within the decision-making framework for justifying investment levels (see Section 5.4.6.)

7.2.3 Characteristics of LVSRs

As a general rule, LVSRs are built to lower geometric and pavement design standards than roads which carry higher traffic volumes. Thus they may be expected to have the following characteristics which have significant implications on maintenance operations:

- *A low cross-section profile* - thus making them more susceptible to moisture ingress and general deterioration, i.e. deterioration of the cross section which has serious impacts on overall performance.

- *Measures to protect the drainage system are usually minimal* - which often leads to increased erosion.

- *Thin bituminous surfacings are commonplace* - consequently, progressive embrittlement, poor construction or other causes of damage to the surface can easily lead to moisture ingress and consequent accelerated deterioration of the pavement.

- *The upper pavement materials are usually plastic in nature* - this can lead to a considerable loss in strength on wetting up, and accelerated deterioration under traffic load.

7.2.4 The Maintenance Challenge

The provision of adequate maintenance for LVSRs becomes even more difficult in an environment of limited funds, where resources become stretched to the limit to contain road deterioration.

LVSRs present a more demanding challenge than the more heavily trafficked HVSRs for their proper maintenance. Their characteristics, particularly their greater sensitivity to the vagaries of the natural environment, often mean that, in order to avoid rapid deterioration, maintenance must be scheduled and carried out more frequently and expeditiously than for HVSRs.

Attitudes to Maintenance

Historically, maintenance has been viewed as being un-attractive and mundane. As a result, it has not received the priority it deserves. This attitude has been strengthened by the preference of some aid agencies to finance capital rather than recurrent costs which has sometimes introduced a bias against maintenance (as recipient governments sought to use their limited funds in new construction, which would attract maximum foreign financial participation).

With maintenance often being seen as a public responsibility, funds allocated for maintenance have, on occasions, been diverted to other sectors that may be considered more deserving causes in the eyes of those involved in high level decisions. Through the 1980's and early 1990's, problems of this kind led to the deterioration of extensive parts of the main road network in many countries in the SADC region. This has contributed to the high transport costs - some four to five times higher than those in developed countries - thereby making the region globally uncompetitive. The cycle of the effects of inadequate maintenance is shown in Figure 7.4.

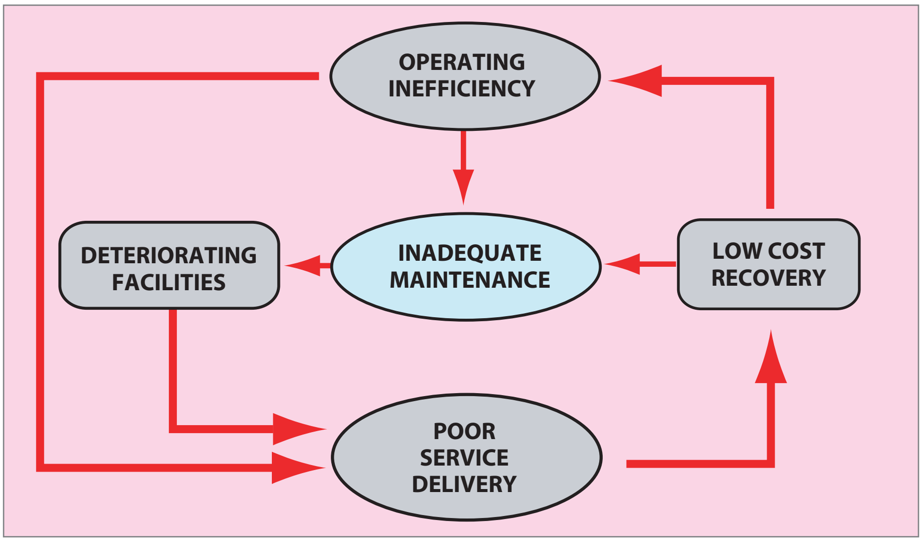


Figure 7.4 - The vicious cycle of inadequate maintenance

Funding of Maintenance

Although the concept of protecting the capital investment of road provision through timely financing of road maintenance is generally well understood, the application of this concept has presented formidable problems, primarily because of a lack of a sustainable source of funding.

In most SADC countries road maintenance expenditures are generally well below the levels needed to keep the road network in a stable long-term condition. Worse, budget allocations are often cut at short notice in response to difficult fiscal conditions, funds are rarely released on time and actual expenditures are often well below agreed budget allocations. This has led to a maintenance crisis in many countries where there is now a build-up of roads in poor condition. The net result is that the road transport sector is operating well below its optimum level, which has had an adverse impact on many other sectors of the national economy.

Box 7.1 - Maintenance backlog on the SADC main road network[2]

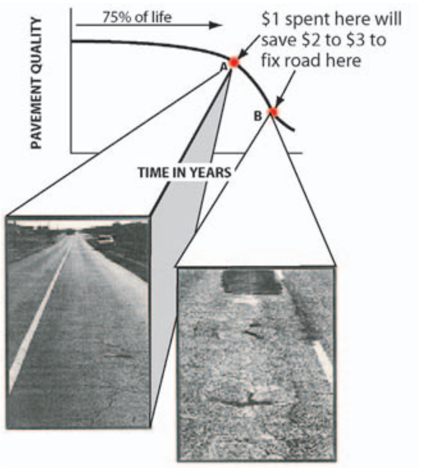
Recent studies indicate that about US$ 1.7 billion per annum (about 1 per cent of regional GDP) needs to be spent on regular maintenance of the region's roads, including a cycle of reseals and rehabilitation of paved roads. However, little more than one half of this amount is allocated.

GDP (1999)	Actual Annual Expenditure	Estimated Annual Requirement	Annual Shortfall	Back-log Maintenance
165,000	960	1,760	800	6,400

Note: All figures in millions of US $

It is also necessary to bring a significant kilometrage of main roads back to maintainable condition which is estimated to cost about US $6.4 billion.

The impact of inadequate maintenance



- *Drains get blocked (leading to flooding), verges become overgrown and obscure the driver's view, thereby increasing the incidence of road accidents.*
- *The surface deteriorates, gets rough, develops potholes and becomes difficult to drive on and vehicle operating costs increase.*
- *Soon, stretches of the road become impassable for long periods of the year.*
- *Eventually, and usually more quickly than most people realise, the road needs reconstructing, often at three to four times the cost of effective and timely maintenance.*
- *Where maintenance funds are not available, the road becomes abandoned, commerce and business stagnates, rural areas become isolated and condemned to remain poor without adequate communications.*

Inadequate Road Maintenance

New paved roads, if inadequately maintained, deteriorate slowly and almost imperceptibly during the first half to two-thirds of their service life, after which they deteriorate much more rapidly. Without timely maintenance, they simply break up and, as a result, the costs of operating vehicles - and of transporting goods - increase rapidly. Worse, vehicle operators who pay these costs, then pass them on to the general public and the cost of living increases.

In rural areas, where roads often become impassable during the rainy season, poor road maintenance has a profound effect on agricultural output. Poor roads and poor transport services also have adverse effects on the provision of health, education and other social services; these effects are not easy to quantify, but are of vital importance to the people living in rural areas and in helping to eliminate poverty in its widest sense.

Box 7.2 - The costs of poor road maintenance

A LVSR in good condition, carrying about 200 vpd, requires resealing, costing about $10,000 per km, every seven years to keep it in good condition. This has a net present value (NPV) discounted at 12 per cent over twenty years, of $7,000 per km. Without maintenance, the road will deteriorate from good to poor condition. This will increase vehicle operating costs by about $2000 per km which has an NPV, when discounted over twenty years, of $18,000 per km. The benefit cost ratio of a fully funded road maintenance programme is almost 3!

Poor road maintenance also increases the long-term costs of maintaining the road network. Maintaining a LVSR for fifteen years costs about $60,000 per km. If the road is not maintained and allowed to deteriorate over the fifteen year period, it will then cost about $200,000 per km to rehabilitate it. Thus, rehabilitating paved roads every ten to twenty years is more than three times as expensive, in cash terms, as maintaining them on a regular basis, and 35 per cent more expensive in terms of NPV, discounted at 12 per cent per year.

In quantitative terms, when a road is not maintained, and is allowed to deteriorate from good to poor condition, each dollar saved from not carrying out maintenance increases VOCs by $2 to $3. Thus, as illustrated in Figure 7.5, ***far from saving money, cutting back on road maintenance increases the costs of road transport and raises the net cost to the economy as a whole. This fact is a powerful one and one which roads agencies can use to convince government of the high cost that countries pay for inadequate funding of road maintenance.***

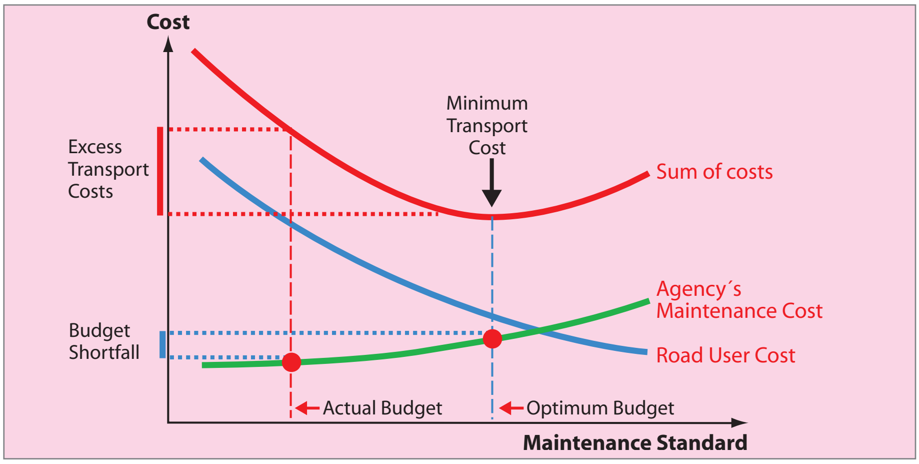


Figure 7.5 - Relationship between maintenance standard and transport cost

Vehicle overloading also has an adverse effect on road safety.

