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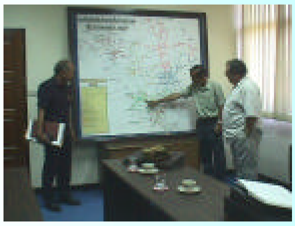

GUIDELINES ON

SELECTION AND OPERATION OF MAINTENANCE MANAGEMENT SYSTEMS

DFID Department for International Development

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This document is available on CD ROM and has been formatted to allow its easy use in training presentations.

GUIDELINES ON
SELECTION AND OPERATION OF MAINTENACE MANAGEMENT SYSTEMS

Section 1
Introduction

1 INTRODUCTION

This guideline has been prepared to compliment the UK Transport Research Laboratory's Overseas Road Note 15. OSRN 15 gives guidelines for the design and operation of road management systems, while this guideline discusses the range of operational and institutional issues that may need to be addressed before the benefits of such systems are realised.

The guideline is produced as an element of a Knowledge and Research (KAR) project whose focus is improved road maintenance for low cost rural roads. The institutional circumstances discussed in the guideline are those encountered during this research, and may not necessarily apply to the management of larger or more heavily trafficked networks. Specifically, this guideline is addressed to those managers of rural networks who may be considering an Information Technology solution to problems related with the management of:

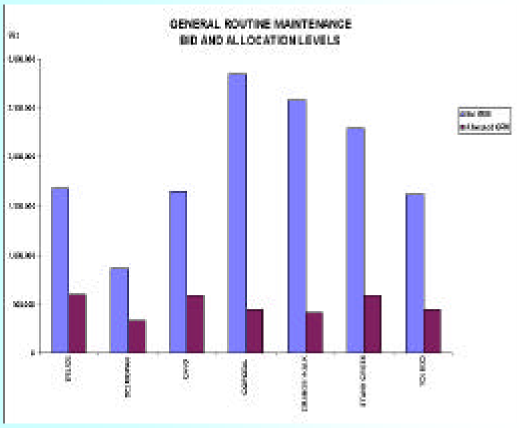
- An ageing road network,
- Increasingly heavy traffic and
- Maintenance budget allocations that are rarely sufficient.

Most of the managers interviewed in the course of this research believed that the "right" Maintenance Management System (MMS) would improve the efficiency and effectiveness of their road maintenance efforts. However, the interviews also revealed a degree of confusion over terminology, with AMS (Asset Management Systems), RMS (Road Management Systems), MMS, PMS (Pavement Management Systems) and RMMS (Routine Maintenance Management Systems) quoted as equivalent systems. In particular, interviewees with little experience of such systems tended to believe that an appropriate PMS would greatly assist in overcoming institutional weakness and result in the delivery of tangible and immediate benefits.

In practice however, tangible benefits from such systems have proved elusive for many organisations. Confused terminology, failure to correctly identify the most appropriate system, inappropriate institutional frameworks and unrealistic expectations are all causes for concern examined in this guideline.

Where appropriate, checklists are provided, to help organisations judge the suitability of particular IT solutions. The authors have applied their practical experience in public and private sector delivery of road maintenance to customise the general approach and principals presented in OSRN 15. Finally, where relevant the authors illustrate comments and advice on key issues by reference to the commercially available maintenance planning system, ROMAPS.

Severly Potholed Road



Budget vs. Allocations

Well maintained Concrete Bridge

Section 2
Road Management Organisations

Regular Meetings

Cascading Gabions preventing Soil Errosion

2 ROAD MANAGEMENT ORGANISATIONS

Reviews carried out under this study confirmed that institutional and organisational problems are widespread. The negative impact of these deficiencies on the delivery of efficient and effective road maintenance is generally recognised and well documented. Most managers are actively seeking ways to improve the effectiveness of their organisations, but no evidence was found to support the expectation that the introduction of an MMS by itself could remedy institutional problems. On the contrary, there is quite convincing evidence that management systems are likely to fail completely if the institutional deficiencies are too severe.

An MMS can also fail because it is not as useful as expected, or because the "costs" of using the system are perceived to be greater than the resulting benefits. In some cases, system capabilities might have been misrepresented, while in others, the organisation may have assumed functionality rather than specifying it. Reviewing literature and viewing a demonstration will not necessarily indicate the likely performance of a system in operation.

Practically all management systems store and sort information about a road network. Many calculate repair cost and prioritise work programmes. However, the value of an MMS is always and only assessed by the end results. If the result is more efficient and effective road maintenance, the system is successful. But if the institution is unable to ensure accurate and up-to-date data, or to translate the recommended work programmes into actions on the road, even the very best systems will fail this test and the system implementation will be considered as a failure.

Thus, critical institutional constraints must be identified and resolved in some way, before seeking greater management efficiencies through the introduction of an MMS. The focus of this chapter is to review the most common institutional problems and offer suggestions on how to deal with them. Key issues are discussed in the specific context of improved road maintenance, and the provision of an appropriate environment for the successful operation of an MMS. For this purposes the most significant constraints have been classified into the following groups:

- Constraints at international level
- Constraints at national level
- Constraints at agency level

2.1 Addressing International Constraints

Constraints at international level are sometimes quoted as contributing to or possibly causing particular maintenance problems. While the issues themselves may cause serious problems, they cannot normally be solved by the agency or even it's national government. Therefore in terms of resolution, external factors such as a weak economy or even poor availability of spares are best thought of as being part of the operating environment. Together with climate and topography, they make up the circumstances that road maintenance and its supporting systems must operate in, and the operating strategies must acknowledge and accommodate all such factors.

Possibly the only addressable international constraints to improved road maintenance are donor activities that inadvertently hinder institutional development. Most donor-funded projects today are sensitive to the need to promote institutional development, and while there remains considerable scope for improvement, relatively few projects are actively counter-productive. However, road agencies should continue to seek out and minimise the impact of "Project" activities that:

a) Extract and "ring-fence" disproportionate funding from the general maintenance budget.

b) Assign key staff to administer to the needs of small sectors of the network to the detriment of the balance.

c) Pay salary incentives to selected staff thus demoralising the remainder of the organisation.

d) Undermine training and development programmes by bypassing in-house capability through the excessive or poorly directed use of external resources.

So far as possible when implementing new projects, organisations should seek capacity building components that:

a) Promote systems, methods and procedures that are effective in the prevailing institutional environment without artificial project support.

b) Pay close attention to the organisation's capacity to change, and have timeframes and programme benchmarks that are flexible and responsive to developmental progress.

Poor Predestrian Facilities

Labour Based Road Construction

Urban Roads

2.2 Addressing National Constraints

National constraints are constraints that are specific to a country but outside the control of that country's road agency.

As with international constraints, many national constraints should also be regarded as part of the environment so far as road maintenance and maintenance planning is concerned. In this context, chronic under funding and shortages of skilled staff are as much a part of the operating environment as are unstable mountainous topography, a monsoon climate or a geology lacking adequate road making materials.

Rural Gravel Road

– Impassable during the Wet Season

While it is obviously necessary to devise long-term strategies to resolve "chronic" institutional problems, organisations must also develop interim implementation strategies, methods and procedures that produce the best possible results in the given circumstances. It is only be possible to specify and identify appropriate support systems such as an MMS when these core operating procedures have been defined.

Before attempting to implement a systematic approach to road maintenance, road agencies should do all they can to resolve or minimise the impact of any institutional problems. In some instances it will be appropriate to formulate strategies that work around "chronic" problems, at other times a more proactive approach may be preferable to raise awareness of maintenance issues in other departments and ministries, - especially those responsible for finance, planning and the public service.

Rut Depth Measurement

Typical issues that usually need to be discussed and considered in consultation with other ministries and departments include:

a) The provision of a work environment that promotes the desired work culture and ethos among road agency staff at all levels. This will often amount to a review of pay and conditions but may sometimes require specific policy changes to ensure and demonstrate the transparent operation of a meritocracy, free of patronage and nepotism.

b) Regardless of absolute funding levels, it is essential that Government adhere to the maintenance allocations awarded at the start of the financial year. If necessary, the planning figure should be close to the lower limit of the available funding envelope, since it is always possible to add works to the program if more funding becomes available but it is not possible to re-prioritise in the light of mid-year budget cuts when half the work has already been completed.

c) Typically, priority maintenance works are programmed with regard to seasonal factors such as climate and agricultural or industrial output. This will normally result in peaks and troughs in the required cash flow. It is important that finance officials are sensitised to the efficiency benefits to be gained by supporting a responsive, non-uniform cash flow.

d) Works Departments need the flexibility to use both day Labour crews and contractors according to the needs of specific repair operations. Occasionally, there are regulatory constraints to such flexibility, and where this exists efforts should be made to persuade the responsible authority should b to review the offending regulation.

e) More commonly however, the constraint to flexible and efficient resource utilisation is financial, with day-labour and state-owned plant costs "subsidised" in one way or another, when compared to an equivalent contract rate. In particular, labour costs relating to leave, sickness, supervision and termination may all be met from non-maintenance budget heads, while plant replacement allowances may be omitted entirely from government's internal plant hire rates. All these omissions mean that maintenance budget goes further using the state's in-house resources; but it does not mean that maintenance works cost less. If the allowances and provisions from all the various sources are gathered together and calculated back into new unit costs, the rates are often considerably higher than those of a contractor, since by definition, such "hidden" costs are not subject to scrutiny and audit. It is therefore important to sensitise the relevant authority to the cost efficiency gains to be had by moving to "commercial rates" for the management and operation of all internal maintenance repair resources.

Culvert Failure with Poor Repairs

2.3 Addressing Departmental Constraints

Strip Concrete Pavement

Departmental constraints are constraints that exist within the road authority and these can generally be resolved by executive decision within the agency.

Many of these constraints will be specific to a particular organisation, and if such constraints are suspected or identified but without obvious solution, it could be appropriate to engage an institutional or organisational specialist from outside the organisation to carry out the required review.

In addition to specific constraints, there are also a number of common issues that make the execution of maintenance works inefficient and the monitoring of such works ineffective. For example:

a) In all but the smallest road management agencies, it is highly desirable that organisations include specialist road maintenance capability. Ideally, a Road Maintenance Unit or Section should be formed within the organisation's head quarters, with representatives throughout the field management hierarchy, down to and including maintenance superintendents, overseers and supervisors. In the smaller organisations, consideration can be given to obtaining the necessary maintenance management services from appropriately qualified consultants. The lack of a defined maintenance organisation hinders motivation, training and monitoring efforts, and may prevent the development of the participatory methods and strategies.

