# SECTION C: IMPLEMENTATION

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# 12 Construction

## 12.1 Introduction

The construction of a LVRR is the outcome of the planning, investigation and design phases of the project cycle. The aim is the construction of a road (or roads) as specified in the contract documents with appropriate levels of supervision and quality control such that the roads are capable of being maintained to acceptable performance levels throughout their design life (Cook et al, 2013).

This chapter outlines key principles guiding the planning and general implementation of LVRR construction programmes. It does not provide detailed guidance on the procedures for LVRR construction which should be contained in a Myanmar LVRR Construction Manual as a complement to this LVRR Design Manual. Typical examples of detailed construction guidance may be found in SEACAP (2006), SDAC (2003) and SANRAL (2013a, b, c).

## 12.2 General Principles

The quality of the road construction process is critical as it can impact directly on the performance and the subsequent costs of maintaining the road. Whatever construction strategy is adopted, the ultimate goal of all stakeholders should be to make optimal use of the available resources to meet the prescribed designs in the most efficient and effective manner. Any apparent savings made during construction through poor adherence to the specifications are likely to be paid for many times over during the life of the road through additional maintenance and road user costs (Intech-TRL, 2006a).

Good practice "Fit for Purpose" construction procedures should be compatible with the local road environment. This may require modification of the conventional construction management techniques, and engineering procedures normally used for the construction of major, high-volume roads (Intech-TRL, 2006b). Variations can be considerable as regards to the choice of construction method, type of resources available and type of construction materials being used. Within the context of good construction practice, technologies for constructing rural roads should in particular:

- Respond to appropriate contract documentation;
- Utilise appropriate equipment technology options and reduce reliance on heavy equipment imports where feasible and cost-effective;
- Promote road construction technologies that create local employment and enterprise opportunities;
- Use contract models that support the development of domestic contractors and consultants;
- Take into account threats posed by climate in construction planning and recognise potential impacts on construction;
- Include an as-built survey as part of the completion certification.

## 12.3 Documentation

### 12.3.1 Contract Documents

Conventional Bill of Quantities (BoQ) based contracts are likely to be those most applied to LVRR programmes in Myanmar under DRRD. In this process the contractor prices the tender with the knowledge of what is required and how to achieve those requirements. The client (DRRD) has systems and resources, such as consulting engineers, in place to ensure that the contractor achieves these desired requirements during construction, in the knowledge that if these are achieved, the project will be successful. Core documentation for these contracts is likely to comprise:

- Conditions of Contract
- General Specifications
- Detailed Technical Specifications
- An environmental and Social Impact Assessment
- Bills of Quantity
- Drawings

Alternative contracting options that could be utilised by DRRD include:

Design and Construct: This involves a contractor employing a designer to design the project to meet the intended purpose defined by the Client (DRRD). The technical contract documents need only specify the intended purpose of the project and any related performance requirements. (SANRAL, 2013a) The contractor's team then design the asset to suit the contractors own capabilities, and to meet the performance requirements. This form of contract is unlikely to be suited to small LVRR contractors in Myanmar, although there are some specialist situations where it could be considered (with experienced contractors): for example, difficult bridge sites, or road alignments in steep mountainous terrain where ground conditions are highly unpredictable.

Output and Performance-Based Road Contract: In this model, responsibility for design, initial construction of the road, together with ongoing maintenance and improvement work is outsourced to the contractor, it is normally called OPRC (Output and Performance-Based Road Contract). In the OPRC model, the contractor is responsible for the initial construction or rehabilitation of the road. The contractor has to partly pre-finance this rehabilitation and he will be paid a monthly sum for the initial rehabilitation and a monthly sum for maintenance the following years (Gericke et al, 2015). The advantage of the OPRC model is that the contractor has an incentive to undertake efficient planning and good quality works in the initial work on the road, since he will have to maintain the road for a number of years, usually 5 years or more. It also reduces the workload for the road authority, since planning and design responsibility is outsourced to the contractor. The disadvantages are the need for experienced contractors and Clients and a revised framework of contract and financial regulation. Although this model is being championed by funding agencies for larger road projects it, ir carries with it significant challenges unless all contract parties are fully aware of their responsibilities and their levels of risk (Silva M M et al, 2011).

Lump Sum Contract: Under a lump sum contract, a single 'lump sum' price for all the works is agreed before the works begin. It is defined as a fixed price contract, where the contractors agrees to execute the works for a stated total sum of money. Lump sum contracts are generally appropriate where the project scope of works, (and quantities), are well defined when the tenders are sought and significant changes to requirements are unlikely. This means that the contractor is able to accurately price the works they are being asked to carry out.

The main advantage to the client is that the overall price is known in advance. However if the contractor feels that the scope of works provided by the client is not very clear then the contractor may provide a higher price, to cover any potential risks. Depending on the scope of works and project duration the agreed payment system could be one payment when the works are completed or staged payments, (say monthly), based on percentage of work completed against an agreed Implementation programme.

### 12.3.2 Technical Specifications

Whatever contracting mechanism is employed, appropriate and realistic technical specifications and construction drawings are an essential pre-requisite for successful construction. Ideally, specifications should be concise and capable of being clearly understood by the contractors and supervisors alike. LVRR projects in Myanmar should be able to draw-down from a comprehensive DRRD list of technical specifications for a wide range of conventional and innovative pavement, earthwork, drainage and structural operations.

Some new procedural options are likely to be best controlled by a tightly overseen method specification approach. This is particularly true of operations where control testing may involve significant delays, e.g. concrete surfaces and lime or cement stabilisation (Intech-TRL, 2006b).

## 12.4 Planning

### 12.4.1 Construction Programming

Contractors should be required to prepare a clear programme and related method statement. This programme as well as defining contract-compliant construction procedures together with necessary plant and manpower should include statements as to how the potential impacts of climate are to be mitigated. In contrast, cost savings can be made where timing of the construction operations can be seasonally programmed to suit favourable weather conditions.

The impact of severe climate events on partially constructed road pavements and earthworks can be devastating. Key points to note:

- Major earthworks and pavement compaction/sealing should not be undertaken during monsoon seasons;
- Earthwork and pavement drainage must be in place prior to monsoon seasons;
- Temporary works (bypasses, bridges) must be appropriately climate resilient.

**Figure 12.1 Climate Impacts During Construction**

Earthworks without drainage or support prior to monsoon season, Vietnam.

Temporary diversion bridge destroyed by tropical storm floods, Laos PDR

One particular point to emphasise when planning material haulage for road pavements intended for only light commercial traffic is that the movements of heavy construction trucks must be limited and avoided as much as possible. This can be achieved by "back-dumping" construction materials for each pavement layer and by being especially cautious when building the capping layer over weak natural subgrades. Back-dumping is a construction process where heavy construction equipment does not unnecessarily travel on the uncompleted or unprotected construction layer (Roughton International 2000).

### 12.4.2 Capacity Building

When using local community or casual labour from the location of the works, it is essential that the foremen are trained to identify, train-up and mentor the unskilled labour (Bentall et al 1999). This can be much cheaper than importing and housing experienced labour for the duration of the works.

A number of capacity issues are likely to require attention during the construction phase of the cycle (Intech-TRL, 2006a):

1. Small scale local contractors are generally not used to following technical specifications closely and may require a combination of easy-to-follow guidelines, training and initial close supervision, especially for newly introduced options.

2. There can be a general initial resistance to new procedures, with many contractors tending to use locally established practice as default procedures without reference to contract specifications.

3. The role of site supervisors in controlling the contractors' procedures and material usage is not universally accepted in the rural road sector in S E Asia. Current practice appears to be concerned largely with observation and reporting of progress rather than technical control.
4. There are potential difficulties with supervisors being unable to exert influence on the contractors to abide by specifications and the unwillingness of contractors to heed advice from supervisors.
5. Contractor performance and progress may be inhibited by severe cash-flow difficulties, which are not helped by unrealistic delays in processing agreed payment certificates. This may partly explain the reluctance to consider the plant-hire and labour based options.
6. Small Scale contractors may be reluctant to invest in supervisor and labour training for new techniques if there is little prospect of continuity for such works.

The above issues highlight the need for appropriate training and guidance on construction and construction supervision in conjunction with the implementation of a LVRR Construction Manual.

## 12.5 Appropriate Technology

### 12.5.1 Construction Methodology

Road works can be carried out through a range of methods using various mixes of labour and equipment. These methods can be grouped as follows:

1. Labour-intensive ; use of labour for all activities, including only unpowered hand tools,
2. Labour-based;– use of labour for most activities, but utilising equipment for specific activities where it is more cost-effective; e.g. haulage and compaction,
3. Intermediate technology; labour based, as above, but supplemented by the use of low capital cost intermediate equipment such as agricultural tractors and simple locally manufactured equipment.
4. Equipment-based – predominant use of specialised civil engineering equipment designed for high output, single activity applications (sometimes called 'equipment-intensive', 'heavy equipment' or 'capital-intensive').

**Figure 12.2 Locally based Construction Technology**

Labour-based construction of cobble road
Photo J Cook

Use of agricultural machinery in mixing of lime and local soil for LVRR stabilised base layer.
Photo J Cook

The aim should be to use the most suitable mixture of labour and equipment in a given social, technical and economic context. An appropriate intermediate technology-based approach is the general model applied in most regions of Myanmar. A number of activities are well suited to labour-based methods such as site clearance/bush clearing and ditch excavation while other activities, such as compaction of pavement layers or haulage of materials over long distances, are not.