Overload Control

To protect the huge investment in road infrastructure, all SADC countries have promulgated Road Traffic Acts that stipulate permissible axle load and gross vehicle mass limits. These limits are meant to ensure that roads last for their full design life with normal maintenance expenditures. Unfortunately, overloading is rife in most countries, with rates of up to 50%. Such overloading causes not only a disproportionately high degree of road damage, because of the exponential relationship between axle load and road damage, but also contributes to the poor road safety record in many countries. Thus, overload control is particularly important on LVSRs.

Unfortunately, the current, traditional government-driven approaches to overload control have been ineffective in many countries for the following reasons:

- current systems provide a criminal response with low conviction rates
- in-house operation with low-paid staff is susceptible to corrupt practices
- there is no link between level of fines and damage to the road
- constraints in the criminal justice system result in low priority being given to overloading offences
- road authorities often have a limited role in regulating overloading
- current systems do not have the primary goal of preserving road infrastructure

There is, therefore, a need for a new approach and a vehicle loading reform strategy has been developed for the region which will form annexes to the SADC Protocol on Transport, Communications and Meteorology.
The main elements of this initiative are:

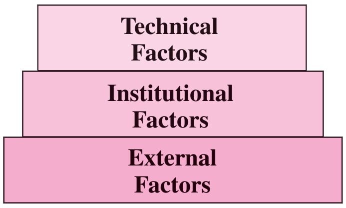
- introduction of a Regional Overloading Control Association
- introduction of a regional strategy for overload control
- operation of a self-regulatory system by transport operators
- decriminalisation of offenders by administering an overloading fee
- linking the level of the imposed fees to the actual cost of road damage
- outsourcing weighbridge operations to the private sector

7.2.5 Lessons Learned

The ineffectiveness of maintenance operations, management and financing of LVSRs (and, indeed, of all roads) in the SADC region has been the subject of much study and investigation by international and local organisations. The worst cases of maintenance ineffectiveness have been found to occur in countries where some or all of the following conditions occur, not necessarily in order of importance:

- a weak institutional framework which suffers from high vacancy rates and reliance on contract personnel
- a large amount of maintenance work carried out through “force account” operations with reliance on plant and equipment provided from government plant pools “free of cost”
- lack of basic management systems and procedures which has compromised the ability of roads agencies to manage their road networks in a satisfactory manner

Hierarchy of management issues
(Adapted from Brooks et al., 1989)



Until the external and institutional frameworks are improved, it is extremely difficult to overcome the numerous technical and human resource problems which hamper attainment of efficient and effective management of road networks in the SADC region.

- poor regulation of various aspects of road management, including control of overloading
- inadequate involvement of the community in maintenance

It is apparent that the key issues raised above are predominantly social and organisational rather than technical. They support the widely emerging view in the SADC region that many of the endemic problems associated with inefficient and ineffective management of road networks are symptoms of a deeper problem. The real causes are weak or unsuitable institutional arrangements for managing and financing roads.

New approaches

As indicated in Chapter 2, through the SADC Protocol on Transport, Communications and Meteorology[3], the SADC region has embarked on a programme of road sector reform that has fundamentally changed the way in which road maintenance is undertaken and financed.

Box 7.3 - New approaches to road maintenance operations, management and financing in the SADC Region

A new approach to road maintenance in its various aspects is emerging in the SADC region. It is no longer being viewed as a mundane topic for second-rate engineers. Today, it operates in a changed environment and with a changed approach. It now holds a key position in roads agencies as a concept that espouses the need to preserve the value of the road asset, to provide improved service to road users and to contribute to environmental quality. Sustainable sources of road maintenance financing are increasingly being provided by road users.

7.3 Maintenance Management

7.3.1 Main Purpose

Maintenance management is essentially a systematic means of efficiently planning, programming, budgeting, scheduling, controlling, collecting data, monitoring, etc. In conjunction with the road planning, appraisal and design processes, it attempts to optimise the overall performance of the road network over time. At a practical level it aims to ensure that the correct activities are performed on the network at the right time, and to the desired quality. The challenge is to set policies which can contribute the greatest benefit to communities whilst supporting broad national goals.

The undertaking of the various inter-related activities associated with the management of maintenance can be facilitated by the use of an appropriate maintenance management system. Such a system must be well conceived and careful consideration should be given to pursuing a strategy for its development which should be based on methodologies, techniques and resources that are matched to local circumstances.

7.3.2 Inventory

A road inventory is necessary for any maintenance function. It is used as a basic reference for planning and carrying out inspections in relation to a location reference system. The essential elements include road nodes, route name and length, functional classification, type of pavement and surfacing.

The inventory is a set of information about the basic engineering characteristics of the road network and is vital for any management function. It defines the key features of each section of road and is an essential reference source for inspection and analysis. The content of the inventory should be directly relevant to maintenance management. When it is first drawn up it should be as simple as possible and need only contain information on the following items.

- route name
- functional classification
- section length
- type of surface and construction
- cross-section width

As the inventory is built up, further information can be added on all factors influencing the management activities. In addition, data about the distribution and engineering properties of soils will be useful in identifying possible sources of maintenance materials. Inventory data are expensive to collect and keep up-to-date. Generally, the inventory should be as simple as possible and not be overloaded with unnecessary information.

7.3.3 Components

There are four distinct and inter-related components of road maintenance which, together, comprise a management framework for successfully addressing the maintenance challenge[4]. As illustrated in Figure 7.6, these are: Planning, Programming, Preparation and Operations.

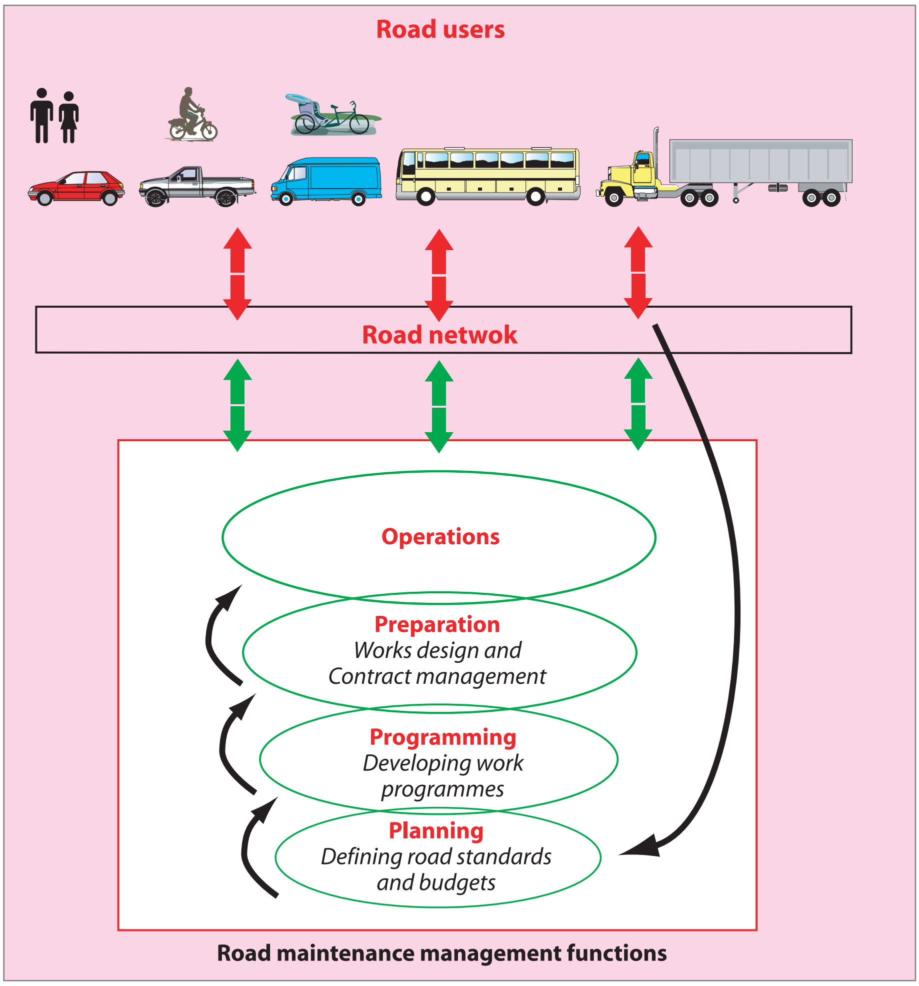


Figure 7.6 - Road maintenance management functions in relation to the road network and users [5]

Road maintenance management

At a practical level, road maintenance management aims to ensure that the correct activities are performed on the network at the right time and to the desired quality. The challenge is to set policies which can contribute the greatest benefit to communities whilst supporting broad national goals.

An implication of Figure 7.6 is that, if road maintenance at the point of delivery is to be optimised, then there is also a need to *optimise* the higher-level functions of planning, programming and preparation. However, the higher level functions will need to reflect the needs of road users on the network - an issue that has taken on added significance with the more commercialised approaches to road management currently being pursued in the SADC region in which road users have become *"customers"* of roads agencies which are now *"service providers'*. The challenge is to set policies which can contribute the greatest benefits to stakeholders whilst supporting broad national goals.

An important conclusion from the above is that any successful change to improve maintenance operations on SADC road networks should be driven from the needs and requirements of users and the network ("bottom-up") whilst supporting broader national goals of economic development and poverty alleviation. The remainder of this chapter focuses on such issues in the context of the LVSRs maintenance management cycle.

7.3.4 Management Cycle

Maintenance management strives to achieve maintenance policy objectives through a series of well defined, organised and executed functions. They relate to both long- and short-term decisions, and concern the whole network, sub-networks and individual lengths of road. The sequence of activities moves in a cycle that begins with planning and moves through programming, preparation and then operations in the manner shown in Figure 7.7[4,6].