Crocodile Cracking Failure

b) Line Item budgeting dates back to colonial times when overseas procurement orders were fulfilled by sea freight and item orders had to be consolidated both to benefit from economies of scale, and for practical logistic reasons. Today however, the situation is quite different. It is far more important to know the rate per square metre of road grading, base compaction or double bituminous surface treatment, than to know the component cost of tyres, fuel, and wages within each activity. It is highly desirable that Agencies responsible for the execution of road works adopt a rates-based accounting system to ensure that activity costs are properly recognised, and to facilitate comparisons with alternative methodologies or resources.

c) Line Items are also used to allocate funding to specific maintenance activities, individual roads or even work sections. In some organisations, this process allows parliamentarians to determine funding priorities at a level of detail that excludes any form of economic or needs-based prioritisation and resource management. It is therefore highly desirable that affected Road Agencies press for a more flexible approach to maintenance funding. Desirably, they should seek to implement either a global maintenance budget under the authority of the financial delegate, or at the very least secure program budgets allocated by maintenance head or strategy. This is practically the only type of funding can be allocated to roads and tasks using current, up-to-date needs assessments and policy-based priorities calculated by an MMS.

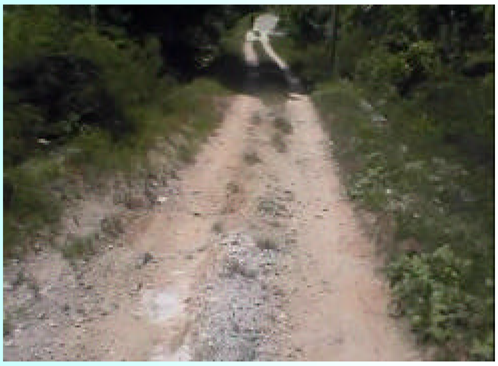
d) The desirability of moving from day labour to contract execution of maintenance work may result from anticipated or perceived efficiency gains. More often however, it is a necessary response to falling budget levels that no longer meet the cost of continuously employed repair resources. This issue can be critical to the efficient use of scarce maintenance funding, particularly when considered in conjunction with preceding points. Unfortunately, however, appropriate employment strategies are often hindered by out-dated labour cost accounting and plant pricing strategies. In particular, it is essential that departmental internal hire rates recover the full operating and replacement cost of plant. In the first instance, this affords a logical method for funding a plant replacement fund, but possibly more importantly, and as noted above, it will ensure budget levels that allow rational choice between departmental and contract resources.

Axle Load Survey Undeway

Section 3
Road Asset
Management

3 ROAD ASSET MANAGEMENT

3.1 Management Levels



Poor Quality Gravel Road – Track

Dictionaries define the term "Asset" as something that can be owned, - something advantageous or well worth having. In terms of physical infrastructure, assets can refer to public buildings, schools, hospitals, offices, car parks or in this instance, roads.

Public infrastructure assets are built or acquired for a purpose. Generally, the purpose is the delivery of a service, and "Management" involves having responsibility for all the activities that are necessary for the delivery of that service. In the case of a hospital or school the nature of the service is clear, - the care and recovery of the sick, or the education of the young. The management of roads also involves responsibility for the activities necessary for the delivery of a service. Unlike hospitals and schools however, there is no established service delivery or management scope defined for roads. In practice, the scope of the managed service depends on the delegated responsibilities of the managing road agency.

At it's broadest the remit of the managing agency may be the safe, efficient and effective operation of road transportation. More commonly, the remit of managers of rural and feeder road networks is simply to preserve the as-built functionality of their networks. The differences are very significant, as illustrated in Table 3-1 below:

Management Function	Management Responsibility									
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10
Preserve as-built functionality	●	●	●	●	●	●	●	●	●	●
Ensure road safety	●	●	●	●	●	●	●	●	●	
Provide adequate capacity	●	●	●	●	●	●	●	●		
Road network development	●	●	●	●	●	●	●			
Axle-weight control	●	●	●	●	●	●				
Vehicle licencing	●	●	●	●	●					
Vehicle Inspectorate	●	●	●	●						
Traffic Policing	●	●	●							
Accident Recovery	●	●								
Provision of full emergency services	●									

Table 3-1 Asset Management

In terms of this chart, the responsibility of rural and feeder road network managers is typically Level 9 or Level 10, and the functionality of their MMS should be matched accordingly.

3.2 The Purpose of Road Asset Management

The aim of level 9 or level 10 road management is to 'enable the network to withstand the damage caused by wear and tear, to prevent substandard conditions from developing, and to ensure that traffic can continue to travel, in a manner which is safe, efficient, reliable and which causes the least damage to the environment[i]. This achieved through activities such as routine and periodic maintenance, (categorised by the frequency and budget). OSRN 15 states that the four main functions of management are: planning, programming, preparation and operations. A Maintenance Management System methodology should therefore assist in each of the management functions, but particularly with the preparation and operations stages. This principal remains true regardless of the size of the network or the level of service it is required to provide.

Good Quality Concrete Road

3.3 Road Management Environment

The management process may be thought of as a cycle of events, and each step of the cycle requires information (data)[ii]. Most road management systems have been developed to gather, manage and process this data and their value rests on the assumption that a more informed institution will generally be a more efficient and effective one as well. This is undoubtedly true in an appropriate environment, but as noted above, the application of technology to maintenance management will only deliver effective road maintenance if the process takes place within a consistent and unambiguous institutional policy framework.

Poor Quality Concrete Road

In general the road management process consists an initial set up activity where management purposes and policies are defined, followed by an annual cycle of events:

- Assessing needs
- Determining actions
- Determining costs
- Determining priorities
- Programming and implementing activities
- Monitoring and auditing

Labour Intensive Wooden Bridge

Labour Intensive Road Repairs

3.4 General System Functionality

The actual tasks involved depend upon the management functions of planning, programming, preparation and operation and the road administration must have a well defined policy framework and hence procedures for activities[iii]. Key features of an appropriate system should include the following:

a) A Maintenance Management System should enforce national maintenance policies and departmental regulations and should standardise maintenance practices countrywide. The staff must understand the procedures and desirably should be involved in their development, as this will promote sustainability.

b) A Maintenance Management System should support all common maintenance strategies. i.e.:

- Emergency Maintenance
- Routine Maintenance
- Periodic maintenance
- Preventative maintenance
- Rehabilitative Maintenance

c) The system should also acknowledge international maintenance works categories and sub categories i.e.:

- Emergency: Minor
Major
- Routine: Programmed
Responsive
- Periodic: Pavements
Structures
- Preventative: Minor Works (structural)
Minor Works (road safety)

d) The Maintenance Management System (MMS) methodology must support the Road Agency's administrative framework. In general the system should be able to schedule work in formats suitable for all resource classes and in particular for:

- Lengthmen
- Community contractors
- Medium contractors
- Direct labour forces

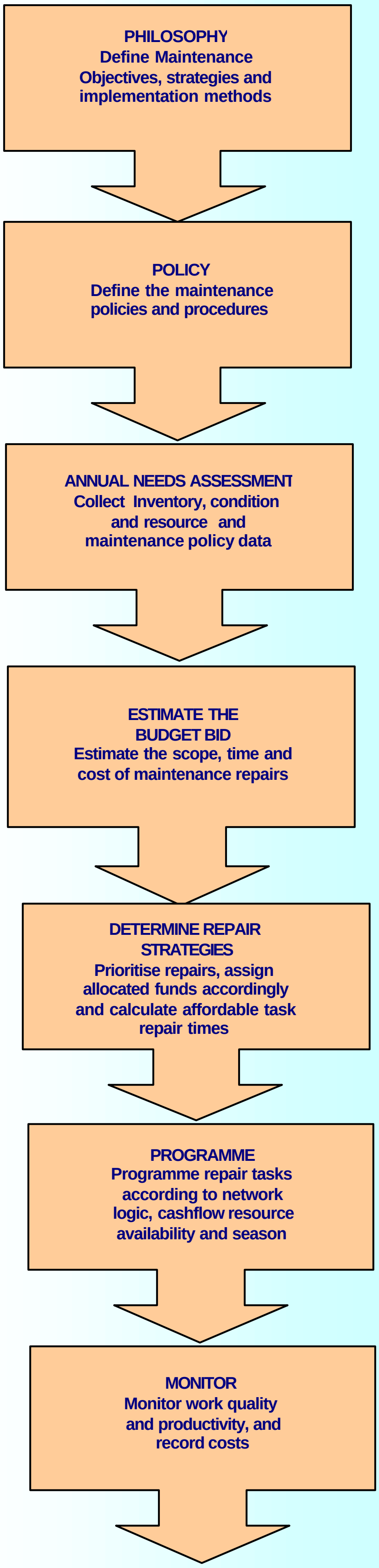
e) The methodology may partially support Line Item Budgeting, but full benefits are only realised when departments operate program budgets based on actual resource costs and productivities.

f) All maintenance management systems promote systematic road maintenance. Most produce prioritised work schedules and programmes, and organisations and road networks benefit from the system by following the programmes and thereby ensuring that scarce resources are utilised to best advantage. The methods by which the system-generated schedules are conveyed to the executing agency or field staff must also be regarded as part of the MMS. Since effective implementation of the work programmes is fundamental to the delivery of system benefits, the MMS should have a default set of implementing methods and procedures that can be modified to match prevailing or customary practice within the organisation.

g) Many organisations embody their maintenance philosophy in the form of a mission statement. The MMS must be able to recognise and implement the purpose of such a statement. The system should guide the organisation into formulating the policy objectives that will provide the basis for prioritising maintenance activities.

h) The recommendations resulting from system calculations must always be transparent; the system should never be regarded as a black box. The policies must be recognised as Departmental Maintenance Policies. Maintenance strategies should be those traditionally implemented whenever possible. If new procedures are needed, these should be defined and developed by maintenance field staff. The organisation's maintenance planners should detail the methodologies and the MMS support system need do little more than take over the paper-based management functions arising from the above processes.

i) While a minimal MMS need do little more than replace the manual processes defined by the methodology, most will provide a much more extensive functionality, as shown in the table on the next page.