### 12.5.2 Appropriate Equipment

There is now a very viable and effective alternative to having to rely on the use of heavy/expensive equipment, or solely on labour-based methods. Proven technology and methods designed principally around affordable agricultural tractors and intermediate equipment ensure that local contractors, with the right support, can now not only compete for local road construction and maintenance contracts, but also diversify their operations into supporting agricultural and transport needs in their region. (Petts, 2012). In this situation both Myanmar in general and local people can benefit through increased employment and income generation, as well as improved roads and local agricultural efficiency.

## 12.6 Quality Management

### 12.6.1 Quality Framework

The construction process in the LVRR sector is frequently not as well-controlled as expected or desired. Good, cost-effective outcomes from the construction phase require robust quality management.

Road construction must be implemented within a clear quality framework that comprises both and Quality Control undertaken by the Contractor and Quality Assurance undertaken by Client (DRRD) or their Consultant (SANRAL, 2013c).

Quality Control (QC) is undertaken by the Contractor in line with his submitted Quality Plan (QP). QC is generally concerned with measuring properties and checking that specifications have been met consistently throughout the project. Examples of quality control activities include site inspections, field and laboratory testing. Such activities are performed after the work has been completed. A good practice for QC is the development and use of a checklist for monitoring and inspecting the construction of the road. Checklists must be specific to the project in question, but in general should include the following comparisons against the Technical Specifications and BoQ.

- Quality of as-delivered materials;
- Construction methodology;
- Asset geometry (eg pavement thickness, earthwork slope angle, bridge deck/supports);
- In situ testing;
- Health and Safety issues;
- Environmental impact.

The Quality Plan (QP) refers to a written plan submitted by the contractor, which is reviewed and approved by the Client/ supervising engineer as part of the QA process. This document clearly demonstrates how the contractor will control the processes used during construction in order to meet the requirements set out in the technical specifications. The QP will typically include the sequence of tests to be performed on the materials intended for use at a prescribed frequency, with the objective of demonstrating that the intent of the specification is being satisfied.

Quality Assurance (QA) is the overview and documentation required to show that the contractor is following the Quality Plan. It incorporates standard procedures and methodologies and applies to all site activities aimed at significantly reducing or eliminating, non-conformance before it occurs. QA activities are determined before construction work begins and are performed throughout construction. Components of a QA system typically include process checklists and construction supervision.

It is important that the supervision organisation is already set up and functional when work is started. Information on the Quality Plan and associated responsibilities must be available. Preparations should include a clear organisation plan with lines of command and delineation of responsibilities. The number of the staff required will depend on the size and complexity of the project.

### 12.6.2 Key Quality Assurance Decisions

A number of key QA decisions need to be taken during the construction phase; these include:

- Approval of construction plant;
- Acceptance of pavement layers;
- Acceptance of material;
- Modification in design;
- Variations in BoQ items.

In reviewing plant resources it has to be acknowledged that small contractors in some regions of Myanmar may have limited plant resources; for example, they may rely heavily on standard 8-10 tonne, 3-wheel, static rollers for compaction, which have limitations for certain types of materials.

### 12.6.3 Materials Approval

Material approvals are an essential element of LVRR QA and in this context QC should be normally undertaken in two distinct phases:

1. General approval of source materials.
2. Approval of materials as delivered to site.

It is not realistic to force contractors to meet inappropriate or unobtainable material standards. For overall cost-effectiveness and minimisation of environmental impact, the LVRR road specifications should consider, where possible, locally available materials. Material approval for use should be accompanied by clear guidelines laying out the limits within which the approval is valid. These limits may take a number of forms, namely:

- Material characteristics after compaction;
- In situ moisture regime;
- Subgrade design value and in situ moisture condition;
- Pavement layer thickness design;
- Construction methodology;
- Traffic level, type and loading.

The approval of construction materials must be on the basis of the materials as-delivered on site. It is not unusual for delivered materials to have significantly different geotechnical characteristics from those approved at source during planning and design stages (Roughton International, 2000).

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 occurs when borrow pit operations are not kept sufficiently ahead of the construction.

### 12.6.4 Site Supervision

The supervision of construction and its quality control are essential elements in the road cycle and must be given a high priority. Experience backed by recent research has clearly indicated that poor construction has major impact on early pavement deterioration (Intech-TRL, 2006).

To guarantee the quality of works, it is necessary to establish control over the contractor's workmanship and materials. Quality supervision can be considered as comprising two principal elements.

<u>Site Inspection</u>: The works are inspected visually to detect any deviation from the specified requirements. Visual assessment is an essential element of pavement layer approval, particularly for example in the identification of oversize in lower pavement layers or gravel wearing course. Physical measurements of thickness, widths and crossfall are an essential element of this assessment. This activity is supplemented by simple in-situ checking of specified procedures; for example, temperature of bitumen and spray rates, and concrete slump, Table 12.1.

The quantity or spacing of QA testing will be a function of the type and size of the asset; Table 12.2 summarises some typical examples from recent regional LVRR construction projects.

**Table 12.1 Supervision Testing**

| Procedure | Description | Reference |
|---|---|---|
| The DCP test | May be used as a control on quality as construction proceeds. It may also be used as quality check on already constructed layers. The DCP test may be undertaken in conjunction with in situ density testing and moisture content testing for correlation purposes. | Intech-TRL, 2006b |
| Sand Replacement Density test | This is a common requirement in specifications. It may be replaced in some cases for quality control purpose by the DCP test, but only after satisfactory correlations have been established for the specific constituent materials. | ASTM D1556 |
| Concrete Slump Test | An essential on-site test for supervisors to use as a general control on the concrete mix actually being produced. Addition of excess water in the concrete mix is a common malpractice (high slump). Concrete samples should be taken from the mixer at the specified intervals for slump tests as well as concrete cube testing. Figure 12.3 | ASTM C143 |
| Tray Tests | These tests for bitumen and chipping spray rates are an essential element in the control of thin bituminous surfacings for either machine or labour based operations. | Roughton, 2012 |
| Schmidt Rebound Hammer[1] | A non-destructive index test used to indicate the strength of placed concrete. A very useful tool to give an indication of poor-quality concrete in bridges and culverts. Figure 12.3 | ASTM D5873 |
| Photographs | Date and time-stamped photographs are an important part of supervision, particularly if local (non-professional) community or NGO staff are involved in supervision | Intech-TRL, 2006b |

**Figure 12.3 Slump and Hammer Testing**


Concrete Slump Test equipment.

Schmidt Hammer testing

Laboratory and in situ testing: Materials as well as the finished product are subject to laboratory testing for such characteristics as grading, plasticity, density and strength. Special testing may be required for specific pavement options; for example, cement or lime content in stabilised materials; crushing strength of bricks or the compressive strength of stone blocks (see Chapter 8 and Annex II).

On larger projects it may be possible for the contractor to set up and maintain a basic Field Laboratory for routine tests for quality control required to be conducted on a day to day basis. The Field Laboratory will

[1] The Schmidt rebound hammer test is a non-destructive testing method of concrete which provides a rapid indication of the compressive strength. The Schmidt hammer that consists of a spring controlled mass that slides on a plunger within a tubular housing. The rebound value can then be correlated with concrete properties

normally have test equipment that does not require electric power supply and is relevant to the project specifications. There are also portable field test kits that have been developed that are very suitable for testing of LVRRs and provide the simple equipment for basic control tests (ARRB, 2009).

Specifications should include requirements for aftercare, such as curing of concrete or stabilisation layers, or remedial work on minor defects such as aggregate loss or bleeding of bitumen seals. “Aftercare” issues are an integral part of the construction process and it is important that supervisors ensure that these requirements are adhered to.

**Table 12.2 Typical Supervision Test Spacing**

| Construction | Activity | Typical Frequency |
|---|---|---|
| Embankment | Soil index and grading; MDD, OMC and CBR | One set per 5,000m$^3$ with a minimum of two analysis per cut or borrow area, or at every change of material. |
| | In situ density/ set of 3 DCP | Minimum one test per 500m. |
| Imported sub-grade | Soil index and grading; MDD, OMC and CBR | One set per 4,000m$^3$ with a minimum of two analysis per cut or borrow area, or at every change of material. |
| | In situ density/ set of 3 DCP | Minimum one test per 250m. |
| Granular sub-base-base | Soil index and grading; MDD, OMC and CBR | One set per 4,000m$^3$ with a minimum of two analysis per cut or borrow area, or at every change of material. |
| | In situ density/ set of 3 DCP | Minimum one test per 200m. |
| Surfacing aggregate | Water absorption, LA, grading | One set per 1.0km, more frequently if material character changes. |
| | Bitumen-stone adhesion | One set per source of stone/bitumen. |
| Concrete/clay bricks or blocks | Density, compressive strength, water absorption | Two sets of 5 per material source (more frequently if material character changes) and one per km of road. |
| Stone macadam | Uni-axial compressive strength, LAA, sodium sulphate soundness, grading/max size | One set per 500m with a minimum of two analysis per quarry area, or at every change of material. |
| Stone, cobbles, setts | Uni-axial compressive strength, LAA, sodium sulphate soundness. Size dimensions | Two sets of 5 per material source (more frequently if material character changes) and one per km of road. |
| Block/brick joint sands | Grading, sand equivalent | One per material source (more frequently if material character changes) and one per km of road. |
| Concrete pavement | Aggregate properties, such as LAA, water absorption, particle size and shape, sodium sulphate soundness. | One set per 1km or every 1000 m$^3$ or change of quarry (more frequently if material character changes) |
| | Concrete cube strength | One set of 3 cubes to be crushed at 7 days and one set of 3 cubes to be crushed at 28 days for mix design per materials source.<br>One set of 3 cubes to be crushed at 7 days and one set of 3 cubes to be crushed at 28 days per 500m of pavement |
| | Concrete slump test | One test per concrete batch; minimum one test per work shift. |

## 12.7 Environmental Management

### 12.7.1 Key Issues

It is necessary to ensure the existence of and adherence to the 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.