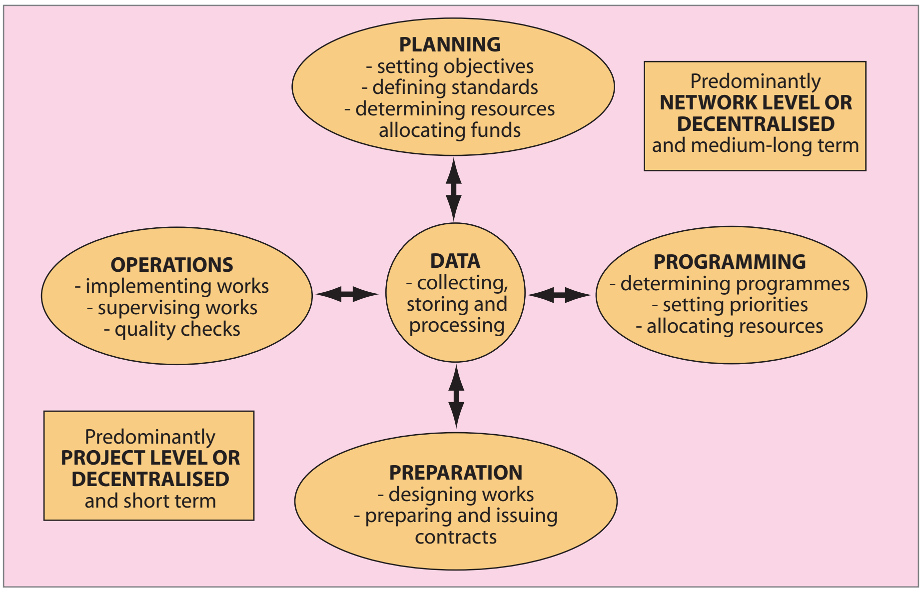


Figure 7.7 - The cycle and scope of maintenance management functions

The following issues are important, though not exclusive, to LVSRs:

- Effective management depends on the availability of sufficiently comprehensive data on all assets, traffic and costs.
- Participation, or effective representation, at the highest level, i.e. network planning, is usually essential to ensure that adequate resources are made available for maintenance.
- Whilst general programming and prioritisation might be done at a central level, more detailed programming will benefit from greater local knowledge and participation.

At each stage, procedures are required to guide staff in their duties, and should form the basis of more formal management systems which, for low-volume sealed roads, may comprise simple manual or spreadsheet-based systems.

Having defined in general terms the nature of maintenance, the following sections consider the operational environment within which maintenance resides with a view to offering solutions to its more effective delivery.

7.3.5 Maintenance Policy and Organisation

A policy framework is required to provide the context within which road maintenance is carried out in the SADC region. Maintenance policy would be expected to support Government policy in the roads sector. Increasingly, maintenance policy is now focusing on broader national issues pertaining to the attainment of socio-economic goals, greater involvement of the private sector and more attention to fulfilling users' expectations.

Box 7.4 - Typical Maintenance Policy Objectives for LVSRs

The following are examples of typical policy objectives which are essential for ensuring that maintenance is carried out in a sustainable way:

- Poverty reduction through employment creation and the related use of labour-based methods wherever feasible.
- Local community involvement in the planning and execution of maintenance of rural road facilities.
- Private sector involvement (local contractors) in road maintenance (rather than undertaking such maintenance by force account operations).
- The use of the most cost-effective rather than most technologically advanced approaches in carrying out road maintenance.
- Minimising the environmental impact of material resource developments by adopting Environmental Impact Assessments.
- The use of maintenance standards that balance life-cycle costs (construction, maintenance and vehicle operating costs).
- The use of simple contract documents appropriate for use by small contractors.

The SADC protocol on Transport, Communications and Meteorology envisages an institutional framework which clearly differentiates between the roles played by road sector stakeholders in policy formulation, policy delivery and works execution. The arrangements were illustrated earlier in the General Introduction to this Guideline (Chapter 2, Figure 2.5 - SADC institutional framework). This is a significant change from the previous arrangements which led, in one way or another, to the road maintenance crisis of the 80's and 90's.

Another significant change relates to the private sector, which is now involved as network maintenance contractors and network management consultants. The nature of the contracts may also be long-term and outcome-based, as opposed to the more traditional "schedule of rates" approaches.

Regional agencies, with a greater degree of autonomy than previously, can be expected to be involved in priority setting and communities might also deliver services at the operations level.

Table 7.3 - Functions of various road sector stakeholders

Function	Typical aims	Spatial coverage	Organisations concerned
Policy	Policy formulation. Formulation of strategic objectives. Defining standards.	Network-wide.	Ministry.
Strategic Planning	Determining resources to support defined standards and objectives.	Network-wide.	Roads Agency (HQ) with approval by Ministry policy advisors.
Programming	Determining the work programme that can be executed within the budget period and resource constraints, including local priorities.	Network-wide to Region or sub-network wide.	Regional Agencies or Consultant and Contractors and Communities.
Preparation	Design of works. Preparation and issue of contracts and works instructions.	Sub-network, Road-link, Section or project.	Regional Agencies or Consultants and Contractors.
Operations	Undertaking tasks as part of works activities.	Sub-network, Road-link, Section or project.	Contractors and Consultants and Communities.
Monitoring and Evaluation	Measuring achievements against performance, end product and financial targets.	Network-wide to project level.	Representatives of all functions, including Road Fund Board.

7.3.6 Maintenance Standards

In the constrained budgetary situations that prevail in most SADC countries, maintenance standards and associated levels of user service should be set, wherever possible, on the basis of minimising total transport costs over the life-cycle of the road link. If maintenance is carried out too frequently, or to a too high standard, the maintenance provided will be unnecessarily costly and resources will be wasted just as they will be if too little maintenance is carried out.

Badly potholed road.
Is this acceptable?
No

Road with occasional potholes which can be maintained through patching, but with a waterproof surface.
Is this appropriate?
Yes

Road in excellent condition.
Is this always affordable?
No

Figure 7.8 - Choosing appropriate maintenance standards

For LVSRs, the range of choices is typically as illustrated in Figure 7.8. In many cases the middle example will often provide the most appropriate solution, but this will depend on local circumstances and the extent to which it fits with the current views of policy makers and users, and those of engineers and planners.

The Engineer and the Planner will need to specify an appropriate standard for all types of maintenance and, importantly, to be able to justify this to policy makers and the paying public. They will also need to be flexible and to take into account local circumstances. Their responses may vary from a comprehensive, ‘Full’ maintenance strategy where the objective is to minimise life-cycle transport costs, to a minimum strategy which will help fulfil ‘Basic’ access standards. A strategy to minimize road user costs, which is the expensive option, is unlikely to be promoted by stakeholders.

Resealing is a typical periodic maintenance activity.

Typical examples of routine maintenance standards, intervention levels and work procedures, in relation to road function, are given in Table 7.4. Similar standards and maintenance strategies can also be developed for periodic maintenance. Many models exists for such analyses (e.g. HDM 4, RED) but their applicability becomes more and more questionable when road user savings are small relative to the cost of the road. In such situations, cost-minimisation strategies become a prudent alternative, *without compromising road safety.*

Table 7.4 - Typical routine maintenance standards

Activity	Standard		
	A	B	C
	Strategic/Primary roads **AADT >150**	**Secondary/Tertiary roads AADT < 150 and > 50**	**Secondary/Tertiary roads AADT < 50**
Grass cutting	Grass height ≤ 30 cm	Grass height ≤ 30 cm where sight distance must be maintained	As the need arises
Removal of obstacles	Clear carriageway immediately; Clear rest of road area and repairs within 5 days	Clear carriageway immediately; Clear rest of road area and repairs within 10 days	Clear carriageway immediately; Clear rest of road area and repairs within 60 days
Culvert clearing/ repairs	Clearing and repairs before wet season; Clear once a week during wet season; Repairs within 20 days	Clearing and repairs before wet season; Clear once every 2 weeks during wet season; Repairs within 30 days	Clearing and repairs before wet season and, when required, during wet season
Bridge clearing/ repairs	As above	As above	As above
Erosion control/ repairs	As above	As above	As above
Drain clearing	Clean out within 5 days when drain depth is reduced by > 20 %	Clean out within 10 day when drain depth is reduced by > 30 %	Clean out within 20 days when drain depth is reduced by > 50 %
Pothole repairs	Repair potholes within 2 days	Repair potholes within 2 days if > 5 potholes/km or during wet season, otherwise repair within 10 days	Repair potholes within 5 days if > 10 potholes/ km or during wet season, otherwise repair within 20 days
Surface patching	Repair within 2 days	Repair within 5 days	Repair within 10 days
Crack sealing	Seal all cracks before wet season starts; Seal immediately during wet season; At other times seal within 5 days if affected road section is > 10 m or if crack width is > 3 mm	Seal all cracks before wet season starts; Seal immediately during wet season; At other times seal within 10 days if affected road section is > 50 m or if crack width is > 3 mm	Seal all cracks before wet season starts; Seal immediately during wet season; At other times seal within 20 days if affected road section is > 50 m or if crack width is > 3 mm
Edge repairs	Edge drop should not be > 15 mm; Correct within 10 days	Edge drop should not be > 25 mm; Correct within 20 days	Edge drop should not be > 25 mm; Correct within 30 days

Note: Adapted from TRL (2003)[7]


Visual condition survey.


Measuring bearing capacity using Benkelman Beams.


Roughness can be measured by using rapid or slow measuring devices such as a Bump Integrator or Merlin device.

7.3.7 Assessing Needs

Road condition surveys are an important aspect of the maintenance process and are carried out to establish maintenance requirements and, subsequently, priorities. Such surveys are normally carried out in two stages:

- Network screening survey - in the first stage, an engineer or senior technician undertakes a drive-over survey of the network to identify those sections likely to need treatment.

- Detailed pavement testing - the second stage involves a small team, led by a technician, whose task is to determine the requirements for reactive and periodic works, and to identify those sections where detailed investigations are needed prior to carrying out renewal works.

