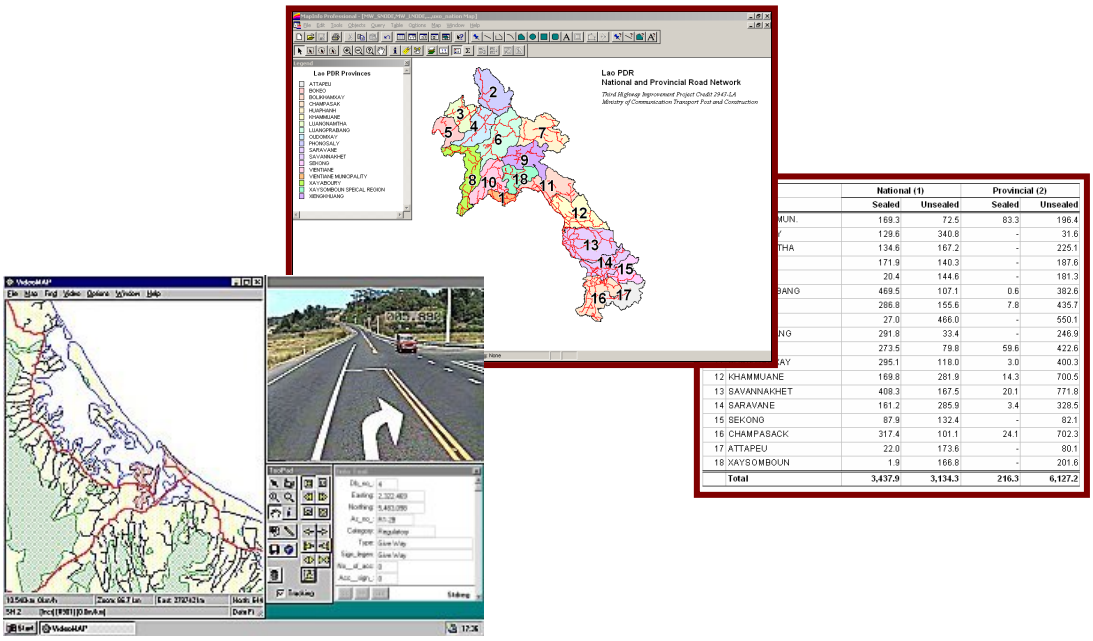


# Success Factors for Road Management Systems

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## Contents

# Executive Summary

The successful implementation of a computerized road management system (RMS) depends on the interaction of three fundamental components: Processes, People and Technology. If any of these components are lacking, the system will not be successful. The best technology in the world will ultimately fail if implemented in an environment where there are no people to run it, or where the processes are not in place to utilize it.

In 2005, the World Bank, funded by TRISP, hired consultants to conduct interviews in 21 different road agencies in 16 countries to gauge their experiences in implementing RMS. A standard questionnaire was completed for each agency. The agencies were chosen to represent a cross-section of experience in different continents. National road agencies were primarily chosen, although some large provincial and state agencies were also interviewed.

What is apparent from the study is that agencies that are successful in their implementations have built strong foundations in all of the fundamental components over a number of years. First and foremost, they have developed an 'asset management mindset', that is, they explicitly and conscientiously implement policies that are geared towards managing their highway infrastructure as an asset whose value must be maintained and improved. Their executives and management promote asset management principles in order to ensure that funding and budget are allocated to appropriate areas. They are explicitly committed to the RMS, in the sense that it is built into their processes and procedures. They ensure that sufficient budget is available for data collection, for upgrades and maintenance of the systems, and for staff training and progression.

If there is no 'asset management mindset' in place, if there is no organizational unit with specific responsibility to implement the system, or if the results of the system are not validated and utilized, then the system can be regarded as a failure. Unfortunately, most agencies were found to have failed in one way or another.

There are several key recommendations made in this study:

- Prior to planning or implementing an RMS, the agency (with assistance from donors if necessary), should review its business processes, people and technology. The resulting project specification document or Terms of Reference (TOR) must focus on all areas. Too often in the past, TORs focused almost exclusively on the technical components (*ie* the computer system or the technical aspects of data collection) while paying scant attention to the organization in which it sits and how it would be used.
- Key elements of institutionalization that must be reviewed and explicitly addressed are business plans, budgets, and policies.