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Repair Estimates:	• Inventory management and reporting to support full road asset management
	• Deterioration modelling
	• Scope of work calculations based the measured size of individual work section elements
	• Resource productivity calculations based on work fitness estimates
	• Repair time calculations based on scopes of work and resource productivities
	• Repair cost estimates based on resource rates and repair times and materials consumption
Budget Management:	• Prioritisation calculations based on multiple policy objectives and detailed condition
	• Economic calculations based on whole life operating cost streams and road user benefits
	• User-defined funding strategies
	• Automatic assignment of funds to tasks according to task priorities
Preparation of Works Programmes:	• Calculation of affordable repair times
	• Preparation of resource utilisation and work implementation programmes
Preparation of Works Orders:	• Related stores and stock management
Default Field Implementation strategies:	• Emergency
	• Routine
	• Periodic
	• Preventative
	• Rehabilitative
Default Work Monitoring Strategies:	• Inspection
	• Keeping work and expenditure records
Feedback options:	• Using historical records to fine-tune the deterioration models
	• The resource productivities
	• The resource utilisation costs

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Section 4
Pavement Management Systems

4 PAVEMENT MANAGEMENT SYSTEMS

4.1 Overview

There are two general types of pavement management system, and their key properties may be summarised as:

	Similarities	Differences
Type I	Both types model pavement deterioration over time according to initial construction standards, current operating environment and predicted usage	Work is prioritised according the economic benefit to road users
Type II		Work is prioritised according the asset preservation considerations

Table 4-1 - Types of PMS

Managers of road networks throughout the developing world will recognise that almost all PMS used on their networks are Type I. By far the most common Type I PMS is the World Bank's HDM program, currently on version III (HDM III) with the release of HDM IV immanent. The World Bank and most other donors generally require an economic evaluation of the benefit of any loan capital invested in national road networks.

Dynamic Cone Penetrometer Testing

Type II PMS are relatively common throughout the developed world. The underlying philosophy is that the economic basis for constructing the asset remains true provided the asset is kept in a serviceable condition. On this basis, repair and reinstatement works are prioritised according to the degree of deterioration or reduced serviceability experienced by each candidate road.

Table 4-2 is adapted from information contained in the Overseas Road Note 15[iv] and illustrates the strategic functions of a PMS.

Strategic Activity	Management Function	Network Coverage	Time Horizon	Management and Staff
Planning	Forecasting network performance Determining future budget requirements	Entire network	Long term	Senior management and policy makers
Programming	Determining the road network investment programme for the current plan period	Selected Sections	Medium term	Managers and budget holders
Preparation	Selection of road sections for remedial works Compilation of contract packages*	Priority Sections	Next budget year	Engineers, technical and contracts staff
Operations	Comparison of routine maintenance intervention strategies**	Selected Sections	As needed	Maintenance managers.

4.2 A Further Look at HDM III

For most of the period between the late 1980's and the present time, periodic resurfacing was the only maintenance treatment considered for funding by the main multi-lateral donors. At same time, these donors were requiring HDM evaluations of most if not all road investment projects, and naturally this included the planning and evaluation of periodic maintenance works.

During the early part of this period most road authorities continued to manage their remaining maintenance strategies, - emergency, routine and preventative maintenance - in the traditional way. This was generally an ad hoc response to needs as funds permitted. Only Periodic Maintenance was managed in a systematic way and so HDM came to be regarded as a Maintenance Management tool, thereby blurring the distinction between a PMS and an MMS.

When considering HDM III as a tool for general Maintenance Management the most significant factors to note are that:

- HDM III not designed to provide MMS functionality. It is normally used to test the economic "worth" of potential road investment programmes where alternative maintenance strategies are a relatively minor factor in the overall evaluation.
- HDM III is designed to model pavement deterioration under predicted traffic and specified maintenance regimes. To do this, it is necessary to provide the system with calibration data, selected link data, and cost and strategy data that defines the proposed routine maintenance interventions.
- HDM III evaluates the performance of road pavements in the context of alternative maintenance scenarios.
- HDM III cannot propose maintenance treatments. It will however compare the economic rate of return delivered by alternative maintenance strategies that are proposed by the user.
- HDM IV will be released for general use during the year 2000. It is expected to offer much more MMS functionality but its value in the workplace is yet to be established.

Axle Load Testing

Deflection Testing

Falling Weight Deflectometer Apparatus

Trial Pit to Determine Pavement Structure

4.3 The Basic Functionality of a PMS

HDM III sets the standard for pavement management systems that are optimised on economic considerations. However, HDM III has been around for 10 years and despite attempts to improve its user interface with the release of HDM95, it remains an outdated program. Previews of HDM IV show it to be a completely new programme with many new features and a much improved user interface. It is also a much more complex program with legacy features that enable it to read HDM III data files, but hinder its interface with other office software. Desirably, a modern pavement management system should:

a) Have an intuitive and user-friendly interface.

b) Integrate easily with common office software for the pre-processing of data in spreadsheets, and the post-processing of reports in word processors.

c) Accurately predict the performance of all pavement types commonly found on the national road network. Such predictions should be sensitive to all key variables, including age, construction standard, operating environment and predicted traffic loading.

d) Calculate initial pavement strength from pavement layer characteristics.

e) Calculate present pavement strength from condition assessment data such as pavement deflections.

f) Calculate future pavement deterioration over time given its current condition and specified traffic parameters and growth factors.

g) Calculate pavement strengthening overlay thicknesses needed to meet specified performance criteria.

h) Evaluate the economic benefit of the proposed treatment by comparing the initial capital cost, the recurrent maintenance cost and the accumulated benefits arising from a smoother riding surface.

i) Be capable of whole network analysis or specific project analysis using data of differing quality.

4.4 The Main Benefits of Using a PMS

OSRN 15 lists the benefits of implementing a road management (planning and programming) system as[v]:

- Better economic management
- Improved advice (better information available for a variety of uses)
- Better design of treatments
- Improved monitoring
- Improved general management

It is important to recall however, that the benefits will only be realised if the system is appropriate to the users and is supported by both policy makers and the users of the system.

Severely Cracked Surface

4.5 Deciding to Implement a PMS

This discussion is based on the procedures necessary to install, calibrate and operate HDM III. Most other systems including HDM IV are either similar, or have more complex procedures, so prospective users can still use the following discussion to judge the likely institutional impact and financial costs involved in implementing such a system. Before taking the final decision:

a) Determine the ownership of the system. Will it be used as a planning tool, or as a maintenance management tool? The answer to this will probably determine which unit or department should own and operate the system, and it may even determine which government ministry it should serve.

b) Decide on primary usage. Will it be used mainly to motivate future development loans, or will it be used to monitor the road network primarily for network management purposes? The answer to this question will determine whether the key staff should be employees or consultants. If usage is likely to be intermittent, it may be preferable to use the services of consultants.

Trial Pit and Pavement Investigation

c) Decide on level of usage. If the system is to be used for network management a substantial organisation may be needed. Given that the generic life of a double bituminous surface treatment is 5 – 7 years, it is desirable to complete an assessment of the full paved network every five years. Survey intervals and progress rates vary considerably depending on the variability of network road pavements. Typically they will range from 5km to 10kms per day, and a realistic figure must be identified for the local network at an early stage in the implementation process so that the number of survey teams can be estimated. e.g.

MERLIN Roughness calibration

Bump Intergrator Equipment

Size of paved network	8000 km
Require annual rate to complete in 5 years	1600 km
Average daily survey rate	10 km
Survey days per month	16
Survey months per year	6
Annual rate per team	960 km
Number of teams required	2

d) Determine the equipment needed by each team to conduct pavement condition assessments, including deflection surveys, DCP surveys, surface condition surveys and road roughness surveys. Consider also the logistics of mobilising the teams to the various parts of the network. Estimate team sizes, equipment procurements costs and annual operating costs.

e) Determine the volumes of data to be managed. Consult with the prospective PMS supplier to determine the capacity of the computer hardware. Consider data backup, power protection and security issues, and estimate procurement and annual operating costs.

f) Determine staff levels and estimate initial and recurrent training requirements and cost

g) Review the institutional environment to ensure that key constraints are either minimised or have been accommodated by the formulation of appropriate operating strategies and procedures.

h) Review the costs and benefits of system ownership.

i) When the decision to proceed has been taken, implementation will occur in three stages:

j) Procurement and installation of hardware, software and equipment

k) Calibration of the system

l) Operator training

4.6 Implementing a PMS

4.6.1 Procurement and Installation

Generally, these processes will be relatively costly and possibly time consuming if equipment has to be procured from overseas, and it is important to allow adequate time for such deliveries in the overall programme. Administratively however, these are the most straightforward activities, as the procurement will generally be governed by prevailing finance regulations and guidelines. Physical installation must be carried out under the supervision of a specialist.

Deflection Testing

4.6.2 System Calibration

HDM-4 requires more calibration inputs than HDM-III, because many factors that were pre-set in the HDM-III can now be customised to local conditions in HDM-4. While new requirements clearly add to the calibration workload, the great majority of the calibration effort still applies to HDM III.

The basic data items required to calibrate both versions of HDM consist of parameters that describe the physical characteristics of the pavements and the network, road user data, traffic data, unit costs and economic data. In establishing input data, the accuracy required is dictated by the objectives of the analysis. If one is doing a very approximate analysis there is no need to quantify the input data to a very high degree of accuracy. Conversely, if one is doing a detailed analysis it is important to quantify the data as accurately as is practical given the available resources.

There are three levels of calibration for HDM, which involve low, moderate and major levels of effort and resources, as follows:

Level 1	Basic Application	Determines the values of required basic input parameters, adopts many default values, and calibrates the most sensitive parameters with best estimates, desk studies or minimal field surveys.
Level 2	Calibration	Requires measurement of additional input parameters and moderate field surveys to calibrate key predictive relationships to local conditions. This level may entail slight modification of the model source code.
Level 3	Adaptation	Undertakes major field surveys and controlled experiments to enhance the existing predictive relationships or to develop new and locally specific relationships for substitution in the source code of the model.

In terms of effort, these three levels can be viewed as weeks, months and years. An analyst should be able to undertake a Level 1 calibration in about two weeks. For a Level 2 calibration there is an increase in the amount of effort required so it will take at least two months. Level 3 calibrations require a long-term commitment to basic data collection so their extent spans for a year or more.