Figure 7.9 gives a flow diagram of road condition surveys. Visual condition surveys, including a drive-over of the network, are normally adequate for LVSRs, with a detailed walk-over survey done selectively for sections appearing to need major works. Detailed pavement testing e.g. using a FWD, Benkelman Beam or DCP, is required for pavement rehabilitation design but this is not the main concern in this Guideline. The concept of Information Quality Levels (IQL)[8] have been developed with a level of detail that is appropriate for LVSRs.

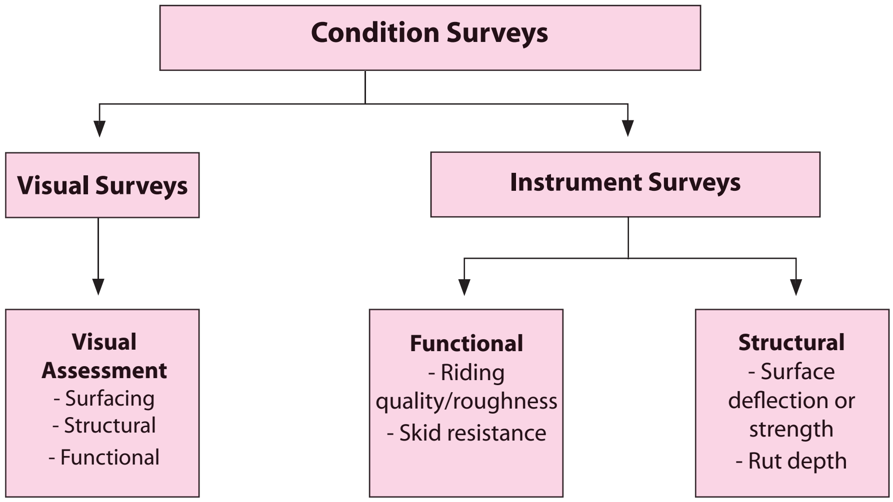


Figure 7.9 - Flow diagram of road condition survey tasks

Common types of road condition data collected during surveys are given in Table 7.5.

Table 7.5 - Condition data elements

Data Category	Data Elements	
Visual (to be followed, if necessary, by more detailed inspection and measurement)	• Texture • Surfacing failure • Surfacing cracks • Block cracks • Crocodile cracks • Longitudinal cracks • Transverse cracks • Pumping	• Aggregate loss • Binder condition • Bleeding/Flushing • Rutting • Settlement • Patching • Potholes
Visual and/or instrument	• Deflection (FWD or • Benkelman Beam) • DCP • Rut depth • Riding quality/roughness • Skid resistance • Surface drainage • Cross - section	• Laboratory tests • Side drainage • Shoulder condition • Edge break • Passability

It is preferable that direct measures for each type of distress are reported for maintenance management purposes rather than combining several distress parameters into a single index. This is because different types of distress often require different treatments. A combined index obscures the severity levels of the various distress types and therefore makes it difficult to identify optimum treatment. Nevertheless, a combined index, such as the Present Serviceability Index (PSI), can be useful for reporting the condition of roads to non-specialists, who are unlikely to understand the engineering importance of the different type of distress that may occur.

Irrespective of the road class, measurement of distress should be undertaken tri-annually, with the statistics presented in a cumulative frequency distribution for each road class, as illustrated in Figure 7.10. This can be used to illustrate the current condition of the asset in relation to target values and previous and current conditions.

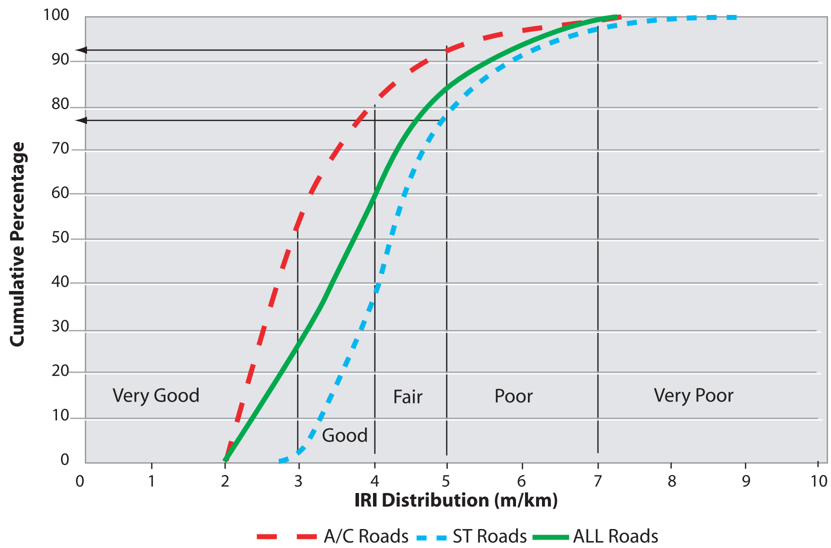


Figure 7.10 - Example of roughness distribution for different road classes

7.3.8 Determining Priorities

Even when standards have been developed on an economic basis or in support of policy objectives, the fact that budget allocations are invariably less than the desired amount means that choices must be made. The types of choices include whether to:

(a) delay investment until more funds are available
(b) lower standards
(c) perform certain activities in preference to others

Different approaches are available for prioritising works. Some depend on the type of road, works type and traffic levels, whilst others take account of issues such as the population served, economic indices, social indices and strategic importance. They are often applied differently to paved or unpaved roads and to high or low-volume roads.

Three approaches are introduced below that span the range of available techniques and may be used to complement each other. They address the range of issues and potential conflicts important for low-volume sealed roads. These are:

- Treatment choice method (TRL, 1987)[7].
- Cost effectiveness methods.
- Economic NPV and NPV/Cost methods.

Treatment Choice Method: In this method, funds are earmarked for 'essential' maintenance activities such as addressing emergency works, access restoration (over short stretches), drainage maintenance and asset preservation. Remaining funds are distributed to more heavily trafficked roads justifying more expensive treatments, with unfunded works being postponed or other budget sources sought. It is both simple and flexible, since the user can specify the order of importance based on local priorities. An economic underpinning does exist in that it is widely recognised that routine maintenance provides a higher economic return than an intervention occurring only after significant distress has already occurred.

Table 7.6 - Example of "Treatment Choice Method"

Hierarchy of maintenance activity	Priority							
	Traffic hierarchy							
	1	2	3	4	5	6	7	8
Traffic range (vpd)	Strategic	> 1000	500-1000	200-500	> 200	< 200	50-200	< 50
Surface type	P	P	P	P	UP	P	UP	UP
Emergency	1	7	8	9	10	11	12	13
Cyclic drainage	2	14	15	16	17	18	19	20
Reactive pavement work	3	21	24	27	30	33	36	39
Periodic preventative	4	22	25	28	31	34	37	40
Other cyclic/reactive	5	23	26	29	32	35	38	41
Overlay/reconstruction	6	42	43	44	45	46	47	48

Note: P = paved, UP = unpaved

Cost-effectiveness methods: These methods introduce other considerations into the prioritisation process that are not addressed by conventional transport economic approaches. These considerations include:

- magnitude of population served
- weighting for degree of poverty in the communities
- potential for agricultural or other development
- number of social and other services

This approach might best be applied to rural feeder or collector roads, where the geographical area which benefits from an improvement can be precisely defined. It also lends itself to application at a local level through the direct participation of representatives of various stakeholder groups. Reference should also be made to Chapter 3 in this regard.

Economic NPV and NPV/Cost methods: These methods are appropriate for relatively heavily trafficked roads relying on user benefits for economically justifying maintenance interventions. They are employed in models such as HDM-4 or RED which have been described in Chapter 3.

7.3.9 Management Systems and Tools

In the SADC region, where allocations to the roads sector have generally not kept pace with requirements, it is vitally important that scarce funds are allocated to competing components of the road system in an optimal manner. However, even with the best of intentions, the determination of such a balance cannot be competently assessed by traditional methods which generally relied on fixed standards, subjective judgement and intuition. Nor can appropriate funding and pricing strategies for promoting more efficient use of resources in the roads sector be developed. To this end, the use of an appropriately structured Road Management System can greatly assist roads agencies in managing and financing their road networks efficiently and effectively.

The main objectives of a Road Management System are to:

- Provide a systematic and structured means of developing annual work programmes, resource requirements and budgets based on optimum *economic standards*.
- Ensure an equitable distribution of funds over the country and enable priorities for allocations to be determined in a rational way when available funds are inadequate.
- Authorise and schedule work.
- Provide a system for monitoring the efficiency and effectiveness of maintenance works.

The potential benefits of efficient road management systems are well documented. However, few systems have been sustainable within developing environments. Current difficulties are partly a consequence of the substantial resources required to operate them effectively, particularly the basic data collection itself and the over ambitious expectations of users. Key elements, such as the importance of cost-effective standards, proven treatment selection and prioritisation methods and the quality of service delivery are often given insufficient attention.

Experience from the SADC region and elsewhere indicates that the 'institutional' dimension has often been sadly neglected and that, if the foundations and commitment required for sustainability do not exist, the systems will fall into disuse and become ineffective. This has been put into sharp focus throughout the region as a result of the road reform process and the resulting changes in responsibilities, which have clearer outcome-based objectives and require more transparency and accountability.

For a road management system to be sustainable, commitment from senior people is vital. However, complexity and excessive resource requirements, especially at the early stages, are serious risks. Sustainability is likely if a step-wise approach is adopted for its introduction, starting with a simple system requiring modest data collection in keeping with the current institutional capacity of the roads agency. An integrated modular design should be employed to facilitate future expansion and improvements and these should be introduced gradually as the operation of the system becomes institutionalised.

Specification of Road Management Systems (RMS)

The approach for developing a specification for a system for application to low-volume sealed roads, and most other categories of road infrastructure, should[6]:

- be simple, since this will ultimately retain a greater feel of transparency and comprehension by users
- specify the *scope* of the system and its component modules or sub-systems
- identify the prospective *users* of the system and their role in managing its various parts and the access they will require across the whole system
- confirm the *outputs* that its users will require
- select the categories of *data* and *models* required to produce the outputs, and how the data will be collected and processed

An example of a simple, basic RMS is shown in Figure 7.11.