The following general procedures should be adopted that:

1. Minimise disturbance to flora and fauna.
2. Minimise sedimentation and erosion by implementing effective drainage/ stormwater control measures
3. Minimise generation of dust and noise.
4. Progressively revegetate disturbed areas during road construction.
5. Minimise visual impacts and environmental disturbance at site camps.
6. Minimise environmental impacts of queries; borrow pits and their stockpiles and storage of materials (Gourley & Greening., 1999).
7. Minimise construction wastes and dispose at an approved environmentally sustainable location.
8. 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.

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# 13 Asset Management

## 13.1 Introduction

An adequately maintained road infrastructure is essential to preserve and enhance road benefits, whilst conversely; a backlog of outstanding maintenance can cause irreversible deterioration of the road network and a decline in road-user benefits. If insufficient maintenance is carried out, roads can need replacing or major repairs after just a few years. That deterioration spread across a road system very quickly results in soaring costs and a major financial impact on the economy and rural communities.

To preserve the assets by preventive maintenance and to balance the long-term need, Road Asset Management programmes or systems can be applied to benefit different road stakeholders. Maintenance is also recognised as a key element of preventative Disaster Risk Management.

Management of the road asset involves the application of engineering, financial and management practices to optimise the level-of-service outcome in return for the most cost-effective financial input. The main objective is simply to apply the right treatment at the right time to achieve the desired level of service, indicating that the road infrastructure is a financial asset for society and the economy (Harral, & Faiz, 1988).

The rural road asset management should be fully integrated within the road administration's management activities and should provide a mechanism for realising the administration's goals in the context of rural road infrastructure (PIARC, 2012; Robinson, 2008).

This chapter focusses on the overall organisation and implementation of systematic and effective management processes for the maintenance of LVRR assets rather than the detailed on-site procedures which should be the subject of practical guidance, either generic (PIARC, 1994; TRL, 2000) or specific, for example (AfCAP, 2012; MoT, Vietnam, 2016).

### 13.1.1 Background

Managing LVRR assets is a challenge for DRRD as for most road organisations. The implementation of asset management and asset management tools will help the responsible parties to fulfil the correct and future requirements in a repeatable and sustainable way.

There are different questions to be answered in the different management processes which DRRD and any roads managing bodies will face and resolve. Typical key questions and challenges in effective management of assets relate to what is the current state of assets in relation to the present and levels of services and performance which are required. Further questions relate to the best road maintenance strategy, what are the required funding strategies, and which are the best disbursement channels to achieve maintenance goals.

Successful implementation of asset management of any project or program, including management of rural roads, is strongly dependent on establishing and following goals and objectives which are directly in line with the vision and expectations, not only of MoC and DRRD but also of the various stakeholders from the Ministry down to the road users and those individuals and groups who benefit from road use.

Effective implementation of asset management requires self-assessment and gap analysis, but more importantly by taking steps towards improving the current situation through individual, policy implementation or through group/team actions (ReCAP/Geddes).

Challenges include increased demand from stakeholders such as road users and rural communities and reduced budgets which will require a strategy to achieve better value for money in providing sustainable rural access where needed. As the costs of operating and repairing roads continue to increase and available funding decreases most road authorities struggle to maintain, upgrade and restructure their road network.

A well-run asset management framework will support DRRD like any other road organisation in effectively manage its assets. While many would see asset management as a pavement management or bridge management computer system, this is not correct. An asset management is not a theoretical or rigid protocol, but a set of business processes for decision making which will support and guide road units to follow continuous and well planned improvements of its infrastructure and road network. Such management systems will ultimately improve decision making based on real facts and needs based upon quality information and decision making (Geddes, 2016).

### 13.1.2 Purpose of maintenance: Why and who benefits?

The purpose of road maintenance is to ensure that the road remains serviceable and is kept to the specified standards to provide the access and services required.

- Maintenance prolongs the life of the road by reducing the rate of deterioration, thereby safeguarding previous investments in construction and rehabilitation;
- Lowers the cost of operating vehicles on the road by providing a smooth running surface;
- Keeps the road open for traffic and contributes to more reliable transport services;
- Sustains social and economic benefits of improved road access; and
- The importance of routine maintenance, particularly as regards drainage, cannot be over-stressed with respect to pre-emptive measures to reduce the likelihood, or impact, of natural disasters (World Bank 2018).

The first purpose mentioned above is primarily in the interest of DRRD and MoC and the regional authorities. The remaining three are of a more general interest to the regional inhabitants and residents and the vehicle operators themselves.

The level and scale of the importance of maintaining quality and reliable rural roads in Myanmar is increasing as the population increases and while the Government is striving to catch up with the backlog of rural road and infrastructure development. Road preservation and maintenance require adequate and reliable funding to ensure regular and timely maintenance.

### 13.1.3 Impact of poor maintenance

The following are six typical categories of impact that will result from poor maintenance of rural roads:

1. Loss of assets: the resulting loss in value of road assets due to neglect in maintenance.
2. Loss of agricultural outputs: Myanmar has a huge land area with wide variety of agricultural conditions. It has more than 65 million hectares of fertile grounds, which is among the highest in South East Asia. The country's rural roads often become impassable due to erosion, flood damage, slides and structural failures which will block the food chain for long periods. This issue has recently been addressed in terms of the "First Mile" concept (ReCAP, 2018).
3. Loss of time and access: More working time is lost as a result of poor or inadequate maintenance which will cause delays or preventing access to work, services like schools, medical facilities, places of worship, and generally can isolate communities for long periods.
4. Increase rehabilitation cost: A large backlog of deferred maintenance is caused, which will result in 4 to 6 times the cost in restoration and rehabilitation.
5. Dependence on slow vehicles: Due to poor condition, road users are compelled to continue to depend on slow moving (or non-motorised) vehicles.
6. Vehicle deterioration: Not only roads get deteriorated due to lack of maintenance, also the vehicles themselves get damaged, break down and often create accidents.

The overall effect of these impacts is a financial burden to the country through increased road repair costs, increased transport costs, loss of agricultural production and access to services including schools, health centres, and markets.

## 13.2 Management

### 13.2.1 Principles

The various levels and steps to improve and ensure growth of a road organisation's efforts through a reliable asset management framework should focus on the **following six (6) tasks**:

1. Organisational goals and objectives;
2. Inventory of pavements, bridges and other major infrastructure assets;
3. Availability of information to undertake life-cycle cost analysis for all major asset types and classes;
4. Information required to undertake risk management analysis at the project level;
5. Information to develop the organisation's/Department's financial plan to support investments;
6. Development of investment and funding distribution strategies to manage the road network for its whole life.

For Departments which have little experience and/or are at the initial stages of setting up an asset management system Table 13.1 is a guide with 5 key questions which will be helpful in their plans:

**Table 13.1 Key Questions to Develop & Coordinate Asset Management**

| QUESTION |
|---|
| **1. What is the current state of your assets?** |
| What are the owned assets? |
| Where are they located? |
| What condition are they in? |
| What is the estimated remaining life? |
| What is its remaining economic value? |
| **2. What is the current state of your assets?** |
| What is the stakeholders demand for services? |
| Are there regulatory requirements which are fulfilled and under control? |
| What is the actual performance level of each (group of) assets? |
| **3. Which Assets are critical to ensure sustained performance?** |
| How does it fail? How can it fail? |
| What are the consequences of failure? |
| What are the costs to repair? |
| **4. What are my best strategies for road operations' investments?** |
| What alternative management options exist? |
| What are the most feasible options available for the Department's road organisation |
| **5. What is the best long-term funding strategy?** |
| What revenues will be acquired? |
| What is the investment gap (surplus or deficit) to meet the goals of asset management? |
| What will be the optimum mix of the following:<br>i) Preservation and routine maintenance<br>ii) Reactive Maintenance? |

| QUESTION | |
|---|---|
| iii) | Rehabilitation |
| iv) | Replacement/reconstruction |
| What is the revenue gap required to keep the assets within an acceptable risk or damage/non-performance level? | |

### 13.2.2 Initiation

Regardless of the size or structure of any road organisation, Road Asset Management starts with a base -level of information on the assets it has to manage. . A three step approach is suggested in order to record the assets and their location and condition.

**Step 1: Establish the asset management goals and objectives which target the desired outcomes and follow business strategy of the Department**

It is important to set goals and strategic targets in order to develop a broader perspective for the various stakeholders. In order to initiate an asset management system, the following questions should be answered:

- What assets does the road organisation (DRRD) have responsibility for; where are they and what condition are they in?
- Does the DRRD have an inventory of their assets?
- Is the inventory is saved in a computerized Management System?
- Does DRRD know the amount which was invested on assets in the past?
- What are the top priorities of short term and long term goals and milestones for the road organisation?
- What are the annual and 5 year goals for the conditions of Low Volume Rural Roads and bridges both as far as quality and network reach and distribution?
- Are these goals realistic, or need to be amended?
- Has the timeline for updating goals been identified?
- What are the expectations concerning asset conditions by the public on a short term and long term basis?
- Have these goals and asset targets been agreed?