- Calibration procedures will obviously vary with the system being implemented, but for HDM the key procedures regardless of calibration level are:

♦ Network Nodes	Before starting any surveys it is advisable to review the entire road network and plan the disposition of network links and nodes.
♦ Representative Links	It is necessary to select representative links to be used during the system set-up and calibration. The validity of system predictions will be tested against actual pavement performance on these links.
♦ Inventory Data	Once the representative links have been selected, topographic and geometric can be conducted.
♦ Traffic Data	It is necessary to carry out classified traffic counts in sufficient detail to establish the traffic mix, typical axle loading and establish annual traffic volumes by vehicle class. It is also necessary to research past traffic counts to establish traffic growth rates.
♦ Vehicle Operating Costs	It is necessary to quantify the operating consumables for each class of vehicle, the rates of consumption and the replacement costs for items ranging from tyres and shock absorbers to oils and fuel.
♦ Calibration Constants	Typically, these constants relate to factors such as crack, rut, ravelling and pothole progression, and the evaluation process a detailed survey of the network to identify similar pavements, similar operating environment and traffic loading, but of differing age, so that age distress profiles can be developed. These measurements have to be precise. A specialist will normally make them, and they are normally time-consuming to complete. The calibration requirements for HDM IV are significantly more stringent for HDM III, and most implementing agencies will need both financial and technical assistance to complete the process.
♦ Condition Surveys	Deflection Surveys At no more than 50m intervals, both lanes for calibration surveys Wide crack area Estimated per link using a 1sq.m frame Area of Fine cracking Estimated per link using a 1sq.m frame Area or ravelling Estimated per link using a 1sq.m frame Area of potholing Estimated per link using a 1sq.m frame Length of shallow rutting Ln.m per link Length of deep rutting Ln.m per link Pavement CBR profile Estimated at 100m intervals for calibration surveys Trial pit samples Sample at 250m intervals for calibration surveys Roughness surveys Continuous, both lanes

4.6.3 Operator Training

The activities involved in setting up and operating a Pavement Management System are highly skilled and not normally present in a maintenance organisation. It is therefore necessary to identify, train and retain one or more PMS implementation teams. If staff loss or turnover is high, it may be necessary to incorporate PMS as part of the organisation's normal training programme, either through in-house training facilities or at a local technical training college. Trainers at such facilities should be senior PMS staff or suitably qualified consultants.

Topics that need to be covered in the training programmes include:

PC and possibly network support

The use and operation of the system programmes

The meaning and use of system outputs

Data collection methods, including:

- Visual condition assessments
- Identifying, classifying and measuring surface distress indicators
- The theory and operation of the chosen deflection measuring equipment
- A knowledge of other leading deflection measurement systems
- The conduct and use of DCP surveys
- Pavement sampling procedures
- The calibration and operation of road roughness measuring equipment

Visual Inspection of Roads

Dynamic Cone Penetrometer Testing

4.7 Using a PMS

4.7.1 Forward Planning for Network Management

The main benefit of PMS the ability to forecast major network investment needs well in advance of implementation. The validity of most national highway 5 and 10-year development plans rely on the predictions of pavement management systems. The development plans enable finance departments to budget for the forthcoming expenses. They provide the data and allow the time needed to negotiate loan funding where needed.

Car Ferry

In summary, long and medium term planning identifies network investment needs sufficiently far in advance to allow time to procure project funding, procure the services of consultants to plan and design the works and engage contractors to execute the works so that the reinstatements are completed at the optimum time.

In the first few years after the installation of a PMS, most highway authorities will wish to carry out an initial condition assessment covering as much of the network as possible. Following an evaluation of this data, planners will be able to assign likely optimum intervention times to the network pavements. This in turn will allow the drafting of the required medium and long-term network management plans.

However, to ensure the on-going validity of such plans, and to gather the pavement detail needed for the design of remedial treatments, it will be necessary to programme and operate an annual rolling survey to update macro planning data on the most critical sections, fill in any remaining "gaps" in the base survey and collect detailed design data for immanent upgrading projects.

Truck Failure on a Gravel Road

4.7.2 Forward Planning for Survey Logistics

The key factor in the provision of useful and timely PMS data is forward planning for PMS survey operations. It is usually necessary to identify priority road sections by some form of visual screening process to supplement the analysis of past condition surveys, and from this prepare pavement condition assessment and evaluation programmes two or three years ahead.

It will be necessary to assess future pavement evaluation requirements in terms of staff and equipment for every future survey year. If there are shortfalls to meet, these must be budgeted for and procured, - a process that typically extends across two financial years.

Before survey teams can be deployed in any current year, their work programme must be planned in detail. Over-night accommodation may need to be arranged. It may be necessary to make special arrangements to provide teams with food, water of fuel. Additionally, it may be necessary to make special transport arrangements to move heave equipment such as a falling weight deflectometer between remote parts of the network.

Whether the data collection process is easy or difficult to organise, it must be undertaken in a comprehensive and systematic manner. If the data is unreliable, the results calculated by the PMS will be unreliable. If the data is out of date the results will be out of date. If benefits are to be realised from the operation and installation of a PMS, the operating organisation must be have a long term commitment to funding and carrying out the required annual surveys, and to implementing the identified investment programme.

Poor Shoulder Maintenance

Section 5
Routine Maintenance Management Systems

Patching Failed Areas

Regular Grading of Gravel Roads

5 ROUTINE MAINTENANCE MANAGEMENT SYSTEMS

5.1 Introduction

General Routine Maintenance (GRM) is used to describe any maintenance strategy that programmes the same repair task one or more times each year. GRM includes a large number of different treatment and repair activities, but individual tasks are relatively small. Despite the small cost of individual repairs however, the large number of activities can result in annual GRM estimates that are greater than the ones for Periodic Maintenance.

Project Managers will readily appreciate that managing numerous small tasks requires particular management skills with overall management and supervision often more demanding than managing the equivalent value of works in a few consolidated projects.

5.2 Manual Systems

Despite the potential management benefits, most available Routine Maintenance Management tools are relatively weak. At present, the majority of the RMMS programs are electronic analogues of paper-based task schedules and expenditure trackers and many organisations prefer to continue with their existing, paper-based systems and *ad hoc* procedures.

Paper-based inventory and condition records (and their electronic equivalents) provide effective methods of recording network stock and repair requirements, - particularly systems that use index cards in conjunction with other forms of information such as national mapping, road strip maps and asset photo albums. Condition assessments for such systems are almost always based on visual inspections and they may also include forms and procedures to record work and expenditure.

Budgets estimated by manual methods are usually widely understood within an organisation, and the organisation's workforce is more likely to respect and support plans based on estimating methods that they understand or have participated in. When prioritisation is needed this may be achieved in a systematic manner using task / traffic weighting indices such as those illustrated in overleaf.

REPAIR TASKS	TRAFFIC GROUP				
	1	2	3	4	5
Pothole Patching	1	2	3	4	4
Crack sealing	1	2	2	2	3
Shoulders	3	3	4	4	4
Side drainage	3	3	3	3	3
Cross drainage	3	3	3	3	3
Road reserve	3	4	5	5	5
Traffic Signs	5	5	5	5	5

Table 5-1 - Task Ranking Indices

ADT ranges per Traffic Group				
1	2	3	4	5
> 1000	700 - 1000	400 – 700	100 – 400	< 100

Table 5-2 - Traffic Groups and ADT ranges

The Table 5-1 is used to ensure that first-ranked tasks are given funding and implementation priority, with the lowest-ranked tasks omitted when funds are insufficient. Table 5-2 illustrates how the Traffic group numbers can represent any set of annual daily traffic (ADT) bands depending on the volume of traffic using the local network.

Similar tables can also be prepared for different sets of tasks. The assignment of index values to each cell in the matrix reflects the maintenance policy of the organisation, defining the relative importance of scheduled tasks and traffic levels. The advantages of such a system are:

- It is easy to implement
- A days training is usually sufficient for most users
- The calculations are consistent and transparent

The importance of a transparent calculation process should not be underestimated. Many trainers have found that workings of complex computer-base systems such as MMS are best illustrated by simplified, paper-based analogues. However, manual systems are onerous and labour-intensive when used to manage large or complex networks, and on such networks, a manual analogue would only be introduced as a pilot scheme on a limited number of roads as part of the system training programme. For the larger road networks, a computer-based RMMS offers the following potential benefits:

Well maintained Side Drains

Pothole collecting Water on a Gravel Road

Retaining Walls

- Large time savings in the preparation of estimates
- Calculations based on up-to-the minute data
- The possibility of complex calculations that are more accurate and better reflect the outcome of interactions between the road network and its local environment
- Automatic allocation of capped budgets to priority tasks
- Automatic allocation of capped budgets to priority tasks
- Automatic preparation of work plans and programmes
- Facilities to track repair progress and expenditure
- Rapid availability of statistical summary data and management reports detailing any aspect of the
- Network, its condition, the remedial and preventative repairs and treatments carried out and the expenditure incurred

The slow development of routine maintenance management and planning systems that offer the full range of potential benefits reflects a belated appreciation of the impact of poor routine maintenance, and the lack of an international sponsor or coordinator.

There is no standard RMMS equivalent of HDM. However, it is relevant to note that the development HDM and its adoption as the de-facto standard for PMS arose from the requirement that lending agencies base their decisions on the economic value of potential road infrastructure investments. The possible role of economics as a decision-making tool for GRM is much less clear. The economic evaluation methodology used by HDM is certainly capable of calculating the optimum unpaved road grading or paved road pothole repair frequency, given the relevant road characteristics and traffic data. It cannot however, calculate an equivalent result for the maintenance of other road elements such as drainage, shoulder, road edges, road signs and road the reserve. - Nor can it offer a means to make comparative judgement between the relative worth of these varied repair activities.

Only a handful of systems offer an alternative to decisions based on subjective tables similar to the one illustrated in Table 5-1 and one of these is reviewed in the final section of this paper.