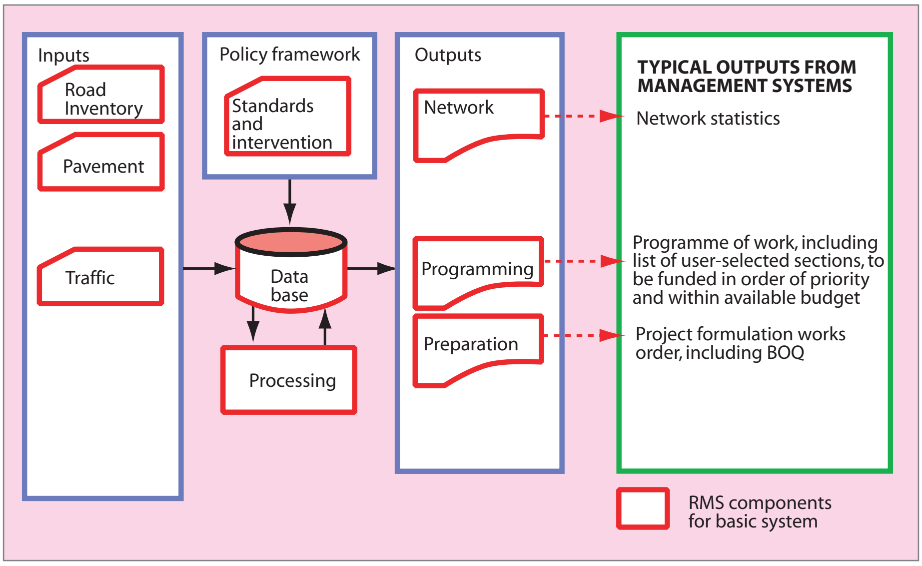


Figure 7.11 - Example of a simple, basic RMS

The scope and components (or sub-systems) typically include:

- A Network Information System at the core that is used to assemble, organise and store data about the network, including road inventory, pavement details, structures, traffic, finance (including budgets), on-going and planned activities, and resources.

- A number of Decision Support Systems (DSS) to assist in the tasks that form the management cycle.

Decision Support Systems produce *outputs* which inform management of decisions, whereas information systems simply list or present input data in tabular, graphical or map format.

The above approach tends to emphasise the overall purpose of the system, and de-emphasise the software and hardware considerations which, though important, are peripheral to the development of a system, at least in its early stages. This approach also emphasises user control, and places systems in their appropriate place.

Whether data are collected and presented in simple tables or spreadsheet formats, or manipulated in databases and processed through an analytical tool, the rules and processes employed should reflect the technical procedures described in the foregoing sections. More detailed guidance on system specification and example outputs are given in various source documents[5,6,7] and proprietary systems manuals.

Data Requirements

Probably the largest component of running costs for a Road Management System is that incurred in data collection. Thus, the type and quality of data to be collected will depend on what is actually needed and what can be realistically achieved. Only data which can be regularly updated and maintained should be collected and verified for consistency and completeness. To this end, the following criteria should be considered when selecting data items:

(1) *relevance:* having a direct influence on the required output

(2) *appropriateness:* both to the stage of planning and management process, and to the authority's capability to undertake the required data collection

(3) *reliability:* in terms of accuracy, coverage, completeness and correctness

(4) *affordability:* in both financial, and staff requirement terms

It is also important to select data acquisition technology that matches the requirements of the road agency. Choices to be made in the selection of data collection methods include:

- Mode of operation
  - manual, semi-automated or automated
  - pedestrian, slow or high-speed
  - independent or composite instrumentation

- Frequency, spatial coverage and spatial sampling of surveys

- Mode of administration
  - centralisation
  - audit process

The range of data quality and detail required, in terms of Information Quality Levels (IQL), depends on the management function and should also be matched with resources available. Guidance on various aspects of data management for road management systems is provided in literature on this subject[7].

7.4 Maintenance Operations

7.4.1 Organisational Roles and Models

Current and previous practice in many countries in the SADC region and, indeed, in most other countries in the world, has been to carry out maintenance (particularly routine maintenance) by direct labour i.e. labour permanently employed by roads agencies. However, this has proved to be inefficient in many countries and, in accordance with the SADC Protocol, there has been a gradual change in the execution of maintenance works towards the increased use of the private sector.

Roles

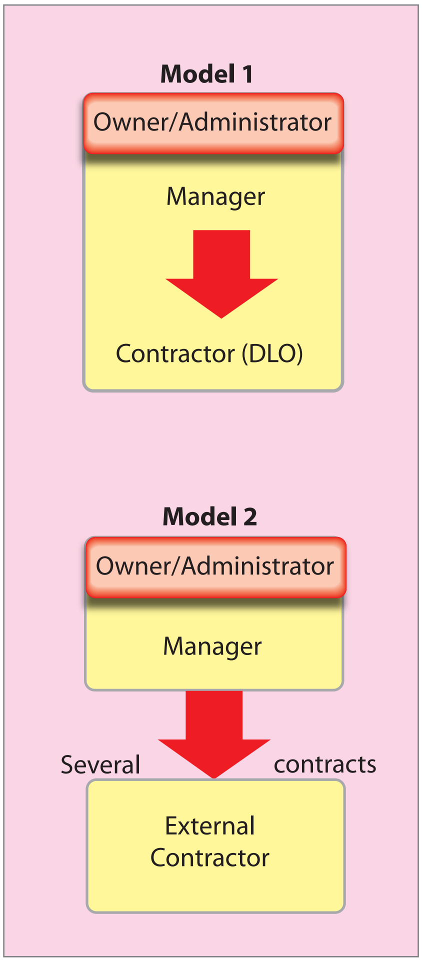
The terms used to describe the organisational roles which prevail in the SADC region are as follows[4]:

Owner: The organisation responsible for funding, establishing road policy and the legal and regulatory framework for management of the road network. Typically, this will be a ministry of transport or works acting as the *de facto* owner on behalf of the state.

Administrator: The organisation responsible for implementing policy and ensuring that the performance of the road network meets the overall political and economic aims of the owner. In many countries, this is referred to as the road authority or agency.

Manager: The organisation, responsible for specifying activities to be carried out, supervising, controlling and monitoring activities. In most situations, the manager role is combined with that of the administrator, but increasingly worldwide there is a move to appoint managers under contract (typically, engineering consultants).

Contractor: The organisation, responsible for delivery of operations by executing or undertaking works for the road administrator.

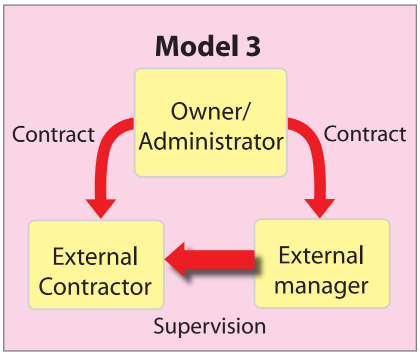


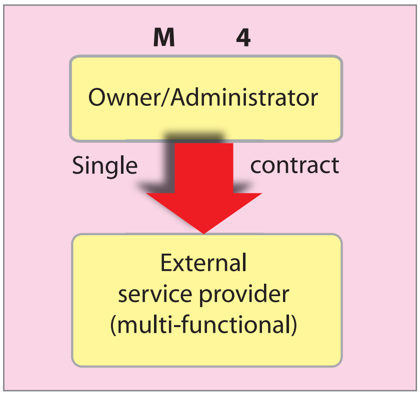
Models

Model 1 - In-house works unit (Direct Labour Organisation - DLO): This is the traditional model for undertaking routine and, occasionally, periodic maintenance works. In this case the administrator, manager and contractor are all part of the same organisation. In many cases, this will be the owner´s organisation, such as a ministry of public works.

This traditional approach is gradually being phased out in the SADC region as more and more agencies are becoming autonomous or semi-autonomous organisations with a greater separation of "client" and "supplier" roles within organisations.

Model 2 - Conventional contractor: In this model, the road administrator, who lets conventional civil engineering contracts to an external contractor for carrying out the works, takes the manager role. The model is widely used for carrying out development and periodic maintenance works but is less widely used for carrying out routine and special maintenance works.





Model 3 - Conventional contractor-consultant: In this model, the road administrator lets contracts for both the manager and contractor roles. Consultants typically undertake the manager´s role and have the task of supervising the work undertaken by contractors.

Many of the new Roads Agencies continue to employ this model, but with the Agency itself being bound by a “Performance Agreement” with the Owner Ministry. Their performance is monitored by a Road Board, or other independent body, which essentially fulfils an audit role.

Model 4 - Total service provision: In this model, a single contract is let by the road administrator to the manager who is responsible for providing services to the administrator. The manager organisation may choose whether to undertake the contractor roles itself, or engage contractors. There are few existing examples of this, although this type of arrangement is gaining favour.

7.4.2 Performance and Contractual Agreements

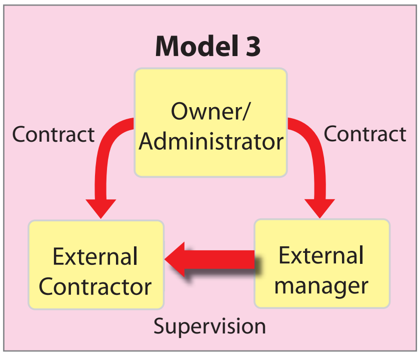
The change in circumstances requires a new set of agreements to be identified which are both legislative in nature, in that they transfer established responsibilities to a new organisation or responsible body, and contractual in nature. The changes also transfer a substantial amount of financial and technical risk to service providers, including road managers and contractors, and require new approaches for monitoring and evaluation. The appropriateness of the arrangements needs to be considered from the perspective of the supplier’s ability to accept risk and to provide the necessary quality management. This will ultimately decide the scope of works which various providers can deliver.