**Step 2:** Undertake a self-assessment and gap analysis to determine DRRD's current position on the basis of other asset management practices either followed by national entities or guidelines set by donors or international organisations.

Based on this comparison establish a set of priorities to meet the road organisations desired goals and timelines of required assets. The most basic self-assessment analysis can be based on the core questions above, followed by a systematic and planned set of actions. This information can also be used to prioritize weak areas or limitations that should be addressed as part of the overall plan of actions.

**Step 3:** Scope the specific improvement actions required to manage the road organisation's assets

Take a pragmatic and objective view of how a new or improved asset management policy or guideline relate to the organisation's mission and strategy in Low Volume Rural Roads. Key issues to be addressed in this exercise include: a) identify the scope of assets to be included in DRRD's Asset Management system, b) the framework and boundaries of the decision making (e.g. technical, financial, personnel, policy compliance, contractually), c) internal business processes, d) capabilities, e) data needs and sources and f) Costs and benefits.

Beyond the day to day activities DRRD needs to look at the "macro" way they do business. This relates in particular to how, when and through whom they conduct a self-assessment of assets and as a result how the departments or internal units need to improve managing their network and resources.

This may need additional data in order to enhance internal asset processing within the road unit, which may need the following questions:

- Is asset management a way of doing business in this road organisation?
- What strategies should be applied to reach the organisation's asset management goals?
- Should added assets be included to improve the organisation's operations and functions?
- Does the road organisation adequately undertake a regular risk analysis?
- Does the road organisation manage its LVRR related assets on a long term basis and/or through a 5 year plan?
- Is a detailed gap analysis study needed?

### 13.2.3 Maturity Models

The measurements of the degree to which a road organisation, a Ministry or Department has implemented their asset management principles will support the respective organisation in identifying its strengths and weaknesses in relation to their intended goals and commitments.

Maturity models can be a valuable tool for this purpose. Such models are simply a set of structured guidelines that describe how various fields of expertise are able to contribute to a set of pre-determined organisational or policy set tasks.

Recent work by ReCAP has focussed on the means to achieve economic and social benefits for local communities as a result of improved performance in LVRR asset management. This project called "Economic Growth through Effective Road Asset Management" (GEM) has developed a framework for measuring performance in road asset management appropriate to sub-national rural road networks and applied it in selected project areas in Africa. It has also developed simple and appropriate tools for monitoring road condition and applies them in the project areas as well as simple indicators of economic and social impact of rural roads and monitors them in the project areas (Geddes, 2016, ReCAP 2018).

The approach to the project is intended to foster self-reliance in road agencies and encourage greater accountability to road users and other sector stakeholders based on the assessment and improvement of 6 key building blocks, which are considered necessary for effective asset management. These are:

- External factors, including political support for roads;
- Institutional arrangements for the road sector;
- Financing of roads;
- Management arrangements in the roads agencies;
- Technical aspects of road agency operations; and
- Operations of the road agencies

The self-assessment of these building blocks drives a process of self-awareness in regional authorities and provides an impetus to improve local asset management[2]. Although focussed on the African maintenance environment, this general approach has valuable lessons to learn for Myanmar.

[2] The details of the research and its outcomes may be found under the "Economic Growth through Effective Road Asset Management, Project ref GEN2018A heading on the ReCAP website

For Myanmar, it is essential that a clear and repeatable definition of its maturity levels is followed for the whole assessment procedure. Therefore, it is recommended to use a unified scale of categories within each road organisation. The number of categories which are assessed or measured should coincide with any existing assessment procedure(s) already in place.

As a starting point it is recommended to use three maturity levels shown in Table 13.2. The maturity model then works with a matrix of these levels together with four management issues

1. Management (organisation, strategies and performance),
2. Data and modelling (inventory, monitoring, risk and life cycle planning),
3. Planning (management and financial planning, asset evaluation and scheduling) and
4. Application (management tools and communication).

**Table 13.2 Maturity Level Description, Asset Management**

| Data Level | Purpose Description |
|---|---|
| **Basic** | The road organisation at this status or level has only limited experience and resources and is operating at a "development stage".<br>It largely views its assets as a cost problem and not as a benefit to its operations and functions. No effective support is provided from strategy, process or tools. In this case there can be lack of motivation to improve. |
| **Proficient** | The road organisation or Department at this level can identify what it does and how it goes about its tasks and chores.<br>An asset management is already clearly defined with process and tools defied and in place.<br>The focus of asset management at this level should be in terms of reliability of data, asset records and concentrate on performance increase. |
| **Advanced** | The road organisation or Department at this level can control what it does as far as plan, design, implement and control outputs both a general level and in aspects of Low Volume Rural Roads.<br>The operational mode and functions of this Department or organisation specifies its tasks, objectives and requirements and ensures that such results are provided through regular feedback.<br>This road organisation is fully willing and capable of learning and adapting itself. It not only uses national and international resources and experience to correct any problems but also uses experience through delegated and direct powers to change the way it operates within accepted and recognized parameters, procedures and lines of communication.<br>Asset management strategies, processes and tools are routinely evaluated, approved and implemented |

**Note:** The three maturity levels can be extended easily subject to the availability of necessary input information

### 13.2.4 Case studies (ReCAP)

**Case Study 1: Asset Management gap analysis and self-assessment effort of the US Federal Highway Administration (FHWA)**

The FHWA is assisting State Departments of Transportation (DOT) in conducting and reviewing the results of an organisational gap analysis, which includes a self-assessment.

The self-assessment considers as a minimum, the adequacy of organisational strategic goals and policies with respect to asset management, whether asset management is considered in the agency's planning and programming of resources. Furthermore, as whether the agency is implementing adequate data collection and analysis policies, undertaking programmatic risk assessments to support an effective asset management programme. Based on the results of the self-assessment a gap analysis is undertaken to determine which areas of the agency's asset management process requires improvement. The self-assessment questions are available at: http://www.fhwa.gov/asset/gap/self assessment.pdf.

Note that the FHWA works with state DOTs in USA in undertaking the asset management gap analysis, which includes the following:

- Review of asset management material;
- Undertake and analyse the results of the asset management self-assessment;
- Interview key personnel from various offices;
- Conduct In-Person Real-Time asset management self-assessment (group work);
- Interview State DOT senior personnel;
- Develop draft implementation plan;
- Coordinate workshops with DOT to review the draft improvement plan;
- Produce and implement Final implementation plan.

**Case Study 2: Rural Road Asset Management in Thailand**

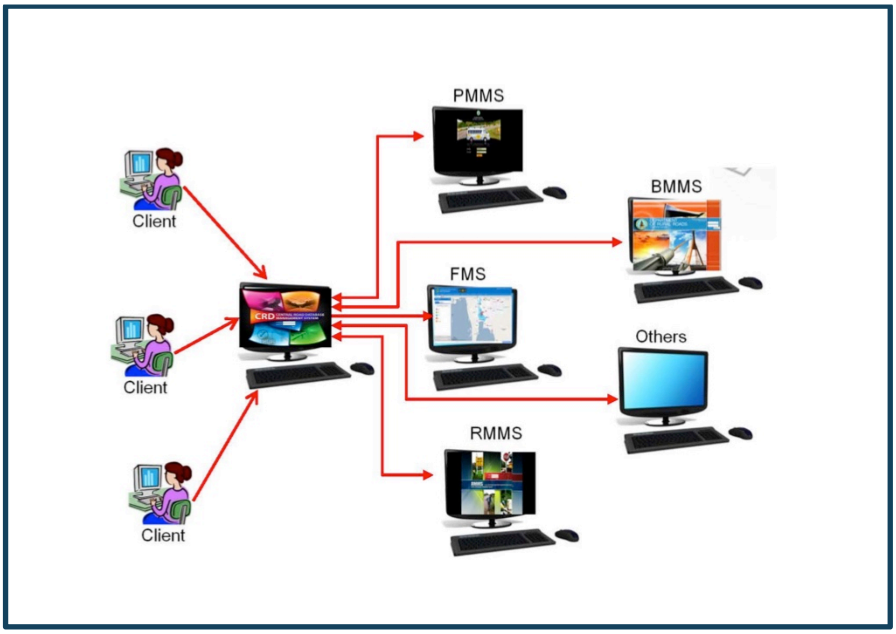
The Department of Rural Roads (DRR) manages approximately 42,000km of paved roads and 5,000km of unsealed laterite roads. The DRR carry out four types of road maintenance:

- **Routine Maintenance**: Remedying the defects that occur on the road from time to time that may cause the road to fail prematurely;
- **Periodic Maintenance**: Road resurfacing programme;
- **Special Maintenance**: Rehabilitation;
- **Emergency Maintenance:** Remedying the unpredictable defects that occur on the road (e.g. flooding).

In order to manage their road network, DRR developed a comprehensive road asset management system between 2004 and 2011. The system comprises the following modules:

1. **Central Road Database (CRD):** This is a centralized database of the rural road network, including road asset information and social data. It links to other systems for data exchange.
2. **Pavement Maintenance Management System (PMMS):** This is an engineering database used for road surface life prediction and strategic planning for road maintenance and financial budgeting. Data for the PMMS is collected using a dedicated survey car, which includes an asset camera, pavement camera and GPS antenna and can evaluate pavement damage using image processing techniques. Further data is collected using Benkelman Beam, Falling Weight Deflect meter and skid resistance.
3. **Flood Management System (FMS):** This is used for flood reporting, damage assessment and cost estimation, budget allocation, project evaluation and repetitive flooding analysis.
4. **Bridge Maintenance Management System (BMMS):** This involves evaluation by specialists and is used for damage assessment data, service life prediction, strategic planning of bridge maintenance and financial budgeting.
5. **Routine Maintenance Management System (RMMS):** This is used for road condition assessment and monitoring the rural road network and for financial budgeting.
6. **Safety Management System (SMS):** This comprises a safety engineering database and an Accident Report Management System for black-spot analysis, treatment and evaluation.