- Staff positions must be filled with pro-active, involved individuals who are committed to the implementation, and who have the requisite management skills and initiative to drive the system.
- In the area of Information Technology (IT), an RMS cannot be implemented in isolation from the IT policies or IT infrastructure of the agency. Many agencies need particular support in this area, and some fundamental polices and procedures often need to be addressed, including IT architectures, IT budgeting, IT procurement, IT replacement strategies, outsourcing of key areas such as computer network support or systems administration, and general IT support and training. Many organizations struggle in these areas, and this can have a major impact on the success of the RMS.
- This study recommends that road agency should try to adopt Commercial Off-the-Shelf (COTS) software wherever possible. Custom developed applications have often proved difficult and expensive to sustain.
- The study includes a set of key functional requirements for RMS that, along with technical requirements, should be used as the basis for any RMS specification. There are several good products in the marketplace that address most of the functional requirements listed.
- If an agency has any concerns about its ability to operate and maintain specialist data collection equipment in-house (in terms of staffing skills, budgeting for spare parts, equipment calibration *etc.*), then the agency should seriously consider outsourcing data collection. Road agencies around the world are littered with expensive equipment that has proved impossible to maintain/sustain, and in some cases have never been used. However, this decision also has repercussions on staffing within the agency. Outsourcing surveys requires strong management and quality assurance policies and procedures. Training of agency staff to manage outsourced contracts must be provided in this regard. This study also includes key principles that should be included for all data collection contracts.

Finally, and most importantly, no system is static. The most successful agencies are always looking for room for refinement and improvement in data collection procedures, quality assurance, road deterioration modelling *etc.* Many agencies that start off with a simple system rapidly start to understand that an RMS s a major on-going investment. Technology continues to move forward in a number of areas – IT, data collection, road maintenance treatments *etc*. Staff must keep themselves abreast of developments and look for opportunities to improve the system and its uptake. Organizational planning and budgeting should take this into account, and agencies should be aware of the long-term impact of implementing RMS.

Annex 1 contains a summary of the key recommendations from the study.

# 1 Introduction

Over the last 20 years almost all road agencies have implemented some form of computerized road management system (RMS). The purpose of these systems is to assist the agency in the planning and prioritization of road investments.

While some systems have been successful, there have also been many which have 'failed' in one or more areas. This is in spite of large investments of time and money. While it is often easy to identify the symptoms of failure, the causes are often complex and multi-layered. However, for every failed system, there is a more successful implementation somewhere in the world, in an agency that often suffers from similar problems and constraints.

The goal of this project was to identify factors that have contributed to the ***successful*** implementation of an RMS. The objective is to use these key components of success to help ensure better future implementations. These key components should be reviewed prior to preparing specifications or Terms of Reference for future projects, and specific steps should be taken to address them during implementation.

To undertake the project, consultants employed by the World Bank conducted interviews in 21 different road agencies in 16 different countries on five continents (see Table 1.1) to gauge their experiences of implementing RMS. Annex 2 contains the TORs for the consultants, and the project. The focus was on developing countries, but some agencies in developed countries were also included. The individual agencies were selected to represent a perceived cross-section of experience. The focus was primarily on national road agencies, although some provincial and state agencies were also interviewed. This ensured that the project had insights for both large and small road networks.

A standard questionnaire was used (see Annex 3) and the consultant visited the chosen agency for 1 – 2 days to interview a variety of personnel from different units in the organization, usually in planning, asset preservation/maintenance, and Information Technology (IT) areas. It was considered that direct surveys would give a better response than simply asking the agency to fill it in a questionnaire and return it. The consultant was able to give a full explanation of the purpose of the question, and had a chance to delve deeper into any issues or solutions that were identified. The consultants were selected because of their experience with RMS and in the region. The consultant also shared their experiences with the agency and often also made specific recommendations to assist the agency.

For the purposes of this study, it was not necessary for the RMS to employ economic analysis and optimization tools (although of course many of them do). Rather, the study investigated the type of RMS the agency used and their experiences with it. Most of the agencies surveyed implemented their systems 7+ years ago, and have had advanced planning and programming capabilities for 5+ years. The oldest implementation in the study is around 20 years old. There is a wealth of more than 150 years experience in these case studies,

giving ample opportunity to reflect on key factors required for successful implementation.