5.3 Routine Maintenance Planning

There are several key considerations to be resolved before preparing detailed routine maintenance plans. These include:

a) Defining the resource to be used for the repair works

b) Defining the network work sections that will form the basis of routine maintenance planning

c) Identifying the road elements that are normally maintained under GRM by the road authority's workforce and defining and repair tasks in each case.

d) Defining an implementation strategy for planning and carrying out the repairs in the most efficient and effective way.

e) Defining the data inputs and report outputs

f) Identifying key issues relating to workforce motivationand programme implantation.

Regular Maintenance

5.4 Defining Resource Types

It may surprise some to note that the most important single factor in GRM planning is the selection of the resources that will be used. This is because the various alternatives differ greatly in their efficiency and flexibility, and have different planning requirements. The types of resource and their typical impact on work planning are described in the following table:

Resource	Advantages	Disadvantages	Impact
Force Account And Day Labour Forces This Group Is Usually Made Up Of Permanently Employed Labour.	Capabilities well understood Flexible for reassignment at short notice Good retention of Training investment Skills developed as needed	Need to be continuously employed. This may be impossible with small budgets. More flexible pay and conditions often produces better productivity	Work programmes will be crew orientated. Roads sections based on crew camps. Task assignment ensure crew is occupied at all times
Petty Contractors 1: Village Groups	Involves community groups, provides income-generation to both unskilled groups and local artisans	Possible poor skills, low productivity. Need good planning and supervision	Work programmes must allow flexible inputs, e.g. low availability at planting and harvesting.
Petty Contractors 2: Length Men	Involves community groups and provides year-round income-generation for selected unskilled workers	Limited to light, unskilled activities Need good planning and on-the-job training	Specific tasks have to be defined. Typically, 2 – 5km road lengths are assigned it individuals full time.
Medium Contractors 1: General Contractors	Can be engaged to attend to all GRM tasks per section. Or group of sections	May appear more costly compared to DL forces under typical government accounting systems. May be inflexible regarding significant changes to funding levels during the year.	All tasks can be programmed to occur at optimum times if the contractor has sufficient resources. If this approach is adopted only adequately resourced contractors should be hired.
Medium Contractors 2: General Contractors	Strategy is appropriate for small contractor development programmes. Trainee contractors only need to acquire specialist equipment for one type of work.	Need adequate work programmes pay off equipment loans May be inflexible regarding significant changes to funding levels during the year.	Careful programming needed to utilise a limited-capacity resource effectively. On the job training and intensive training needed to benefit form this type of contractor.

Table 5 -3 - GRM Resources

Small Wooden Bridge

Labour Intensive Gravel Production

5.5 Defining Work Sections

Most RMMS schedule work by road section or link. Where road sections are used, they must be defined well ahead of system implementation. Relevant considerations when defining work sections are:

5.5.1 Socio-Political Considerations

Section boundaries should always respect the work boundaries of road camps and other administrative, social or political work demarcations, especially when community resources are being considered.

5.5.2 Uniformity of Engineering Environment

The engineering environment of a road describes the topographic, climatic and other operating conditions that affect the present and future performance of the road. A Work section can have only one engineering environment. Each factor in the environment is separately quantified according to a "pick list" of options, but no factor can have two values. The extent to which section definitions respect small changes in one parameter or another depends on the data accuracy considerations discussed below.

5.5.3 Length Considerations

If the RMMS schedules tasks and repair quantities, it will probably do so by Work Section. Work is usually specified by repair quantities, but some systems also provide an option to schedule resources based on quantities and resource productivity. In this case, the scheduled quantity will normally be days. Typical systems schedule a minimum 1-day intervention even when the actual repair should take only an hour or so. This circumstance is most likely to occur on short or very short sections where work quantities are small anyway. To avoid this potential problem, Work sections should normally be at least 30kms in length, and operational reasons, not more than 100kms in length.

5.5.4 Aggregation Options

Work plans are prepared by Section. Resource management involves the "assignment" of section repair tasks to resources. With force account resources, the "value" of such repairs must at least equal the crew annual operating cost. If sections are small, many will be needed to complete the crew programme, and the programme will become excessively complicated. To avoid small sections, consideration should be given to defining logical sections that are aggregates of several physical sections that have the same operating environment.

5.6 Defining GRM Road Elements and Repair Tasks

GRM Work elements are the parts of a road most likely experience superficial wear and tear in the normal course of operations. Typically, damage occurs to GRM elements readily and progresses rapidly, while effective repairs are easy to carried out.

Most but not all element repairs involve different types of work and different artisan skills. Thus routine maintenance planning must provide the timely, efficient and effective deployment of available resources and skills for short periods of time to repair recurring damage foreseen for all exposed road structure surfaces.

Road maintenance organisations often have specific sets of road elements and repair methods that have evolved through years of experience to meet the particular needs of the local network with the locally available resources and skills. Typical GRM elements include:

Regular Grading

Item Description		Maintenance Element
General Items	Road Cleaning	Road sweeping Litter collection
	Vegetation Control	Controlling vegetation in the road reserve Trimming vegetation along the road verges
	Signs And Roadside Furniture	Cleaning road signs Repairing barrier rail Replacing distance and feature markers
Drainage	Side Drains	Clearing silt or obstructions Repairing invert scour
	Culverts	Removing silt from barrels, inlets and outlets Repairing scour from barrels, inlets and outlets
	Bridges	Minor repairs to superstructure, end walls and railings Repairs to bridge deck surfacing Keeping bridge openings clear of debris
Gravel Roads	Wearing Course Repairs	Spot gravelling Light or drag grading Medium grading to cut and smooth corrugations Heavy grading to scarify and reshape the road
Paved Roads	Carriageway Repairs	Repairing base failures Pothole parching Repairs to wide cracks Repairs to fine cracks Repairs to paved road edges
	Paved Shoulders	Patching potholes
	Unpaved Shoulders	Spot gravelling Light grading Medium grading

Table 5-4 - Typical GRM Elements

Labour Based Repairs

5.7 Defining Implementation Strategy

Routine maintenance repairs fall into two general categories. There are:

a) Responsive Maintenance – Repairs that are undertaken in response to a network need

b) Programmed Maintenance – Repairs that are programmed to take place at pre-determined times throughout the year

At first glance, responsive interventions may appear much more efficient since resources are only deployed to carry out repairs to a known defect, while a programmed intervention might be based on a predicted level of damage that is not realised, or is exceeded. However, responsive strategies also have potential disadvantages that make the choice of strategy less obvious. In particular, repairs cannot be carried out timeously unless the defects are speedily detected and adequate resources are available.

Types of defect can be classified for planning purposes by their distribution and probability. The outcome of such a classification is illustrated in Table 5-5 below:

Distribution	Predictability	Type of Defect	Strategy
Local (at Work Section level)	Predictable	Vegetation growth Drain erosion	Routine - Programmed
	Unpredictable	Potholing Base failures	Routine - Responsive
Network (At road or route level)	Predictable	Erosion of wearing surfaces	Periodic - Programmed
		Development of rutting	Rehabilitative - Programmed
	Unpredictable	Landslides Culvert washouts	Emergency - Responsive

Table 5-5 - Distribution and Probability of Defects

Emmergency Repair Required

The distribution and predictability of a defect has an impact on the selection of an appropriate repair strategy. In general a programmed strategy is appropriate if the deterioration is predictable, and responsive if it is not. Routine Maintenance Management Systems provide management guidance for the repair of both predictable and unpredictable defects that have a local or Work Section level distribution. Pavement Management Systems provide guidance for the repair of predictable deterioration at network level. Unpredictable network level damage is typically managed under separate Minor or Major Emergency Repair strategies that are funded from maintenance budget contingencies.

5.8 Inputs, Outputs, Accuracy and Sensitivity

5.8.1 Condition Assessment and Workload Estimates

Routine Maintenance Management Systems take in data about the size and condition of the road network, and output reports that detail repair tasks and costs for budget estimates, and provide prioritised task schedules if maintenance budget allocations are capped below the bid figure. Systems may also schedule repair resources.

Silting Side Drains

Desirably, the repair task schedules will include estimated quantities and repair rates. The repair rates depend on the cost data entered into the system and will be as accurate as the user chooses. Quantities however, will not be.

In some systems, the quantities used will be those measured or estimated during a condition assessment. In this case, the actual quantity will differ from the measured by the deterioration that has taken place between the time of the condition assessment and the moment of intervention, sometime in the following financial year. This period is usually at least 4 months, and often 6 or even 8 months may elapse from the time of the original condition survey to the eventual repair.

Visual Inspections

More complex systems may forecast deterioration levels during the planned maintenance period, but such systems are not common, and typically rely on statistical probabilities based on past maintenance records of variable quality and relevance. In either case, the predicted repair workload is unlikely to be highly accurate, and it is therefore usually inappropriate to invest in an intensive data collection effort for routine maintenance planning purposes.

In practical terms, the inventory data is usually measured rather than estimated, and this is appropriate where such data may be used for other purposes that require improved accuracy. Network-level condition data is usually provided at IQL IV and this is also appropriate for the reasons discussed above. In most systems, including manual systems, the IQL IV assessments are converted into repair quantities by lookup tables similar to the one illustrated in Table 5-6 below.

IQL 4 Description	IQL 4 Level of repair	Vegetation (% of road reserve area)	Culvert Cleaning (% of total culvert length)	Pothole Quantities (% of paved area)
Excellent	Very little	10%	0%	0.00%
Good	Little	33%	13%	0.06%
Fair	Some	55%	25%	0.13%
Poor	Much	78%	38%	0.19%
Bad	Very much	100%	50%	0.25%

Table 5- 6- Element Workloads

Paved Road in a Poor Condition

Visual Inspections

Culvert in a Poor Condition

5.8.2 Condition Sampling Strategies

A single IQL IV assessment represents the average condition of a maintenance element over a specified length of road. A key issue in data accuracy is therefore the sampling rate. Many systems currently in use sample at fixed intervals, with assessors stopping to make condition assessments as frequently as every 100m. The advantage of a fixed interval sampling is that sampling can be made uniform across the entire network. The disadvantage is that close regular sampling will take a long time to complete and will potentially generate a great deal of redundant data, - although both could be minimised somewhat by customising the sampling frequency by road according to condition.

Some systems require assessors to make "snapshot" assessments of each element at the sampling site, and others require "average" element assessments for the road between sample sites. In either case, the management strategy is likely to be based on work sections so at some stage either the estimated element repair quantities will be totalled by section, or element conditions will be averaged by section, and repair quantities estimated accordingly.