**Figure 13.1 Road asset management system – Case Study Thailand**




The DRR road asset management system[3] is comprehensive and has sophisticated data collection and analysis capabilities. While these might not all be appropriate for DRRD at this stage, it is worth noting the Thailand RAMS was developed and introduced over several years and it provides an insight into how the RAMS could be introduced in DRRD.

## 13.3 Maintenance Operations

### 13.3.1 General

Maintenance of rural roads and their drainage systems is essential for the safe passage of traffic and access to public and private services by the residents. Maintenance planning must be started immediately after the completion of construction.

Maintenance operations are generally split into routine maintenance, periodic maintenance, and emergency repairs, defined as follows.

I. **Routine maintenance** involves all those tasks carried out regularly to keep the roadway in good condition, for example, grass cutting, filling of ruts and clearing of the drains.
II. **Periodic maintenance** covers bigger jobs like re-gravelling sections of the road network and major repairs to bridges, culverts and drifts. These jobs are normally required at intervals of several years.
III. **Emergency repairs** are the unplanned repairs that have to be carried out to restore roadworks after disasters have blocked or damaged roads, for example, land slips or "washaways."

Maintenance requirements need to be prioritised by economics, level of service, funding, physical resources and skills available. If smoother running surfaces can be provided by regular maintenance, then it is likely that savings in fuel consumption and reductions in tyre and parts wear can be achieved. Vehicle Operating Costs (VOC) of motor vehicles will therefore come down. Roughness quoted as IRI (International Roughness Index in mm/m) is often used as a guide to pavement condition. Although exact maintenance

[3] An overview of the RAMS is available at https://www.unescap.org/sites/default/files/5-c.Thailand-Koonnamas.pdf.

target figures must be a function of the initial as-constructed road condition and types, IRI roughnesses of <4 mm/m for sealed road and between 3 and 10 mm/m are commonly used as a guide.

All roads require regular maintenance to ensure that their basic function is fulfilled for the duration of their design life. Achieving this will depend on the implementation of suitable maintenance strategies, with operations selected and carried out in a planned manner by qualified engineers and operators. The rural road maintenance regime in Myanmar in general has up to now been under-funded and below requirements to ensure a sustainable rural transport infrastructure. This is however changing, with DRRD giving increased emphasis on the preservation of existing rural road assets.

Routine maintenance of rural roads is currently undertaken by DRRD as well as being carried out through ad-hoc interventions by district councils, commune councils and local people in direct response to events that directly disrupt the daily routine of the community.

Periodic maintenance of rural roads is the responsibility of the DRRD; however these offices are invariably underfunded for the scope of works required. In order to justify the necessary cost estimate for the application maintenance needs, road data collection must be a key activity.

### 13.3.2 Key Elements

Adequate maintenance is crucial to sustainably overcoming the challenges of climate impact on LVRRs and in that context the primary element is the maintenance of adequate drainage. Poor drainage is responsible for most structural deficiencies, surface erosion and deposition of debris. Concentration of scarce resources on maintenance of better drainage measures can reduce total road costs.

The management of the maintenance of the Myanmar LVRR network should be based upon a management system encompassing the following:

- Inventory of the roads, showing road type, width and average annual daily traffic;
- Inspection record of condition;
- Maintenance requirements, derived from the condition records;
- Available resources;
- Prioritisation;
- Work scheduling;
- Monitoring of quality and effectiveness of the work.

### 13.3.3 Timing of Rural Road Maintenance

Rural road maintenance is a continuous activity required to address and prevent deterioration of the road surface and drainage. The timing of maintenance interventions depends on the purpose of each activity. A typical schedule of maintenance activities is as follows:

**Table 13.3 Maturity Level Description, Asset Management**

| Season | Description |
|---|---|
| **Before Rains** | Clean culverts<br>Clean mitre drains<br>Clean side drains<br>Repair side drain erosion and scour checks |
| **During Rains** | Inspect and remove obstructions<br>Clean culverts<br>Clean mitre drains<br>Clean side drains<br>Repair side drain erosion and scour checks<br>Repair erosion on shoulder |
| **End of Rains** | Fill potholes and ruts in road<br>Reshape carriageway<br>Repair erosion on shoulders, slopes and drains<br>Reinstate scour checks<br>Cut grass |
| **Dry Season** | Clear bush, Repair structures, Reshape carriageway |

These are generic timings to be used as a guide and adapted to Myanmar conditions and practices as government by the differing physical and climatic road environments (Maintenance Contracting Models).

### 13.3.4 Management of the maintenance process

Records should be kept of the labour, tools, equipment and materials used in the work. Each operation is best kept separate so that actual costs can be calculated. In this way the efficiency or various operations of different work groups can be measured and compared. Productivities must be calculated and recorded, and trends should be plotted.

Good quality and well maintained tools will enhance productivity. On a larger roadworks and maintenance works full time equipment repair teams and mechanics should be part of the operation.

Equipment operators must be adequately trained not only in correct use and operation of maintenance tools and equipment but also in service and minor repair works.

Labour based maintenance has been proven cost effective globally for several years. It is suggested that the Client and the regional authorities take that into account in the most rural areas and in particular on laterite or gravel roads for routine maintenance, re-gravelling, clearing or upgrading of smaller structures. Documents and guides produced by ILO as well as the earlier department of ASIST in Africa and Asia are readily available (Johannessen, 1999; Piarc 2001; Donnges et al 2007):

The order of importance of maintenance activities, per Overseas Road Note 1 (1987):

**I) Urgent Work**

- ✓ Emergency Repairs to open blocked or impassable roads
- ✓ Stabilisation of dangerous slopes

**Note:** The nature of emergency work, which demands top priority

**II) Drainage**

- ✓ Restoring side and mitre drains, river crossings and drainage structures like culverts and minor bridges
- ✓ Repair eroded areas and build scour checks and retaining walls
- ✓ Repair drainage structures

**III) Roadworks**

- ✓ Routine maintenance
- ✓ Re-gravelling
- ✓ Side slopes and shoulder repairs

### 13.3.5 Making roads maintainable

There is a growing recognition that even rural roads must not only be properly designed but also follow a well-planned maintenance programme to serve their purpose and periods of their life expectancy.

An "Action Plan" or Implementation Programme with associated cost and manpower equipment schedules should be set up by the Relevant Ministry and Departments. DRRD through the relevant channels would do well to arrange a realistic assessment of the total funds required and formulate the strategy on a regional and priority and Phase-Wise basis. It could be a five year maintenance/rehabilitation plan for rural roads.

### 13.3.6 Maintenance Delivery Models

There are a number of general options for the actual delivery of the maintenance these include

- Direct public works (Force Account)
- Large contractor
- Small local contractor or SME
- Contracted local groups
- Village Groups
- Single contracts (Length-men)

Each of the above has its advantages and disadvantages depending on the physical, climatic and financial environment (Johannessen, 1999).

Overarching some of the above is a decision on the contracting model to be used; traditional BoQ based or some form of performance-based contract. This latter option is being increasingly favoured by donors (Salomonsen & Diachok 2015; Silva et al, 2011).

The contractor in an output or performance-based contract (PBC) for road maintenance is paid on monthly or quarterly basis for maintaining the road at a specified service standard. The resulting condition of the road defined by performance criteria rather than on an input basis as occurs under traditional maintenance contracts where they are paid based on volume of work (Bull et. al 2014). These performance criteria are basic and easily measurable, targeting the principal defects to be addressed (e.g. maximum number, size and depth of potholes; maximum height of vegetation; maximum allowable degree of blockage of the drainage system). This is in contrast to the BoQ-based approach where the contractor is paid strictly in terms of the time and resources used as per a submitted list of costed items.

Whilst there undoubted advantages for the performance based approach, there remain significant challenges for its implementation at the LVRR level in terms of Client/Contractor experience, particularly in terms of appreciation of risk, for example from climate impacts. To be effective a PBC-based LVRR initiative is only applicable for "maintainable roads"; that is roads that are generally fit for purpose and have only minor defects which can be rectified using routine or periodic maintenance, without significant rehabilitation.

### 13.3.7 Key Challenges

A maintenance issue that should be recognised with respect to rural roads is not merely the shortage of funds. There are also technical and institutional issues that require careful consideration.

Furthermore, the measures required to improve the situation, both as far as keeping the road structure and the adjacent areas in good order, are often under estimated. These include the level of support, capacity development and time required by the Client as well as the lead time required by the Department to provide regular timely and quality maintenance to the entire road network and plan for the future.

## 13.4 Capacity Building

### 13.4.1 Institutional reform and Strengthening Accountability

In order to plan and implement an effective rural road maintenance programme the Departments require to develop a clear delegation of functions related to policy and planning of maintenance as a part of post construction follow up in the overall infrastructure development master plan.

The various regional authorities that report to MoC and DRRD should be part of an annual performance evaluation as far as assessment of annual road maintenance.