**Table 1.1: Agencies Participating in the Project**

| Country | Organization | Length of Road Network Under Management (km) | Year of System Implement-ation | Year of Advanced Planning / Programming Capability[1] |
|---|---|---|---|---|
| Argentina | Provincial Highway Directorate (DVP), Santa Fe | 14,179 | 2002 | 2002 |
| Bangladesh | Roads and Highways Department | 21,522 | 1996 | 2000 |
| Botswana | Ministry of Works and Transport, Roads Department | 8,916 | 1993 | 1996 |
| Burkina Faso | Ministère des Infrastructures, du Transport et de l'Habitat (MITH) | 15,271 | 2000 | 2000 |
| Cameroon | Direction des Routes | 49,143 | 2000 | 2006 |
| Chile | Ministry of Public Works | 80,672 | 1980 | 1985 |
| China | Fujian Provincial Highway Administration Bureau | 36,000 | 2002 | - |
| China | Henan Highway Administration Bureau | 70,000 | 2003 | 2003 |
| China | Hubei Provincial Highway Administration Bureau | 89,674 | 2003 | - |
| Costa Rica | Ministry of Public Works and Transportation (MOPT), & National Road Board (CONAVI) | 7,424 | 1998 | 1998 |
| India | National Highways Authority of India (NHAI) | 24,000 with more sections being added | System being Developed | 1997 |
| India | Public Works Department, Government of Kerala | 22,991 | System being Developed | 2005 |
| India | Public Works Department, Government of Rajasthan | 82,024 | 1996 | 1996 |
| Indonesia | Directorate General of Regional Infrastructure | 35,000 | 1985 | 1990 |
| Mozambique | Administração National de Estradas (ANE) | 12,902 | 1997 | 1997 |
| New Zealand | Transit New Zealand (TNZ) | 10,786 | late 1980's | 1998 |
| New Zealand | Papakura District Council (PDC) | 280 | 1998 | 1998 |
| Papua New Guinea | Department of Works | 27,500 | 2000 | 2004 |
| Tanzania | Ministry of Works, Tanzanian National Roads Agency | 28,892 | 2001 | 2002 |
| Uruguay | National Highway Directorate (DNV) | 8,680 | 1999 | 1999 |
| USA | Vermont Agency of Transportation | 5,310 | 1995 | 1995 |

Notes: 1/ Advanced planning and programming capability consists of computerized models to allow for multi-year programming and optimization of investments.

# 2 Road Management Systems

## 2.1 Overview

Roads are a major economic asset, and the management of this asset is tremendously important for economic development. The major functions of the road management process can be categorized as:

- Planning;
- Programming; and,
- Operations.

RMS are concerned with highway monitoring, planning and programming. Major activities include:

- Needs Assessment;
- Strategic Planning, including budgeting for new development and asset preservation;
- Development, under budget constraints, of multi-year works expenditure programs; and,
- Collection of Data. All of the above activities need data. Major data items include highway inventory, condition, traffic, and economic data.

**RMS Definition**

An RMS is defined here as any system that is used to store and process road and/or bridge inventory, condition, traffic and related data, for highway planning and programming. Associated with the RMS are appropriate business processes to use the RMS to execute the business needs of the highway agency.

Figure 2.1 is an example of a typical computerized RMS framework. Not all RMS implementations contain all elements in Figure 2.1, however, there is always as a minimum a central database and some form of reporting.