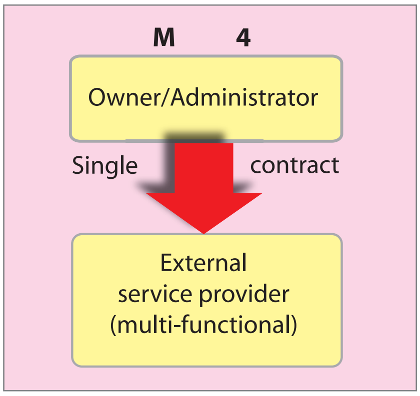
The characteristics of the various types of contract, in which their relevance in rural situations, is emphasised, are indicated below:

Day labour: This type is purely a supply-only contract, and could be extended to include plant and materials. It continues to be appropriate where contractor development and the scale of operations is small or uncertain. An appropriate example would be the supply of labour by ‘lengthmen’ contractors, perhaps organised through a community association, but with overall management vested in a local works department or managing agents.

Schedule of rates: This is the most common form of contract, (Model 2 above,) where the contractor is not subject to significant performance-based requirements, and undertakes a prescribed set of activities at specified intervals, or when conditions exceed ‘intervention standards’. Rates are negotiated, or in some cases stipulated by the purchaser; the reason for the latter is related to the stage of ‘commercialisation’ in the sector. The quality of workmanship will be specified, *and work planning and method guidelines* may be provided to ensure consistency in approach to each operation. Many road authorities in the region have adopted such guidelines.

Performance-based, short-term: Performance-based contracts require the contractor to accept the greater part of the risk and to plan and specify the long-term maintenance needs to satisfy the outcome-based performance specification of the Client, and are usually lump sum contracts. The scope of work includes routine and emergency works and can extend to include





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Performance-based, short-term: Performance-based contracts require the contractor to accept the greater part of the risk and to plan and specify the long-term maintenance needs to satisfy the outcome-based performance specification of the Client, and are usually lump sum contracts. The scope of work includes routine and emergency works and can extend to include periodic works, the need for which requires approval processes to be actioned by the Client. In many cases, the contract incorporates provision for periodic works, thus reducing the need for new procurement processes within the contract term thereby providing a greater guarantee of workload for the contractor. Such contracts are generally termed *Network Maintenance Contracts* (in Australia) or *Term Maintenance Contracts* (in the United Kingdom) and are usually managed according to Model 3 above.

Performance based, long-term: These extend the responsibilities to the service provider, who provides a 'total service' as illustrated in Model 4 above. The long-term nature of these contracts means that substantial planning and management capability must reside within the service provider. The works include all maintenance activities and rehabilitation. Key Performance Indicators need to be set by the Client for long-term and short-term attributes. It is then the contractors who specify how the targets will be achieved and this will be incorporated into their tendered proposals.

Contracts of this kind are becoming common-place in Australia and New Zealand[5], with entire rural road networks managed under such arrangements in Western Australia and parts of New Zealand (10% increasing to 30% in future). Independent auditing of achievement becomes a Client responsibility. These contracts allow considerable innovation on the part of the Contractors.

7.4.3 Acceptance of Risk

The form of contract defines each party's responsibilities and allocates the various risks between them. Risks can be grouped according to those that affect:

- Quality - the possibility of the work not meeting the requirements of the client.
- Cost - the possibility of the cost of work being different from that predicted.
- Time - timely delivery is less of an issue for maintenance than for construction projects, and is closely related to cost.

The political trend in recent years has been to transfer as much risk as possible to the private sector, but experience has now shown it is best allocated to the party most suited to cope with that risk[9,10]. In countries where maintenance has traditionally been carried out by in-house units, the private sector will often not be in a position to take on significant new risk, nor will the road administration be in a position to manage the private sector properly. Table 7.7 illustrates issues of risk allocation for road maintenance.

Table 7.7 - Contracting strategies and allocation of risk

Issue	Client to manage risk	←	→		Contractor to manage risk
Type of contract	Hourly rates	Single activity	Grouped activity	Performance based (short)	Performance-based (long)
Payment method	Cost reim-bursable	Target cost	Schedule of rates		Lump sum
Term of contract	Short term	←	→		Long term
Packaging	Many small contracts	←	→		Few large contracts

LBM

Boiling of bitumen on road side and later mixing with aggregate, is an appropriate method for patching potholes in a sealed road.

LBM

Road marking using labours have been successfully used in many SADC countries.

7.4.4 Increasing the Use of Small-scale Contractors

A range of clients and contractors of differing capacity are usually present in all countries. Different sized contractors will respond to different types of client: for example, medium- and large-scale contractors will often have little interest in low-cost, dispersed rural routine maintenance contracts. In addition, many smaller local contractors might only be working currently in the building sector. A contractor development programme would enable them to compete for work in road maintenance and might achieve the objectives of increased use of labour-based methods and increased local employment in such areas. This has been done in some countries. The use of local contractors and scope for labour-based maintenance, community involvement and responsibility has been dealt with in some detail in road maintenance policy seminars as part of the Road Maintenance Initiative (see Bibliography.)

Community Contracting

Many maintenance works offer possibilities for community participation and contracting, that are often not fully exploited. However, this is only likely to happen if:

- the infrastructure concerned is of direct benefit to them
- a sustainable institutional framework exists
- initial external inputs are made available for system development, funding, demonstration and training

Participation in community contracting initiatives implies stakeholder involvement in the planning, organising and implementation of the works. To this end, community bodies decide on local priorities and become responsible for managing the execution of the maintenance works by agreed means (e.g. through local contracts, paid labour/unpaid labour freely provided by the community with material support etc.).

Ultimately the successful involvement of small contractors or communities in carrying out maintenance works, by using labour-based methods where feasible, is important as a means of creating employment and helping to alleviate poverty. Fortunately, there are a number of manuals and guidelines available which deal with the development of small contractors employing labour-based techniques, including an introduction to business principles[11].

7.5 Summary

The key points arising in this chapter are:

1. Largely as a result of inadequate funding, the provision of satisfactory road maintenance still remains an elusive goal in many countries. The net effect is poor road conditions, high operating costs and an adverse impact on national economies.

2 The key maintenance challenges are predominantly political, social and institutional rather than technical.

3. The road sector reform process currently being pursued in the region, including the establishment of dedicated road funds, is critically important for the sustainability of maintenance funding. In this regard, the recommendations of the SADC Protocol on Transport, Communications and Meteorology should be implemented.

4. The pursuit of sustainable maintenance policies through the use of labour-based methods, where cost-effective, and the involvement of local communities and small contractors, is crucially important as a means of employment creation and are directly linked to poverty alleviation.

5. The lack of a systematic and structured approach to road maintenance results in inefficient and ineffective utilisation of scarce funds. However, the use of elaborate and complex management systems should be avoided and, instead, simple systems which are appropriate to local conditions should be introduced and implemented gradually.

The subject of road maintenance and its management aspects that are essential for the preservation of the LVSR network as well as other influencing factors, such as vehicle overloading, have been covered in this chapter. The potential benefits to be derived from the recommendations contained in this chapter and earlier chapters of this Guideline will only be realised through implementation, which is discussed in Chapter 8.

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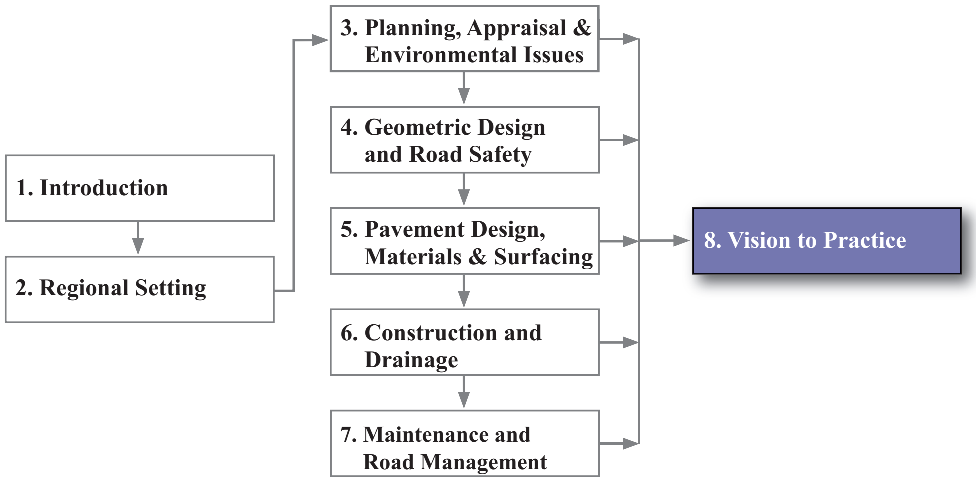
Chapter 8



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Vision to Practice

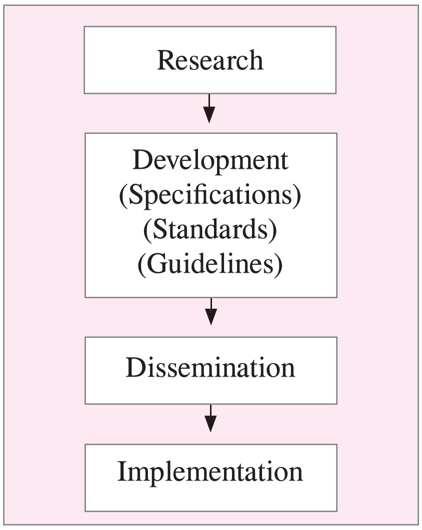
8

8.1 Motivation

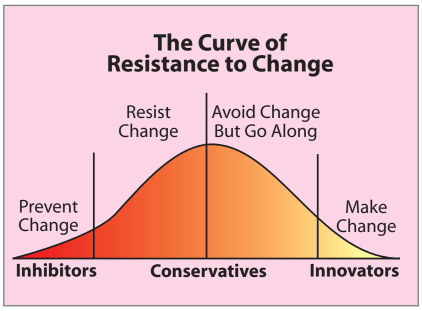
There has been a very strong motivation for preparing this Guideline on Low-volume Sealed Roads in the SADC region. In essence:

- Many aspects of LVSR provision have stemmed from technology and research in Europe and the USA in environments very different from that prevailing in the SADC region.
- Whilst changes have inevitably occurred in the region, much of the basic philosophy concerning LVSR provision remains unchanged, as have many of the norms and standards to be found in guidance documents, which have not been revised for many years.
- A significant amount of research work spanning some 20 - 30 years has been carried out in the region by a number of specialist organisations, collaborating country agencies and, in some cases, by country agencies themselves.
- Much of the research has been aimed at low-volume secondary and feeder roads including planning, appraisal, design, use of local materials, surfacing techniques, construction methods and finance for maintenance. Where implemented, the results of this research have invariably been highly beneficial and cost-effective.
- Unfortunately, there is still a general tendency to use a conventional approach to provision of LVSRs that is often perceived to be “safe”. As a result, few of the results of relevant research have been put into practice and the potential benefits of so doing have not been gained.