Some of the important performance indicators that can be considered for this purpose are:

- Percentage of Rural Road Network hat received routine maintenance;
- Percentage of Core Rural Road Network actually subjected to periodic maintenance;
- Percentage of core Rural Road Network in good condition;
- Unit cost of routine/periodic maintenance;
- Percentage of maintenance expenditures compared to the amount required as per norm.

Performance audits should relate financial flows and physical performance indicators to the condition of the roads. Internal accountability among the technical officers and engineers at various levels will be responsible for this.

### 13.4.2 Human Resource Development

Another vital source for planning, implementing and managing any Rural Roads maintenance programmes is the human source development of the staff at various levels under the Ministerial and Department levels. Significant efforts and budgets are needed to fully meet those tasks. It recommended to invest significantly in support training programmes to make this possible. To fully satisfy the needs for present and future responsibilities within the maintenance management sector, the state may formulate a 5-year training calendar for Department staff which would include courses in maintenance planning, management, procurement and supervision of works on the ground.

## 13.5 Data requirements and Analysis Procedures

Asset management systems generally make use of data from a wide range of sources, both within and outside a road administration. Typically, a RAMS in use by a road administration will utilise of the following data:

- Definition of the network;
- Definition of the assets on the network (e.g. bridge, pavement);
- Location of the assets on the network;

- Condition of the assets;
- Levels of use (e.g. traffic flows);
- Policies and standards (e.g. maintenance standards and treatment designs as well as monitoring information such as performance measures);
- Budget information (e.g. broken down by asset type, programme level).

### 13.5.1 Data Administration

The connection between the data, the ownership of the data and a detailed description of the data must be correctly established and defined at the outset and maintained throughout the life of the system. The organisation shall promote the importance of effective data administration and ensure that staff are well-equipped and have an appropriate mandate for the realisation of this task. Particular attention should be paid on what information is required, which organisations are responsible and what data are to be supplied. The adoption of a structured approach will identify any gaps in the data and will highlight any data that are of inadequate quality.

### 13.5.2 Data Collection and Storage

The accuracy of the data collected, its location and lifetime should be clear. A reliable quality control procedure for checking these elements is necessary. Typically, a quality control procedure for data collection should include:

- A formal quality management procedure (e.g. operating under ISO certification);
- Pre-defined warning values or historical data that can be used in control procedures;
- A requirement that all equipment must be calibrated regularly;
- Reasonable storage mechanisms for raw data (i.e. data used to produce the data in the RAMS).

Once the collected data has been supplied data quality control procedures should be performed. These include:

- Data verification (i.e. data should be checked for integrity, location, time, completeness and accuracy);
- Application to both incoming data and existing stored data.

### 13.5.3 Management System

A simple Road Asset Management System (RAMS) should to be introduced by each Region or Province which is based on the current arrangement of collecting and analysing maintenance data for their respective roads in the Rural Road Network.

This system should be simple, but also allow ensuring maximising the benefits of the available/allocated maintenance funds for the particular network within the particular work calendar. Such a system should also help in assessing impact on deterioration. This will enable the responsible parties, both regional and at central level, to decide on whether or not it is possible to allocate added funds. The expected output from the RAMS would be:

- Road Inventory;
- Network condition, pavement condition index;
- Needs – Based Maintenance Plan for a given budget;
- Annual Maintenance Plan for a given budget;
- Impact on deterioration of roads due to gaps between funds required vs funds made available;

**Asset Management System: Essential Tools** (Donnges eta l, 2007)[4]

- Means and procedures for establishing and maintaining road inventory, providing detailed information about the road assets;
- Established procedures for and logistical means to carry out regular inspection of the network;
- Road standards to provide guidance on how and when maintenance works should be carried out including procedures on how priorities are set for selection of where maintenance should first be carried out;
- Programming and budgeting procedures for the preparation of master plans, periodic plans and annual plans;
- Works implementation procedures: guidelines on choice of technology, use of the private sector and contracting arrangements;
- Skilled staff to carry out planning and works supervision;
- Logistical means to oversee the performance of the network and inspection of works;
- Financial and administrative support services to ensure effective budgetary and expenditure control.

### 13.5.4 Data Analysis

Asset management systems generally carry out the following data analyses:

- Interpretation of the condition data collected on the individual assets;
- Identification of “optimal” treatments;
- Calculation of life-cycle costs;
- Prioritisation of maintenance treatments against budgets

Asset management generally examines such factors as investment levels, maintenance standards and economic importance.

**Table 13.4 Typical Data Analyses**

| Data Level | Analysis |
|---|---|
| **Technical** | Condition of the asset<br>Causes of maintenance<br>Age and degradation of the asset<br>Use of the network |
| **Economic** | Budget required<br>Budget allocations (e.g. budget breakdown)<br>Variations in unit prices<br>Deviations between out-turns and estimated costs<br>Maintenance costs of assets<br>Total costs and budget |
| **General** | Comparison of prioritisation with political preferences<br>Comparison of detailed and outline technical plans<br>Changes in performance monitoring statistics<br>Comparison of regional performance monitoring statistics |

*Source: OECD 2001*

[4] Source: ILO: Rural Roads Maintenance – Sustaining the Benefits of Improved Access by Chris Donnges, Geoff Edmonds and Bjorn Johannsen, SETP-19 (2007).

### 13.5.5 Software

The level of technical expertise, knowledge, data management and funding of the organisation should be considered for the choice of the appropriate and sustainable software for road data collection system mainly when it refers to rural or low volume roads.

The majority of the road data collection systems are designed for high volume, national roads, where the level of data about the road carriageways tends to be much greater, with a complex analysis undertaken subsequently. This is neither appropriate nor sustainable for rural roads, especially for organisations with limited technical capacity and funding.

The road asset management software, especially for rural roads, should record and store data about road network assets in a systematic and inexpensive manner. Some beneficial characteristics are:

- No complex or expensive specialised equipment
- Practical, easy use
- Fast process
- No internet requirement
- Remote monitoring
- Data storing, mapping and reporting

### 13.5.6 Case study (Shan State)

<u>DRRD Requirements</u>

In developing something appropriate, the following considerations were important:

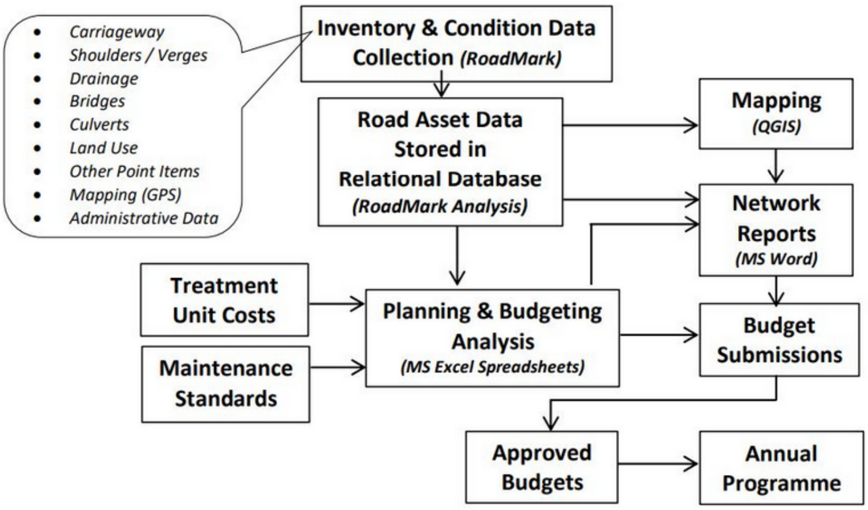
- Whilst extensive, the rural road network was poorly defined, with no road numbering or network referencing system in use. The ability to map the network would therefore be a significant advantage to road managers.
- The large size of the rural road network required data collection to be as quick as possible, in order to minimise its cost.
- The technical, staffing and financial capabilities of the road agency were very limited, especially at the local level, through which data collection would be expected to be managed. This precluded the use of expensive or sophisticated systems, or any that required specialised equipment or high technology.
- The ability to store and process a large volume of data locally was limited.
- Most of the areas served by the rural road network had no or very limited mobile phone coverage.
- Access to the internet was slow, unreliable and/or expensive in many offices in local towns. This meant that it was not possible to provide remote access to a central server via the internet, and data transfers had to be kept small.
- Local security concerns meant that any collected data had to be stored locally and not offshore (thus, a ‘cloud’ based option was not acceptable).

<u>System Overview</u>

In response to these conditions, a system (RoadMark) has been developed and piloted locally. As part of this project, just over 500km of rural roads were surveyed using a smartphone app.

The data from these surveys was stored in an electronic database. This data was then exported for subsequent analysis using a simple Excel spreadsheet, from which estimated network needs and budgets were derived. The data was also mapped using the freely available QGIS software. A summary of the overall system architecture is shown in Figure 13.2

**Figure 13.2 Summary of Overall Planning & Budgeting Framewok**

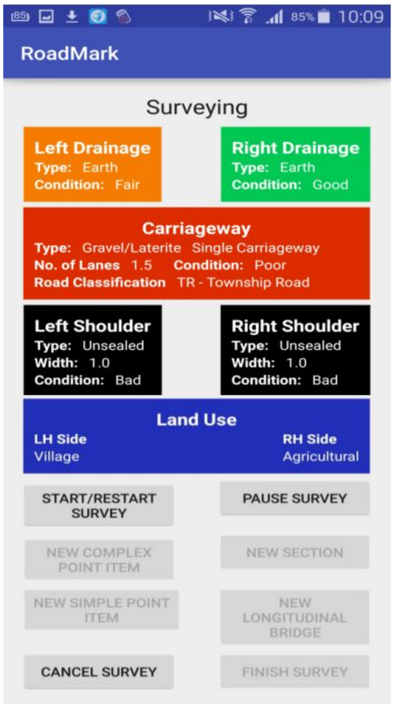



<u>Data Collection</u>

A dedicated application was developed to allow a wide range of road asset data to be collected quickly using an Android Smartphone. This application was designed to be used by non-technical inspectors, in areas that have no mobile or internet connections, on poorly defined road networks. The system allows basic inventory and condition data to be captured for each of the main types of road assets. All data is date and time stamped and geo-located, allowing the data to be mapped subsequently.