Table 5-4 Typical GRM Elements lists 27 common repair activities. Most organisations will undertake at least 12 of these activities on any given road, and organisations find it very onerous to collect deterioration data for each repair if sampling is required at frequent intervals.

When more than 4 or 5 maintenance elements are to be assessed, the most efficient approach is to conduct a moving assessment and use road distance lists to record the locations where each element condition changes. However, experience has shown that assessors can only realistically track the condition of 1 or 2 elements at a time so as to know when a previous condition rating should change. This means that a 6-person assessment team is needed to record the condition change points for 12 maintenance elements.

As before, condition assessments recorded using element change point lists are also summarised for maintenance management purposes, and so a third option is to collect a single condition parameter for each maintenance element to indicate the average condition for the entire section directly. The choice of method depends on the needs and constraints of the maintenance organisation.

If there are valid reasons for wanting condition assessments at frequent intervals beyond the needs of the RMMS, then either the fixed sampling strategy, or the moving assessment strategy must be adopted. If in addition, cost is the greater constraint, then the fixed interval strategy should be used. If the additional key constraint is time, then select a system that uses a variant of the moving assessment method.

It is feasible to conduct trials to determine the difference in section condition assessments arrived at by the three different approaches. In most cases it will be found that the result are the same or so close that the resulting resource inputs are substantially the same.

5.9 Training at Headquarters

5.9.1 RMMS Users

System user training must meet the needs of the following groups of users:

User	Skills required
System Administrator	To be responsible for installing and re-installing the system, and any updates and patched that the supplier may issue. Should be familiar with the underlying system design, so far as the supplier permits.
Principal Users	Responsible for calibrating the system Should be familiar with the logic, calculations and methods used in system processes Data structures All the skills listed for general users
General Users	Should be familiar with the use and purpose of all available menus, forms, tables, and reports Understand system input requirements and data formats Calculation and reporting options All skills listed for keyboard operators
Keyboard Operators	Should be familiar with aspects of the PC and it's operating system as necessary to start up and use the system. Should be familiar with all assigned data entry forms. Should be familiar with, and competent to use any form controls and keyboard options applicable to data entry and editing.

Table 5-7 RMMS Training Requirements (Headquarters)

5.9.2 RMMS Beneficiaries

In addition to training the employee groups who will have hands-on use of the system, it is also necessary to sensitise and inform the managers and groups who will use the system outputs. The introduction of any kind of Road Asset Management System must have the support of all key stakeholder departments and agencies before it advances from a proposal to a project. However, once the system is commissioned, this support must be strengthened and consolidated by seminars, presentations and workshops to demonstrate the functionality of the system, the management and operational benefits that will result from the correct operation of the system., and the administrative environment needed to realise these benefits.

Road Repairs

Road Repairs and Training

a) In particular, it is essential to have strong commitment to the use of the system form the maintenance-funding agency of department. For example, a Finance Department should be convinced.

b) That budget estimates prepared with the help of the new system are realistic estimates of actual road needs.

c) That the implementing agency is truly able to manage and spend allocated funding in accordance with system recommendations.

To delegate the detailed distribution of the maintenance allocation to the implementing agency, so that all available funding is utilised in accordance with the network priorities identified by the system.

5.10 Training for the Field Organisation

5.10.1 Annual Data Collection

Inventory and condition data must be updated every year. If it is not, systems that use the data will calculate and schedule incorrect solutions to current maintenance problems, and the system will loose credibility. There are various basic methods for collecting data, and it is important to select the one most appropriate to local circumstances. The basic options are shown in Table 5- 8 below:

Option		Advantages	Disadvantages
I	Set up and train data collection teams to travel the network	Suitable for IQL 3 condition assessment and measurement. Data should be consistent. Appropriate for relatively small networks or compact networks	May take a long time to collect the data May involve costly or complex logistics to ensure transport and accommodation for the team
ii	Train road supervisors to collect data for local sub-networks	Suitable for IQL 4 condition assessment and measurement. Appropriate for any size of network	Relatively large numbers of staff to train and organise every year. Ongoing training needed to meet staff turnover.
iii	Introduce and operate automatic data collection systems	Fast and consistent data collection at IQL 3 or IQL 2. Suitable for large networks when management systems require high quality data	Very costly to procure and operate. Only a limited set of pavement parameters can be measured.

Table 5-8 - Data Collection Options

Option (ii) in the above table widely accepted to be the most appropriate for updating RMMS data. It has the double advantage of:

- Being the least cost solution
- Maximising field involvement in planning routine maintenance operations

Effective use of this approach depends on:

a) A field management organisation that is disciplined and able to get thing done

b) Well-designed data collection forms

c) Appropriate staff training

5.10.2 Using RMMS Work Plans

The RMMS should assist managers to provide the best possible maintenance service under given policy provisions and funding constraints. If the system is properly installed, calibrated and initialised with current network data it will undoubtedly meet these expectations, - but only to the limits of it's design, - and then, only on paper. The road-using public will not experience these benefits if the optimised plans are not put into practice.

- Road workers must be persuaded that the benefits of the programme are real, and justify any additional effort that may be required.
- Road workers must be persuaded to follow the plans in accordance wit the system's operating procedures
- Local pressure groups or individuals who want to alter the work plans must be referred to an official in the organisation designated to provide an explanation of the plan benefits.

Pavement Investigations

Section 6
Maintenance Management Systems

6 MAINTENANCE MANAGEMENT SYSTEMS

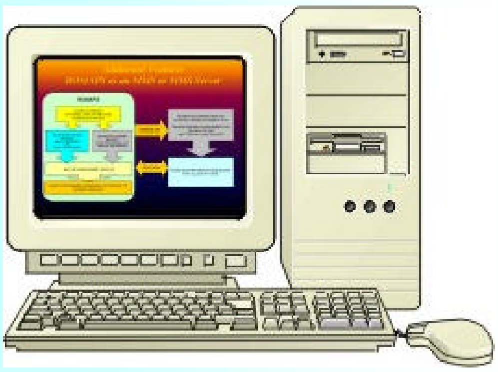
6.1 The Function of an MMS

An indication of the range of responsibilities that may be supported by a Network Asset Management System is given by Table 6.1. Maintenance Management Systems are the sub-set of network Asset Management Systems that as a minimum provide basic Pavement Management and Routine Maintenance Management. In practice, most MMS will support a range of maintenance strategies similar to the ones described in Table 5-8. Table 6-1 illustrates the four main strategies, their implementation priority and defining intervention frequency.

Priority	Strategy	Intervention Frequency
1	Emergency Maintenance	Frequent, - as required
2	Routine Maintenance	Intervention >= 1 per year
3	Periodic Maintenance	Intervention period 2 – 10 years
4	Rehabilitative Maintenance	Intervention period > 10 years

Table 6-1 - MMS Strategies

6.2 Maintenance Classification and Funding Strategies



Computer Based System

Normally, each strategy will be financed under it's own budget head. Typically, the Minor emergency and routine maintenance heads are funded from the recurrent budget, with Periodic and Rehabilitative Maintenance funded from the capital budget. It is therefore very important that planners classify work correctly and the MMS should include guidelines to illustrate the classification of all common maintenance activities. One of the most common classification errors concerns the correct identification of emergency work. If a treatment is delayed excessively, e.g. due to lack of funds, deterioration may get so bad that managers conclude that only an emergency intervention can prevent complete failure. However, the classification of work is not directly based on urgency, but on the type and frequency of treatment. Urgency is acknowledged by task priorities within each maintenance head.

6.3 Head and Task Prioritisation

If maintenance funds are allocation to the implementing as a single lump sum, the MMS may use institutional policy to propose a split between budget funding heads for the various maintenance strategies. It may then be necessary for maintenance managers to review their policy guideline to ensure that they provide a basis for prioritising and funding the various strategies. For example, Emergency Maintenance repairs are usually classified as the highest priority work. Similar ranking policy may be needed for the other heads.

Axle Load Surveys

6.4 Maintenance Standards

6.4.1 Workmanship

Maintenance standards clearly depend on the quality of workmanship and materials applied to individual repairs. However, most organisations expect to achieve a uniform quality of repair at all times except where policy guide lines specifically call for a variation. Rather than altering the quality of repairs, maintenance systems achieve the required variation by adjusting the time between repair interventions, and possibly the amount of damage repaired during each intervention.

Box Culvert

6.4.2 Intervention Frequency

Repair interventions are initiated when an allowable level of deterioration is reached. Where rates of deterioration are relatively predictable, intervention frequencies may be specified directly based on anticipated levels of deterioration. Other repair interventions rely on regular road condition monitoring.

Threshold deterioration levels are often defined as further maintenance policies. As such, they may be established by economic considerations where these are readily applied, they may be based on accumulated experience in the asset preservation needs of the local network or they may be established for socio-political reasons.

6.4.3 Extent of Repairs

When funding is less that required, the MMS may be set to fully fund tasks repairs in order of priority and ignore the remaining network needs. Alternatively, the system may be required to allocate funding to all designated roads and tasks, with relative funding levels depending on the priority of each task. For example, under such a system the highest priority tasks might receive say, 80% of the estimated repair requirement, with the lowest getting possibly 20% or less of the required amount. In this case, maintenance standards are affected by the extent of repair that can be afforded. This may mean fewer interventions per year, and it may also mean that less damage is repaired per cycle.

Deflection Surveys

Road Repairs

6.4.4 Temporary repairs

Normally however, repairs that are undertaken will be in accordance with national standards of workmanship. An exception to uniform workmanship or repair standard may apply to Emergency maintenance Repairs under some systems where guidelines state that minor emergency repairs are temporary, with permanent repairs provided under different funding or implementation strategies.

6.5 Implementation

Implementation issues have been discussed in the context of institutional preparation, implementing a PMS and implementing an RMMS, and all of this discussion applies to the implementation of an MMS. However, because MMS includes the functionality of both PMS and RMMS, implementation is often larger and more complex undertaking, requiring particular care in areas such as staff consultation, training and the development of an appropriate institutional environment.

6.6 Institutional Issues

If a particular institutional framework is considered necessary before an MMS can fully deliver its benefits, it may be desirable to implement the project in stages. Combined institutional change and MMS projects tend not to be particularly successful, because sustainable institutional change is rarely achieved through external intervention. This is a relatively common scenario because poor asset maintenance is a common consequence of weak institutions and institutional management.