8.2 Pathway to Implementation



Moving technology from the research environment to an operating environment will involve considerable technology transfer effort and resources to overcome various obstacles to implementation.



"There is nothing more difficult to take in hand, more perilous to conduct or more uncertain in its success, than to take the introduction of a new order of things, because the innovator makes enemies of all those who prospered under the old order, and only lukewarm support from those who would prosper under the new".

Machiavelli, The Prince (1513).

The benefits of the Guideline will only be achieved if the approaches recommended are implemented. However, the path from research to implementation is a tortuous and time-consuming one. It has been estimated that, in engineering, in each of the steps in the pathway that begins in obtaining funding for research through to implementation, the magnitude of difficulty increases by a factor of between 2 and 8. These activities include carrying out the research, processing the results, developing standards, disseminating the information, right through to actual implementation. Thus, it can be quite difficult to get the results of engineering research put into practice, despite the evidence that very large savings can accrue where this has been done.

The implementation stage can be accelerated by understanding the process that is involved in technology transfer, identifying the likely obstacles and adopting a strategy that seeks to mitigate them. In broad terms there are five stages to the process of innovation[1]:

Stage 1: Idea generator - the initial perceived need for developing the Guideline.

Stage 2: Technology generation, adaptation and transfer - which has been achieved by raising awareness of the results of research carried out in the region, the adaptation of appropriate standards and the knowledge shared in the development of the Guideline.

Stage 3: State and local roads agencies - the importance of "buy-in", which has been achieved through the process of stakeholder involvement in the compilation of the Guideline.

Stage 4: Specifications and contracts - the modification of conventional specifications and contract types to suit local conditions; the important role of contractors in embracing the new approaches as embodied in project applications.

Stage 5: Benefits - the substantial potential benefits to be gained by implementing the recommendations in the Guideline.

The production of this Guideline forms a major part of Step 3 as well as contributing to parts of Steps 2 and 4. This chapter is concerned with the pathway from here to full acceptance and implementation. The various obstacles and associated problems that remain and suggestions for overcoming them are discussed below.

8.2.1 Political

Government Policy: The road transport sector cannot be properly planned without reference to overall government transport policy. For effective planning, SADC governments need to take a comprehensive view of the whole transport sector, with road sector policy being designed to meet the wider social and economic goals of each country.

It is important that the key messages from this Guideline on the benefits to be derived from LVSRs are included in the debate leading to the development of a policy document. The policy should cover such issues as poverty alleviation, employment creation, technology choice, etc. The outcome of this process will dictate the type of planning system that is most appropriate.

In one SADC country, the use of a slurry seal on a low-volume access road was politically over-ruled because in an adjacent constituency the more traditional chip seal had been used on a similar access road and was perceived as being of a "better" standard.

Acceptance of new techniques requires open mindedness and a willingness to learn from planners and engineers who must apply it. It also requires the political will to resist pressure from vested interests and make the best use of the resources that they have at their disposal.

Political and Public Perceptions: The intense competition for scarce public funds makes it imperative that appropriate, cost-effective standards are adopted at all times in the provision of LVSRs. This may well imply the use of lower, but nonetheless appropriate, standards on these roads. However, such standards can still provide a satisfactory level of service with no compromise on road safety.

It is important that the public and political authorities accept the standards adopted for LVSRs. However, their perceptions as to what is an appropriate standard of pavement or surfacing can adversely affect technical decisions. Very often, such perceptions are conditioned by standards adopted for high volume trunk roads; a lower, albeit more appropriate, standard on a LVSR is often perceived to be "sub-standard" and, hence, unacceptable.

More effort needs to be expended on educating politicians and the general public as to the basis on which technical standards are determined so that they are more readily accepted. Ranking policy changes according to their political costs and benefits can help policy makers obtain support from politicians and the general public.

Vehicle overloading is still rife in the SADC region with estimates ranging from 10 - 50%. The costs of such overloading has been estimated to run into millions of dollars.

A 22% overload from 82 to 100 kN will, in broad terms, increase the damaging effect on a pavement by a factor of 2.5 and reduce the pavement life by a factor of 0.6.

Axle Load Control: Inadequate axle load control remains arguably one of the most serious challenges faced by road authorities in the SADC region. As indicated in Chapter 5 of the Guideline, pavement performance is critically influenced by traffic loading which, in turn, controls the life of the pavement. LVSRs are normally constructed of lighter (thinner) pavements using naturally occurring materials that are often very sensitive to the impact of overloading. This makes them particularly susceptible to overloading which has an adverse and disproportionate effect on pavement life. Thus, overloading is not only an increased risk to the road, including bridges, it is also not justified on economic grounds. A more determined effort should be made to control overloading.

Effective control of overloading requires a strong political will which is sometimes not evident. The move towards new methods of overload control, as contained in the SADC Memorandum on Vehicle Loading, provides a strategy Control of Overloading, which should be implemented by all countries as soon as possible.

Risk: The need to adopt more appropriate standards and specifications in the construction of low-volume road pavements has been clearly recognized in the SADC region for some time. However, whilst there are many examples of the successful adoption of such a strategy, few are well documented and, until relatively recently, the conditions necessary for successful performance were not adequately defined. Thus, there has been an understandable reluctance, particularly by consultants and donors from outside the region, to utilize non-standard materials because of an undoubtedly greater perceived risk of problems or even failure.

Fortunately, the results of research undertaken in the region over the past 20 years make it possible to utilize local resources with greater confidence. Moreover, risks can be mitigated by ensuring that standards/specifications apply to local environments.

The perceived risks associated with the use of non-standard materials and non-traditional designs can now be sensibly managed and a larger proportion of unsurfaced roads can be economically surfaced without additional risk.

8.2.2 Social

Appropriate labour-based strategies utilise the dual output of infrastructure provision whilst creating employment. Labour-based methods do not imply the elimination of plant but rather selective replacement. Nonetheless, such methods have a relatively higher potential for employment creation (typically up to four times more than equipment-based methods). Road infrastructure provision offers one of the highest employment potentials compared to other sectors. In the process, there is NO compromise on infrastructure specifications such as fitness for use and purpose.

ASIST Bulletin No. 11 2000.

Employment creation: More and more governments in the SADC region are promoting the use of labour-based methods as an alternative to the more traditional plant-based operations as a means of combating high unemployment levels. In this regard, road programmes that maximize the use of surplus manpower that might exist in a rural community are more likely to engender a positive attitude to the future maintenance of the road than programmes that are plant-based and require the import of a limited amount of skilled manpower.

Despite the above, negative perceptions still persist in some SADC countries that such approaches are uneconomic, time consuming and sub-standard.

Where labour-based operations are indicated, government will need to make a clear policy commitment for change. This will call for special institutional arrangements, comprehensive planning as well as effective managerial and administrative systems and procedures.

8.2.3 Institutional

The institutional framework of roads sector organisations in the SADC region critically affects all aspects of LVSR provision. Historically, traditional approaches to the management and financing of road infrastructure have proved to be unsuccessful. Fortunately, the agreed SADC institutional framework for management and financing of roads offers a promising alternative to traditional approaches and, where implemented, has begun to show positive results.

Where the recommendations of the SADC Protocol on Transport, Communications and Meteorology that deal specifically with road management and financing have not yet been implemented, Governments in the SADC region should accelerate the reform process.

8.2.4 Technical

Use of inconsistent, inappropriate standards should be avoided and, instead, regional standards should be promoted by governments and donors.

Technical Standards: The consistent application of appropriate technical standards and design methods is critical if cost-effective, sustainable solutions are to be obtained. In the past, there was an understandable tendency in the SADC region to rigidly apply imported standards, specifications and geometric and pavement design methods as “best practice” simply because there was little alternative other than taking an unquantified risk in using untried materials and design methods.

With the wealth of research and development work undertaken in the region during the past three decades, new, "indigenous" standards, specifications and pavement design methods have now emerged in a number of innovative ways on the basis of quantified evidence. Nonetheless, due sometimes to donor insistence or to lack of awareness of the existence of regional standards, there is still a tendency in some countries to use imported standards.

The time has come for government policy to stipulate that where regional standards, including specifications and design methods exist, they should be used in preference to imported standards.

8.2.5 Economic

The results of research have shown, quite unequivocally, that adoption of the methods described in this Guideline result in low-volume roads that are less expensive to build, are no more expensive to maintain and reduce the costs of operating both motorised and non-motorised transport during their service lives. Thus, both agency costs and total (life-cycle) costs are reduced. Furthermore, although economic assessments cannot readily take into account social benefits, if these are included, the benefits of following the principles advocated in the Guideline should be obvious. Nevertheless it is necessary to demonstrate this repeatedly and as clearly as possible for the benefit of administrators, economists and others in authority who should not be expected to be conversant with the engineering principles involved in road building and maintenance.

Research should be undertaken to develop improved appraisal methodologies for LVSRs so as to take better account of the socio-economic benefits that are often a large component of the total benefits.