The main screen shown by the Android app during surveying (see Figure 13.3) displays key attributes for each of the main components of the roadway (with changing colours, depending on condition).

**Figure 13.3 Main Android App Screen**



Additional options at the bottom of the form allow the surveyor to record extra details about ‘point items’ such as bridges, culverts, street furniture, and intersection. The system can be used on poorly defined road networks, where no systematic referencing system has been established, (although it can accommodate this if present). The user can trigger a new section if there is a significant change in the road’s characteristics, such as a change of surface type, condition and/or administrative data (e.g. district name or road class).

The desktop application calculates section lengths automatically, based on frequent GPS positions (accurate to within approximately 3m). It can then create sections within the database. Data is checked for logical consistency when entered into the system. Additional checks are carried out when the data is electronically transferred to the desktop application, where additional editing can be undertaken.

Data Storage & Reporting

This application allows all survey data to be stored securely in a relational database, from which a variety of reports and data exports can be generated. Analysis can also provide administrative information about the surveys carried out. This can be useful for monitoring progress, identifying problem areas and estimating how long (and hence the cost) to undertake future surveys.

The analytical process allows basic planning and budgeting estimates to be developed, based directly on the data collected. These estimates include both carriageway and off-carriageway estimates, as basic inventory and condition data included for non-carriageway assets, such as longitudinal drainage, bridges and culverts.

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# 14 Technical Audit

## 14.1 Introduction

### 14.1.1 Purpose and Strategy

The purpose of Technical Audits of road projects is to ensure and enhance the quality of road construction by the addition of a technical oversight layer. A Technical Audit is in addition to the normal quality control and quality assurance procedure that should be undertaken by the Contractor and the supervising Consultant or Engineer (MWTC, 2001; SADC, 2003).

The Technical Audit Team (TAT) is appointed by the Client (DRRD), to whom it reports directly. In order to be completely independent, the TAT should not advise or issue instructions to the contractor or supervising consultant. Communications should focus on seeking clarifications or information regarding the project and should avoid any interference with the smooth operation of the project. The consultant, contractor and Client must make available to the auditor any documents as and when stated in the contract agreement between the Client and the auditor/audit team.

Prior to embarking on the audit the TAT should have good knowledge of the project in general; contract documents and also a knowledge of each of the roads which are to be inspected. The technical auditor will be appointed as early as possible, preferably before the start of the appointment of the contractor. This will allow the TAT to assess the project documents and evolution of the project. Any deficiencies in the design, BOQ or tender document might be reviewed by the auditor, if that is permitted at this preliminary level.

### 14.1.2 The Technical Audit Team

The size and make-up of the TAT will be a function of project size. For single roads or single roads assets The TAM may comprise just one person, whilst for larger multi-road/asset projects a team of up to three professionals could be involved. The TAT would normally be expected to include the following expertise:

- Professional civil engineering covering all phases of a road project from planning design, construction and contract management;
- Proven experience in all aspects of LVRR asset construction;
- Significant knowledge of road construction and audit requirements and procedures;
- Materials engineering;
- Experience in drainage, bridges and minor structures (as relevant to the particular project).

## 14.2 Technical Audit Framework

The technical audit for a typical road construction project should be carried out in four or five stages as presented in Table 14.1, although, for some LVRR projects a simpler two-stage process might be sufficient.

A logical step by step evaluation procedure will provide an adequate warning where rectifications or amendments are required that can be completed within the contract completion date. At the completion of each stage of audit the TAM should submit a comprehensive report of findings and recommendations to the Client.

**Table 14.1 Technical Audit Phases**

| Technical Audit Phase | Timing | Aims |
|---|---|---|
| a. Familiarisation | Prior to Contractor mobilisation. | Site and document review. Background checks on pricing, work programme, personnel, and construction plant capacity. |
| b. Initial Audit | As soon as the Contractor is fully mobilised and primary works are under way. | Assess project management, construction resources and methodologies. |
| c. Intermediate Audit | Mid-point of the project duration. | Assess compliance with specifications, quality and quantity of works, and quality management plans to ensure that it is running smoothly. Review actual cost vs contract budget and planned progress vs actual progress. |
| d. Final Audit | On completion of all the required construction works and as-built surveys. | Determine conformance with all aspects of the contract. Actions of the Consultant (Engineer) and the Contractors should be assessed. |
| e. Post Construction | Only required if recommended by Final Audit. | Assess and make comment and recommendations on technical issues raised during the Audit process that have not been adequately dealt with. |

**Note:** Some LVRR projects may only require a combined (a+b) stage and a (d) stage.

## 14.3 The Technical Audit Procedures

### 14.3.1 Familiarisation

The TAM should clearly understand the TOR, scope and complexity of the project by reviewing all contract documents, including drawings, specifications, material reports and conditions of contract. The tender submitted and awarded to the contractor should be studied as well as undertaking background checks on pricing, work programme, personnel, and technical proposals.

This stage should be carried out immediately after the Auditor has been appointed by the Client and within a reasonable time of the TAM contract award.

During this phase, an Audit team member should visit the project site, preferably with the supervising consultant and the Client to acquaint him or herself with the site conditions prior to start up. During the project familiarisation phase of the technical audit as much existing information as possible should be obtained. Sources will include:

- Design and Drawings;
- Material Reports;
- Tender Documents including BER (Bid Evaluation Report);
- Ownership and location of plant;
- Contractor’s resources, staff list, work program and cash flow;
- Site visit prior to work starts on site.

All necessary Information should be made available through the Client (e.g. DRRD or MoC). It is not the duty of the auditor, however, to determine whether the design is appropriate for the specific circumstances.

### 14.3.2 Initial Audit

This phase should be carried out as soon as the contractor is mobilised on site and primary works are under way, so that correct procedures can be established from the beginning of the project. During the first on-site audit attention should focus on project management issues and construction methodologies. The Auditors should also conduct a review of the Resident Engineers/Consultants project management, supervision, and quality management and approval procedures.

The following is check list of actions:

- Review qualifications of consultant and contractor staff;
- Assess site Communication – review adequacy of site instruction, weekly, monthly report formats;
- Assess knowledge of the Contracts and technical specifications;
- Ensure Quality Assurance (consultant) and quality control (contractor) procedures in place;
- Assess general approach to the project;
- Check that construction methodologies are adequate – including staff and construction plant;
- Review quality and appropriateness of the plant and equipment;
- Assess operator skills;
- Assess adequacy of Material testing facilities including equipment and staff;
- Ensure materials and water supply secured;
- Review site organisation and site management;
- Ensure a satisfactory work programme;
- Check adequacy of Health and safety management procedures;
- Ensure environmental management plan in place;
- Assess construction methodologies; pilot sections, manpower & equipment allocation;

### 14.3.3 Intermediate Audit

At the intermediate level, the TAT should concentrate on compliance with specifications, and ensure that the construction plan is running smoothly. Review of project documents such as built drawings, site reports, measurement of material and equipment on site and review on actual cost vs contract budget and planned progress vs actual progress are essential tasks at this stage.

On larger projects it may be necessary to conduct more than one intermediate audit. In such cases this should be specified in the audit TOR.

The following should be addressed during the intermediate audit(s):

- Review the response to the Initial Audit in terms of actions by Consultant (Engineer) and the Contractor;
- Review all as-built documents since the Initial Audit;
- Inspect and record both the completed work and work in progress;
- Assess the Consultant's Quality Assurance policy is working in practice;
- Review the performance of materials testing recording/reporting procedures;
- Check out location, quality and quantity of borrow pits and material suppliers;
- Check materials as delivered field sampling and independent testing;
- Review actual progress vs planned progress and related contract extensions, Variation orders or penalties;

- Check actual contract cost vs budget and Project Management System (Engineer's and Contractor's);
- Check measured quantities vs payments and BOQ;
- Check Payment Certificates and contract compliance;

#### 14.3.4 Final Audit

The purpose of this final audit is to determine compliance with all aspects of the contract. The principal sources of information will be the as-built drawings, financial records and payment certificates, measurements of work done and contractual variations. The actions of the Engineer and the Contractors should be assessed.

This audit should ideally commence at least four weeks before issuing the substantial completion certificate, and should completed before the staff is demobilized from site. A principal output from the Final Audit should be a recommendation for any further testing that is required to assess the quality and quantity of works completed. A full Final Audit Report on the project should be presented to the Client summarising any further testing necessary and indicating any contractual obligations that have not been fulfilled by either the Engineer or the Contractor, or any other outstanding matters.

Action taken as a result of problems discovered during initial and intermediate audits will minimize problems at the Final Audit stage. In addition to information gained in the intermediate audit(s) audits, the following should also be evaluated:

- Consultant's Construction/Project completion Report;
- Performance of the road to date (as of Final audit);
- Pavement deflection and riding quality;
- Project de-briefing with local residents;
- The need for post construction audit.