Current best practice recommends the following generic process:

I	Identify needs	This starts with network managers in the executing agency, but must eventually have the support of linked line ministries and departments
ii	Identify the system objectives	This means consulting widely within the executing agency at all levels to determine what is wrong and what should be done about it. The consultation process should lead to a use wish list that can form the basis of a system specification.
iii	Identify institutional constraints	Managers and staff in the executing agency should review paragraphs 2.2 - Addressing National Constraints and 2.3 - Addressing Departmental Constraints and identify any areas where institutional change is both necessary and practical
iv	Develop an Institutional development and Change programme	The executing agency may need to conduct workshops and seminars to develop a consensus firstly within its own department and secondly within its partner departments and ministries. The services of an institutional change specialist or change facilitator may be helpful
v	Identify milestones in the Change and development programme that facilitate maintenance planning and operations	The executing agency should consider a staged implementation of MMS consistent with the improving environment. The services of an institutional maintenance specialist may be helpful
vi	Identify System providers	Decide between bespoke of "off the shelf" systems. Select one or more system suppliers who can provide all or part of a staged implementation

The key features of the above schedule are:

- The implementing agency and its partner departments and ministries identify the need for change before an MMS is procured.
- The implementing agency plans and implements its own change and development process.
- MMS is implemented in stages over a timeframe that acknowledged uncertainties within the change process. This could include any or all of the following:
  - A manual inventory and RMMS
  - A database analogue of a manual inventory and RMMS
  - A PMS
  - A full MMS

Section 7
ROMAPS
Example MMS

7 ROMAPS – EXAMPLE MMS

7.1 Overview

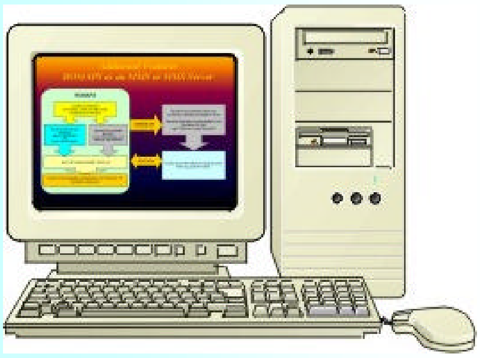
ROMAPS is a Maintenance Management System developed by the author over a period of 15 years to overcome many of the system deficiencies discussed in the foregoing chapters. For this reason, it is marketed as a total maintenance philosophy rather that a “boxed and shrink-wrapped” computer programme. The underlying approach is consistent and applicable in the manual, RMMS and MMS versions of the application.

The calculation approach is the same in all versions. The approach for both the manual and database RMMS has three parts, each of which can be undertaken at user group workshops.

a) The Inception Workshop: Initial Data and system setup

b) Annual Planning Workshops: Condition Assessment and Bid calculation

c) Annual Programming Workshops: Budget allocation dissection and work plans



7.2 The Inception Workshop

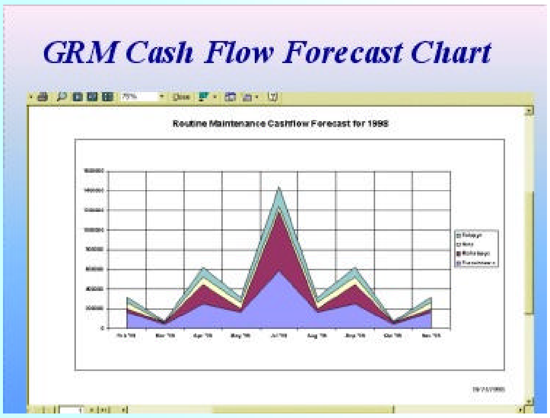
1	The Workshop identifies a set of maintenance elements for the network roads. The set consists of all those parts of the road that may require separate or different routine maintenance treatments. The set typically includes some or all of the elements is shown. Manual systems will have no more than 6 elements, but many database applications schedule up to 20 different GRM tasks.
2	The workshop must define generic resources to be used in repairing the defects. Resources can include length men, village contractors, petty contractors, contractors and day labour forces. Other attributes of a resource include the resource productivity and daily operating cost
3	The workshop also defines the local engineering environment (EE). Engineering environments consists of parameters that can be visually assessed and are considered to affect the life on one or more maintenance elements. Properties include climate, topography and traffic. The EE set must include at least one parameter applicable to the deterioration of every scheduled element. Part of the task definition process includes assigning a generic repair resource from the resource schedule.
4	One or two sets of condition tables are defined for each maintenance element. The first set consists of IQL 4 visual ratings. The second set of tables give typical numeric workload levels that correspond to the visual ratings. Typical ratings and lookup values are illustrated in Table on page7-1.
5	Maintenance policies may be defined either at the workshop, or by senior management beforehand, and notified to other users at the workshop. The main maintenance policies used by ROMAPS are listed below on Page 7.1.
6	The road network is divided up into Work Sections according to customary administrative boundaries in the first instance. Sections may be further subdivided to allow different environments to be defined if this is likely to significantly enhance the accuracy of the management outputs. Local field maintenance staff or their managers should be consulted in this process

Table 7-1- Initial Data and Setup

The following maintenance polices must be either agreed or disseminated at the planning workshop. They all relate to budget management and the planning strategies to be used by the system when allocations are significantly below assessed network needs.

Maintenance Objective	Defines the purpose of GRM in terms of Lower VOC, Asset Preservation and improved road safety objectives.
Road Funding	ROMAPS allocates maintenance funds first to provinces, then the maintenance heads in each province and finally to work elements GPM projects by section. The primary allocation to provinces is based on weighted average values for traffic levels, surface type and surface condition.
Maintenance Deferability	The secondary allocation to maintenance heads is based of Deferability factors. These factors indicate the relative importance of the Emergency, Routine and Periodic Maintenance strategies in terms of the acceptable delay in repairs carried out under each head
GRM Element Fitness	Task definition includes an indication of task purpose expressed in the same terms as the Maintenance Objective. A comparison between the Task Purpose and the Maintenance Objective results in an element fitness index. A compound index made up from fitness and traffic factors is used for the tertiary GRM allocation.
Periodic and Rehabilitative Maintenance	Periodic and Rehabilitative Maintenance projects are ranked for implementation. The ranking factor is a compound index made up of the IRR due to VOC savings, the strategic importance and the pavement condition. If the PMS module is available, ROMAPS will hold all the link, pavement, traffic and cost data needed to calculate overlay thicknesses and evaluate IRR or FYRR economic indicators for all selected links using HDM III.

Table 7-2 - Maintenance Policies



Rut Measurement

7.3 Manual GRM Calculations

When the manual system is set up, maintenance supervisors can use pre-printed forms to estimate their maintenance requirements by the following calculation steps:

a) For each task, calculate the element fitness factor

b) For each road section calculate the size or scope of each scheduled maintenance element

c) Multiply the element fitness factor by the section traffic group to get the section ranking index

d) From the condition assessment calculate the quantity of work per maintenance element

e) From the productivity of the assigned resource, calculate the repair time, to the nearest whole day.

f) From the resource daily operating cost and repair time, calculate the element repair cost

g) Sum to get the section repair cost

h) Sum to get the road repair cost

i) Sum to get the province or district repair coast

j) Sum to get the national repair cost

k) Sum with the other head estimates to get the national maintenance budget estimate.

The above procedure shows that there is an initial ranking calculation for every repair task, and 5 calculation steps in the initial estimate for every work section element. If there are 10 work sections and 6 repair elements, the GRM budget estimate will require 6 task calculations, 300 element cost calculations and 5 summary calculations. The 60 work section elements must be listed in descending order of index ranking and a running total calculated. If a capped budget allocation is provided, only work section elements with running totals within the allocation value will be included in the plan.

Given the calculation effort required, the manual system is clearly best suited for use on very small networks, and 100 work section elements or tasks is considered to be the practical upper limit for any one manager. The database RMMS should be used for larger networks, or more complex maintenance strategies. The system uses the same basic calculation approach with the addition of an element deterioration forecast calculation that further modifies the repair workload. The RMMS is often used to prepare MER, GRM and GPM budget estimates as part of the Annual Planning Workshop.

7.4 The Annual Planning Workshop

1	Annual planning workshops are convened each year in every province or district office at the appropriate time in the budget cycle. They are attended by HQ maintenance planners and district maintenance staff all of whom should have a thorough knowledge of their local sub-networks. Maintenance staff must bring with them, updates to their various road and asset inventories
2	The workshop convenors run ROMAPS throughout the workshop. If practical, screen images are projected for all to see. The district network inventory is reviewed first, with each supervisor expected to indicate any necessary changes as the records for his area are displayed.
3	When the district inventory has been updated, the process is repeated for the condition assessment, with supervisors classifying average network conditions over the course of the past year. Peer pressure and peer review help to ensure the accuracy and completeness of this process
4	The third stage in the process is to calculate the budget estimate. This is then examined by the workshop section by section. Calculations can be fine tuned if necessary until field staff concur with the predicted needs
5	This process ensures rapid data capture, rapid production of results and gives full ownership of the process jointly the HQ staff who will present it to higher authority, and to the field staff who will implement maintenance plans based on the estimates in due course

Table 7-3 Annual Planning Workshop

Optionally, delegates to the Planning Workshop may take copies of their maintenance budget estimates to be consolidated with other components of their provincial budgets to be submitted to headquarters in due course. In any case, the maintenance estimates from all provinces or districts have to be consolidated to national summary totals and supporting documentation, for submission to the road funding agency at the appropriate time, and ROMAPS includes facilities for doing this.

ROMAPS includes a range of standard reports that detail all aspects of the proposed expenditure in terms of roads, present conditions, repair tasks and anticipated future conditions depending on funding levels. If the road-funding agency needs additional reports users who are able to design queries and reports in MS Access can create their own, or else the system suppliers will undertake the required customisation.

After submission of the budget, the final set in the annual budget cycle is to prepare prioritised work plans when the budget allocations are released. The default procedure is to prepare the work plans at annual Programming Workshops.