8.2.6 Financial

The financing of road building and maintenance has been mentioned frequently in the Guideline. The main challenge is to secure sufficient funding both to maintain the existing network and to accommodate the extensions to the network that are deemed to be necessary for rural development and for the attainment of poverty reduction goals.

The SADC Protocol on Transport Communications and Meteorology has addressed comprehensively the issue of road financing and the associated institutional arrangements necessary to secure sustainable funding to maintain road networks in the region. The measures recommended in the Guideline support the goals set out in the protocol.

In those countries where Road Funds have not yet been established, the Governments concerned should expedite their creation.

8.2.7 Environmental

The continued use of large amounts of gravel is not only causing serious environmental problems in the SADC region but is also unsustainable in the medium to long term. This provides a strong impetus for adopting the strategies that are promoted in the Guideline which seek to improve the "environmental" performance of the road transport sector. This can be achieved, for example, through more extensive use of local materials, use of low-cost road surfaces, preservation of resources of high quality stone, cost and safety conscious design, consideration of non-motorised traffic, community participation in planning and many more.

The establishment of a government body to address environmental issues, including those associated with road provision, should also be promoted in the region.

8.3 Vision to Practice

The technology transfer effort, which is so essential for the successful implementation of the Guideline, has encompassed the following activities leading to the production of the Guideline:

- Early involvement of stakeholders in the research planning phase to ensure that the Guideline responds to user needs.
- Continuous involvement of stakeholders in the compilation of the Guideline through their participation in a number of regional workshops.

Other aspects of the technology transfer process that will require consideration and possible external support to ensure successful implementation include:

- Technical assistance to support the implementation of the Guideline.
- Technical staff training, where in-house staff do not have the required expertise, and training to address internal resistance to change.
- Changes to country standards, design manuals and specifications needed to accelerate the implementation of the Guideline.
- Monitoring of acceptance, adoption, refinement and satisfaction amongst users of the Guideline.

By its very nature, the Guideline is aimed at all stakeholders in the rural transport system but the primary target audience are those who are in a position to foster change and to implement the ideas presented in the document.

For more information on the topics herein, the reader is encouraged to refer to the bibliographies in each chapter. Additional references can also be obtained by contacting the organisations listed in Appendix B.

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List of Useful Organisations

American Association of State Highway & Transportation Officials (AASHTO)
AASHTO is a not-for-profit, nonpartisan association representing highway and transportation departments in the USA and Puerto Rico. It represents the five transportation modes of air, highways, public transportation, rail and water. Its goal is to foster the development, operation and maintenance of an integrated national transportation system by advocating transportation policies, providing technical services, demonstrating the contributions of transportation and facilitating institutional change.

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www.transportation.org/aashto/home.nsf/FrontPage

ASTM International
ASTM International is a not-for-profit organisation that provides a forum for the development and publication of voluntary consensus standards for materials, products, systems, and services. These standards are an important part of the information infrastructure that guides design, manufacturing, and trade in the global economy. ASTM International has more than 20,000 members from over 100 countries representing producers, users, consumers, government and academia.

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T: +1 (610) 832 9585
F: +1 (610) 832 9555
E:service@astm.org
(Customer service)
www.astm.org

Australian Road Research Board (ARRB) Transport Research
ARRB is the leading Australian provider of transport-related research and technical services. It has a pool of experienced researchers, engineers, laboratory technicians and support staff and has particular expertise in infrastructure asset surveying and management, road safety and traffic engineering and transport policy and management. ARRB works in many countries throughout Asia, Europe and the Americas with a variety of customers, including international aid agencies, national and local governments, state road authorities and construction, transport and mining companies.

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Austroads
Austroads is the association of Australian and New Zealand road transport and traffic authorities. Its purpose is to contribute to improved Australian and New Zealand transport by developing and promoting best practice for the safe and effective management of the road system, providing professional support and advice to members, assessing and developing Australian and New Zealand standards and managing the National Strategic Research Programme.

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Council for Scientific and Industrial Research (CSIR)
CSIR is a scientific and technological research, development and implementation organization and plays a part in the development of South Africa as a nation and in the Southern African Development Community. One of eight operational divisions, Transportek offers specialist expertise in the fields of transportation research, traffic management, transport infrastructure and technology and information management, contractor development and rural and accessibility planning.

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T: + 27 12 841 2911
F: +27 12 349 1153
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Department for International Development (DFID)
DFID has a large programme of development assistance and also commissions research and dissemination projects with a transport theme. DFID also has a website whose purpose is to raise awareness of the importance of transport for development, within the context of developing countries. Many documents can be downloaded from this website. The address is www.transport-links.org

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T:P (within the UK):
0845 300 4100
T (outside the UK):
+44 (0)1355 84 3132
F: +44 (0)1355 843 632
E: enquiry@dfid.gov.uk
www.dfid.gov.uk

ILO – Advisory Support, Information Services and Training (ILO/ASIST)
The International Labour Organisation (ILO) is the UN agency which seeks the promotion of social justice and internationally recognised human and labour rights. The ILO has a unique tripartite structure with workers and employers participating as equal partners with governments. ILO/ASIST, part of the ILO's Employment-Intensive Investment Programme, seeks to contribute towards the alleviation of poverty through the use of local-level planning methodologies and employment-intensive strategies in the provision of rural and urban infrastructure. ILO/ASIST has two Regional Programmes, run by the following offices, and publishes a regular *Bulletin*.

ASIST – Asia Pacific
UN Building 7th Floor B-side
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Bangkok 10200
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T: +66 2 2882235
F: +66 2 2881062
E: asist-ap@ilo.org
www.ilo.org/asist & www.iloasist.org

ASIST – Africa
PO Box 210
Harare
Zimbabwe
T: +263 4 369 824-8
F: +263 4 369 829
E: asist@ilo.org
www.ilo.org/asist

Institution of Civil Engineers (ICE)
ICE is an independent engineering institution representing almost 80,000 professionally qualified civil engineers in the UK and worldwide. The objectives of ICE are to promote learning and training, provide professional status, act as a voice of the profession and facilitate best practice. ICE also publishes standard forms of contact, including the NEC series of contracts, suitable for international use.

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London SW1P 3AA
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T: +44 (0)207 222 7722
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www.ice.org.uk

International Forum for Rural Transport and Development (IFRTD)
IFRTD is a global network of individuals and organisations encompassing community organisations, national and international NGOs, academia, governments, donor agencies, consultants and technical institutions. Its mission is to promote policies and practices that address access and mobility as a means to eradicating rural poverty. IRFTD has a decentralised Secretariat based in the UK, Kenya, Peru and Senegal. IFRTD publishes *Forum News* quarterly. The UK address is given above.

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www.ifrtd.org

International Federation of Consulting Engineers (FIDIC)
FIDIC is an international federation of national associations of consulting engineers. FIDIC acts as a forum for the exchange of views and information and actively encourages the discussion of matters of mutual concern among member associations. More information, including order forms for contracts and other publications, is available on the website.

PO Box 311
CH-1215
Geneva 15
Switzerland
T: +41 22 799 49 00
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E: fidic@fidic.org
www.fidic.org

International Road Federation (IRF)
The IRF is a non-governmental, not-for-profit international organization with public sector, private sector and institutional members in approximately 70 countries. Established in 1948 by business and industry leaders, its mission is to encourage and promote the development and maintenance of better and safer roads and road networks. Today the IRF continues to provide the lead in international road infrastructure and management development through its two programme centres listed below.

Geneva Programme Centre
Chemin de Blandonnet 2
CH-1214 Vernier (Geneva)
Switzerland
T: +41 22 306 0260
F: +41 22 306 0270

Washington Program Centre
1010 Massachusetts Avenue NW
Suite 410
Washington DC 20001
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T: +1 (202) 371 5544
F: +1 (202) 371 5565
info@irfnet.org
www.irfnet.org

Norwegian Public Roads Administration (NPRA)
NPRA is the national road authority in Norway. It is responsible for national and county roads, totalling approximately 54,000 km and its duties comprise strategic planning of the network and other modes of transport, contracting of construction and maintenance, traffic management, technical standards, registering and inspecting vehicles and licensing drivers. The Office for International Affairs coordinates Institutional Cooperation with a number of European and African countries.
Statens vegvesen

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0033 OSLO	E: firmapost@vegvesen.no
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Southern African Bitumen Association (Sabita)
Sabita leads the bituminous products industry's contribution to development in southern Africa. Funded by its members, Sabita's threefold mission is to promote social and economic development through its road provision programmes, educate and train employees within the industry through formally sanctioned schemes and advance best practice to give competitive delivery of bituminous products and costeffective construction and maintenance of roads.

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Southern Africa Transport and Communications Commission (SATCC)
The main function of the SATCC Technical Unit (SATCC-TU) is to provide administrative and technical support to the implementation agencies and monitor compliance by member states of their obligations in terms of the implementation of the SADC Protocol on Transport, Communications and Meteorology.

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Transportation Research Board (TRB)
TRB is a unit of the National Research Council, a private, nonprofit institution that is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering. TRB's mission is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research results. TRB hosts an annual meeting which attracts a large number of transport professionals from around the world.

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TRL Limited
TRL Limited is one of the largest and most comprehensive international independent research centres working in land transport. The international staff work on projects for a range of clients, including DFID, the World Bank and the African and Asian Development Banks.

Centre for International Development	T: +44 (0)1344 773131
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World Bank
The World Bank finances many rural transport projects in developing countries and coordinates the Rural Travel and Transport Programme and the Road Maintenance Initiative of the Sub-Saharan African Transport Program (SSATP). Its Rural Transport Thematic Group has produced important knowledge products on rural transport. A large amount of material is available at www.worldbank.org/transport/rt_over.htm

1818 H Street N.W.	T: +1 (202) 473-1000
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World Road Association (PIARC)
PIARC is a non-political and non-commercial association with a main objective of becoming the world leader in providing information on roads and road transport policy and practices within an integrated sustainable transport context. It co-ordinates international technical committees, organises international seminars and publishes documents.

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