#### 14.3.5 Post Construction Audit

Where there is any doubt as to construction requirements being fulfilled during the project and for which no remedial action having been taken, the Final Audit should recommend that a Post Construction Technical Audit be carried out. The required actions include (but are not limited to):

- The data previously obtained re-assessed to cross-check that works have been constructed according to contractual requirements;
- Checking all the pavement layers to be to the specific thickness and compacted strength;
- Checking all material to meet the specific requirements;
- Checking all structures built to specification;
- Assessing that all Contractual Construction standards and specifications have been met and that records show this.

As a general guide, the post construction audit is classified on a five level scale, Table 14.2.

**Table 14.2 Levels of Post Construction Audit**

| Level | Description |
|---|---|
| 1 | Assessment and verification of records: none; only minor problems during construction. No variations or claim. |
| 2 | Sufficient quality records available. Some issues with construction methodologies. Claims and variations caused minor extensions. |
| 3 | Limited pavement or structures quality issues require investigation, for example by restricted DCP testing or non-destructive concrete testing required. Reasonable contract variations. |
| 4 | Significant pavement or structures quality issues. More DCPs and some trial observation pits; possible concrete coring. Poor appearance in final product; many variations and disruptions during construction; Excessive claims. |
| 5 | Major quality issues require extensive investigation, DCPs, test pits, concrete coring. Poor performance and results; Unreasonable claims and contract extension. |

## 14.4 Key Data

### 14.4.1 Background

**Tender Documents**

The TAT should assess the tender documents very carefully, in particular with regard to the high and low unit rates, to justify and explain the decision of the award.

Specific note should be addressed with respect to any alternative methods or materials proposed by the tenderer. It is not within the scope of work of the audit team to evaluate the tender prices or process, but rather aspects that might influence the quality of construction should be highlighted.

**Bill of Quantities**

The Bill of Quantities should be assessed by the TAT to identify unusual quantities and largely familiarise it with the scope and pricing of the project. Aspects which could lead to a future claim should be highlighted for further reference and attention.

**Communication, procedures and chain of command**

The availability and quality of documentation (e.g. work programme, laboratory records and recording systems, control and approval procedures.) and method and frequency of communication, meetings, reports, memos between the various team players on the project should be assessed An important aspect to assess from the outset is what role the "Engineer" will play in the management. Supervision and reporting on the project, i.e. whether he/she is also the Project Manager, the Client's Representative with such delegated powers or simply the Engineer with only supervision responsibility.

### 14.4.2 Laboratories; test records

Only Client and Project approved laboratories should be used on the project. Routine laboratory test procedures (and subsequently results), frequency, location, timing and record keeping and communication should be inspected to ensure full compliance with the Contract. The auditor should inspect the laboratories and their equipment and assess whether added site laboratories can be approved to save time. Daily/weekly/monthly construction progress should be recorded; frequency, location and standard agenda should be agreed as early as the kick-off meeting of the project with recorded minutes should be agreed.

The evaluation of material compliance will, in the first instance, be based on the results available from the consultant and the contractor. The most important parameter is usually the California Bearing Ratio (CBR) or the unconfined compression test (UCS) for stabilized material. Test results should be carefully compared with the Contract Specifications. California Bearing Ratio (CBR) or concrete cube tests or cylinder tests should be scrutinised for compliance, in addition to verification of recent and acceptable calibration of the testing equipment.

### 14.4.3 Variation order, claims

It is vital that the Engineer and the Client agree prior to the contract award the systems to follow and responsibilities for processing claims, variations, contract amendments and payments. Such agreements and responsibilities must be very clear also related to procedures of any applications for extension, timing, and penalties. The auditor should have access to such procedures at the first session of familiarisation of the contract.

### 14.4.4 Pavement and structures

Where doubt exists, quick and non-destructive testing can be performed on most pavements by DCP (Dynamic Cone Penetrometer) which can give a good indication of the presence of specific layers as well as both the pavement strength and the pavement thickness.

The most common and reliable pavement density control is the site sand displacement test The TAT must verify the quality of such tests. The TAT should not only rely on the records from these vital test results but also witness some tests being taken on site. The post construction audit of asphalt surfacing records is more difficult as asphalt surfacing often mask any deficiency in the finish of the underlying layers.-Test pitting may have to be undertaken (Figure 14.1).

**Figure 14.1 Test Pit**

Test Pit through surfacing and pavement layers to top of subgrade. Photo J Cook

DCP and density testing in Test Pit. Photo J Cook

The TAT should review records of concrete slump and laboratory strength tests for structures and concrete pavement also witness some of the tests. Use of the Schmidt Hammer may also guide the TAM in checking structural works.

**Post Construction audit procedures**

When type 4 or 5 post construction audits are found to be necessary a full range of non-destructive tests will be required. This should be conducted during the contractual maintenance period and completed before the official completion and hand over. When type 3 and sometimes type 4 audits are required it should be noted that condemnation of poor sections of road results could be necessary.

To carry out the audit cost effectively the road should be sub divided into uniform sections. The structural responses can only be determined for new roads using deflection surveys or DCP testing as visual characterisation seldom reveals significant flaws.

Although DCP tests are rapid and cheap, it should be remembered however that this test was originally devised for soft material and results obtained in crushed stone and stabilised material must be interpreted with caution. In addition, DCP test results are also highly sensitive to moisture and variations in density (TRL, 2006)

Observation/Test Pits: These are small excavations in the road, mostly used to check the quality and nature of the material and the thickness of the upper layers. Generally, they should not be used to investigate deeper than 250-500mm. Observation holes require significant resources and time to excavate and backfill, but are particularly useful for inspecting the material and thickness of the surfacing, prime and base/subbase courses. Test pitting is commonly used when serious quality issues are suspected and should be carefully considered and designed to minimise the cost, disruption to traffic and political unacceptability. It is usual to excavate test pits adjacent to or around the point that a DCP test was done. Test pits will also allow in situ density testing to be undertaken..

## 14.5 Assessment of Audit Results and Compliance

1. In assessing a project through technical audit of rural roads the TAT may be working within the framework of two contracts: a) Between the Client and the Engineer and b) a contract between the Client and the Contractor. Key issues to be assessed are: Design compliance: The engineer's intentions for the construction of the project are largely conveyed to the contractor by the way of design drawings. Assessment of compliance by the contractor should in the first instance come from a review by the engineer's inspection and records of compliance through as built drawings and recorded measurements of works done compared to work to be done. The degree of (non-) compliance will be submitted to the auditor who will include in his records and recommendations to the Client.
2. Material Compliance: Material compliance will be evaluated using statistical techniques. Although the strength/stiffness and durability of the rural roads are the primary requirements for pavement or surface dressing material and the overall functions of the road, a number of other criteria and properties are typically specified in the contract documents. The technical auditor should bear this in mind during the audit but should use some discretion with occasional results that are slightly out of specification criteria. Graphic plotting of test results is a common and useful tool and easily checked through spreadsheet data, which cover mean-medium-standard deviations and coefficients of variations should be indicated and explained.
3. Consequences and Implications: A fundamental responsibility of the audit team is to recognise and report the consequences of construction tolerances or material specifications not being met. Instead of the road carrying the traffic it was designed for, a poorly constructed road will require premature maintenance or rehabilitation/strengthening works.

Where the audit leads to the conclusion that either the Engineer or the Contractor has been in breach of their respective contracts, then the audit report should refer to the relevant clause of the contract. Based on this the Client can take appropriate action.

The most appropriate method of evaluating the consequences of poor pavement construction or substandard material is to estimate the remaining structural capacity of the pavement using deflection measurements and to compare this with the design traffic. If the total cumulative traffic is less than the design traffic loading the contractual implications will require careful assessment, and a potential reconstructed road.

## 14.6 Audit Reporting

### 14.6.1 General

All aspects of technical audit should be carefully and fully reported. In general, the audit reports tend to contain large quantities of information but should not repeat the contract data. It is essential that the audit reports are submitted as soon as possible in order for the Client to take timely and corrective action. All audit reports should be submitted within 3 weeks of completion of the respective audits.

### 14.6.2 Familiarisation Phase

A written report is required from the Familiarisation Phase of the audit which should clearly bring out deficiencies in design, tendering or other documentation. It is also recommended that the technical auditor prepares notes to assist him with assessment and audit tasks as the project progresses.

### 14.6.3 Initial audit

The report at the end of the initial audit should include details of any critical issue that the auditor considers could have possible influence on the successful completion of the project and the actual functions of the roads. The suggested actions for the Client (e.g. MoC/DRRD) must be clearly highlighted and prioritised with summaries of the possible implications of the issues not being rectified.

### 14.6.4 Intermediate Audit

The report produced after the completion of the intermediate audit should be handled in the same manner as in the previous report. In this case, however, emphasis should be placed on the material and on the construction techniques, and whether issues in the earlier phases have been addressed.

### 14.6.5 Final Audit

The report on the final audit session will summarise the total project and make recommendations on any further investigation (Post Construction Audit) deemed to be necessary by the auditors. It is essential that the Engineer submits a full completion report as soon as possible after the construction has been completed and handed over to the Client. This report should contain all the relevant information regarding the progress of the project including all quality control, test results, and financial records.

The completion report must be carefully evaluated by the audit team, particularly focussing on quality and financial control and compliance with the contract documents.

### References

MWTC, 2001. Technical Auditing of Road Projects. Technical Guideline No.7. Ministry of Works, Transport & Communications, Botswana

SADC. 2003. Guideline on Low-Volume Sealed Roads; Chapter 6 Construction and Drainage.