Pipe Culvert

Routine Maintenance

Rough Gravel Road

7.5 The Annual Programming Workshop

a) Annual programming workshops are convened each year in every province or district office at the appropriate time in the budget cycle. They are attended by HQ maintenance planners and district maintenance staff all of whom should have a thorough knowledge of their local sub- networks.

b) The workshop convenors run ROMAPS throughout the workshop. If practical, screen images are projected for all to see. ROMAPS is able to dissect a maintenance allocation to prioritised budget heads and tasks. The system includes numerous facilities to apply secondary allocation policies or rules such as:

- Reduce all expenditures on gravel roads
- Exclude roads with traffic counts less than 50 v.p.d.
- Increase expenditure on culverts and drains on Class I roads by 20%
- Eliminate grass cutting on all Class III and Class IV roads

ROMAPS usually makes a default dissection as a starting point for network supervisors to consider. The procedure then allows each supervisor the opportunity to seek refinements to the basic dissection to reflect the specific needs of their local networks.

c) The Workshop convenor is normally a senior maintenance manager, and he will usually allow any reasonable customisation based on actual network factors, so that when the task resource schedules are printed out, they already have a high level of workforce approval.

d) The resource planning schedules are lists of intervention times and places for tasks having the same generic repair resource. Local maintenance supervisors assign these tasks to real resources in their area using Resource Year Planners and coloured bars to represent different tasks and locations.

Locations of successive interventions are assigned with regard to local network logic. Interventions may be spread evenly across a year, or concentrated at particular times having regard to climate and agricultural seasons. The year planning process should ensure that the working year of day labour forces is filled with scheduled maintenance works. This will inevitably mean that some activities are undertaken at sub-optimal or inappropriate times of the year. However, when constructing year planners for contractors, it may be possible to programme work without regard to workload distribution, so that all tasks are carried out at their optimal times.

7.6 Using Year Planners

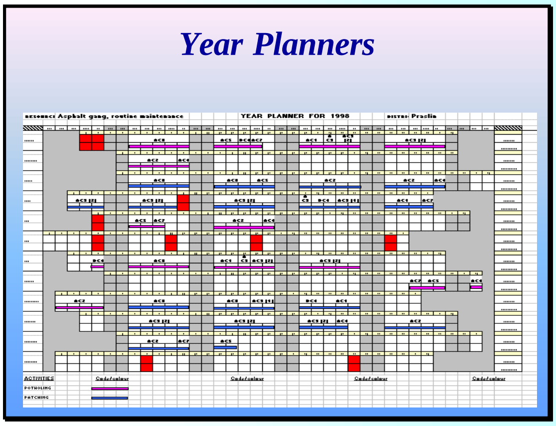
7.6.1 Year Planners for Supervisors

Under the system described above, local supervisors prepare year planners with repair tasks shown as coloured bars that indicate both start dates and repair durations. Each start date is a key date for the crew and their managers. The supervisor may have several resource units or crews operating in his area, each with its own set of key dates. To ensure effective management of several crews, each with its own detailed programme supervisors should also use a year planner that shows the following information:

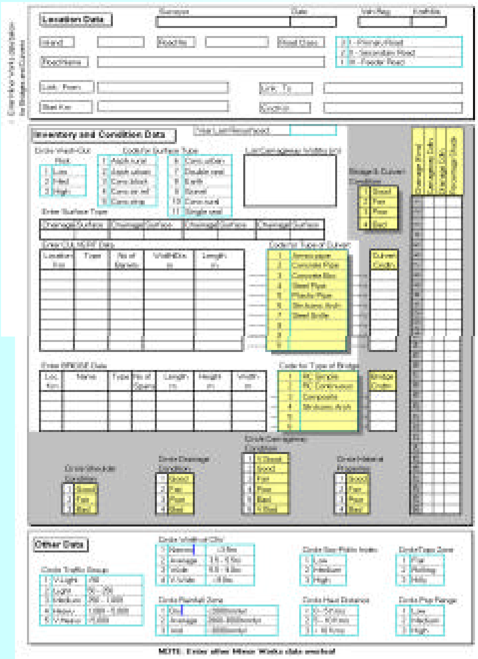
a) **Pre-inspection dates.** These dates are assigned 5 - 10 days prior to all resource key dates

b) **Mid-inspection dates.** These dates are assigned during the intervention period so that such inspections occur at least every two weeks.

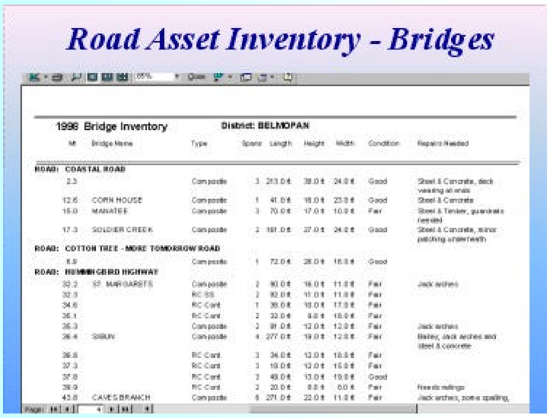
c) **Post-inspection dates.** These dates occur from 1 - 3 days prior to the completion of each intervention



Year Planner



Input Sheet



7.6.2 Pre-intervention Field Inspections

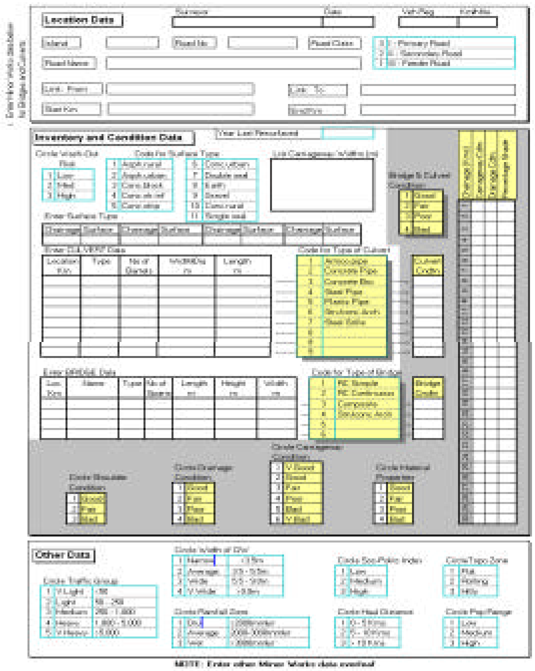
The supervisor and the crew overseer carry out pre-inspections together. The purpose of the inspection is to identify and specify all repairs on a daily basis. The specifications or worksheets should detail the location and scope of each day's work and follow the formats illustrated in the four volumes of the International Road Maintenance Handbook (TRL-1) .The ROMAPS methodology refers to these handbooks for all field maintenance descriptions and repair methods. A sufficient number of these books should therefore be provided as part of the ROMAPS installation. Included in the worksheet format is the following information:

- Location
- Repair method or process
- Measurement quantity if appropriate
- Materials
- Particular tools required
- Particular plant and equipment

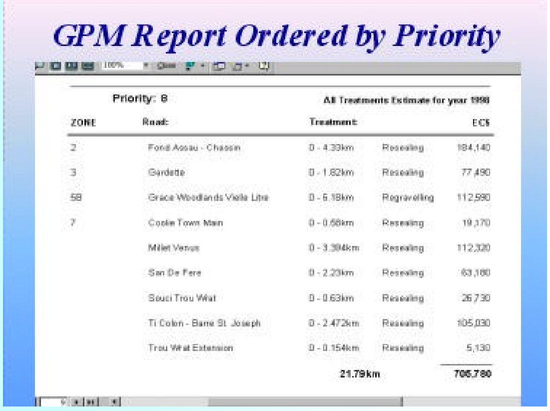
7.7 Using Daily Work Sheets

Daily repairs must be ranked so that the most urgent repairs are done first. Frequently the overall time allocations will be insufficient to accommodate all necessary repairs, especially if the maintenance funding allocation is significantly less than the estimated requirement. In such instances it is inevitable that some identified daily repair tasks will not be carried out. Occasionally however the pre-inspection may determine that excess time has been allocated to a particular intervention. In such cases the surplus time can be used to undertake unscheduled repairs at the Supervisors discretion.

At the completion of each day's work the overseers must fill out daily work completion forms indicating: The Task from the worksheet, Manpower inputs, Materials consumed and Plant & Equipment hours used.



The daily work completion forms will be reviewed and discussed during the supervisors mid and post-inspection visits. The forms will then be returned to the local district or provincial maintenance office to be recorded and consolidated so that progress is monitored. The accumulated data will be used to estimate new workload and productivity data for future budget estimates.



GPM Report Ordered by Priority

Priority: 8 — All Treatments Estimate for year 1998

ZONE	Road:	Treatment:		EC$
2	Fond Assau - Chassin	0 - 4.33km	Resealing	184,140
3	Gardette	0 - 1.82km	Resealing	77,490
58	Grace Woodlands Vielle Litre	0 - 5.18km	Regravelling	112,590
7	Coolie Town Main	0 - 0.68km	Resealing	19,170
	Millet Venus	0 - 3.384km	Resealing	112,320
	San De Fere	0 - 2.23km	Resealing	63,180
	Souci Trou Wiat	0 - 0.63km	Resealing	26,730
	Ti Colon - Barre St. Joseph	0 - 2.472km	Resealing	105,030
	Trou Wiat Extension	0 - 0.154km	Resealing	5,130
		21.79km		705,780

7.8 Inspection and Approval of Work

The works should be inspected at two-weekly intervals, (and more frequently if possible), and approved (for payment, in the case of contractors). Approval certificates should also be in the form of pre-printed pages from a triplicate book (examples given in the International Road Maintenance Handbooks).

7.9 Monitoring Performance and Costs

The daily job sheets and the task approval forms are returned to the local road maintenance administration as primary data for performance monitoring, expenditure control and job costing. These performance indicators are important to the overall management of maintenance, and are often required as an acquittal of maintenance funds allocated. The required indicators should therefore be produced in the road authority's customary format.

In addition the workload, cost and productivity data collected each year provide essential feedback to the ROMAPS calculations. Thus the final ROMAPS procedure is an annual review of current calculation parameters, updating them in the light of the latest operating experience wherever appropriate. This ensures that the system always uses up-to-date costs and productivities. It also enables ROMAPS to be implemented under conditions where there is little base data, since the system is essentially self-tuning