With reference to Figure 2.1, the following are the components of an RMS:

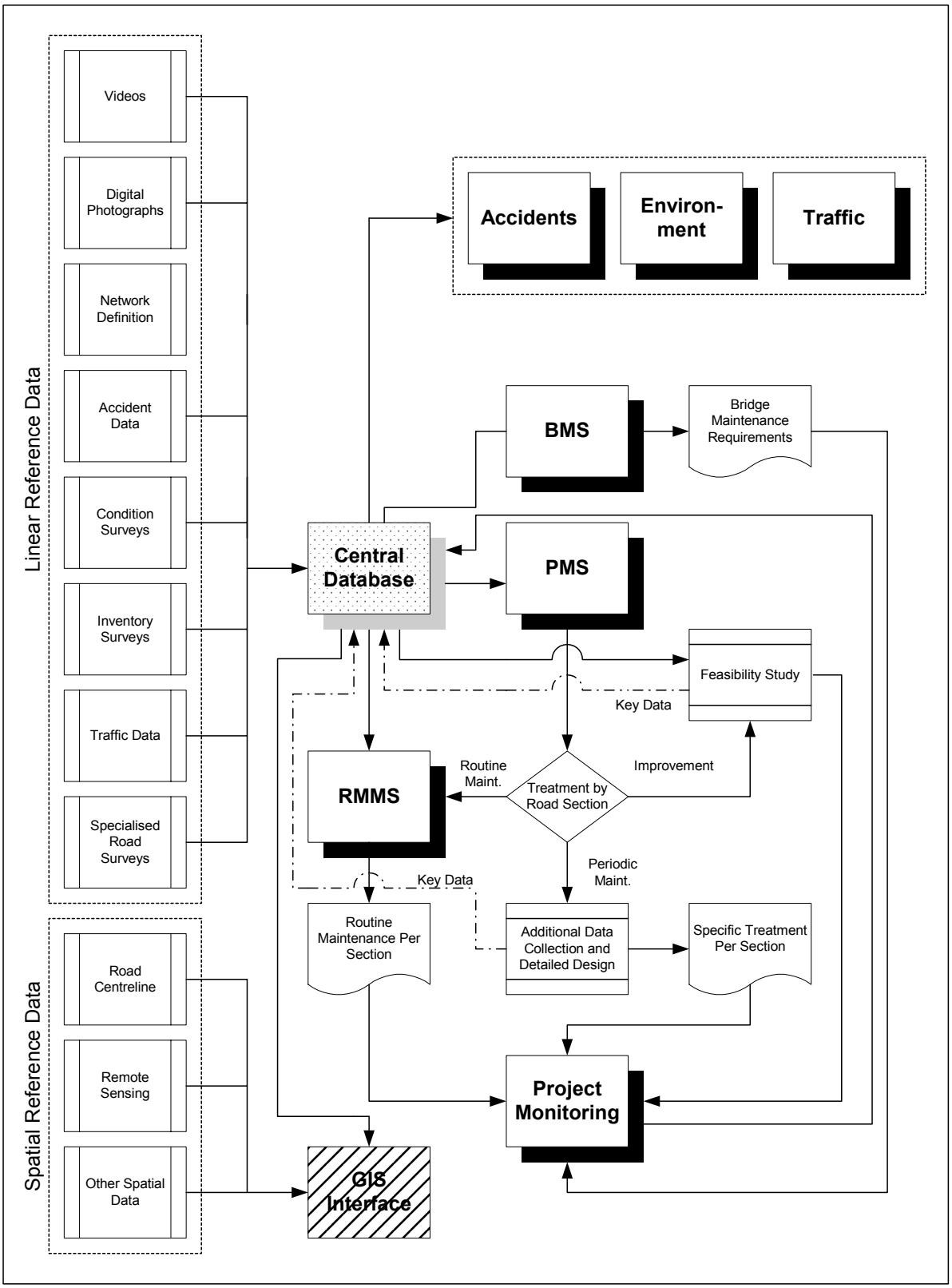



**Figure 2.1: Example of RMS Framework**

- Data Collection;
- Central Database;
- Pavement Management System (PMS);
- Routine Maintenance Management System (RMMS);
- Bridge Management System (BMS);
- Traffic Monitoring System (TMS);
- Accident Information System (AIS);
- Environment Management System (EMS);
- Project Monitoring; and,
- Geographic Information System (GIS) Interface.

The focus of this project was on the first three components of RMS: data collection, central database and pavement management system, as these are the most common to all agencies. Most agencies also have some form of bridge management system, and many of the observations made here will apply to these systems. However, they warrant detailed investigation in future along with the other RMS components.

## 2.2 Processes, People, Technology and Funding

Like ***any*** system, an RMS relies on three fundamental components: Processes, People, and Technology, and appropriate funding. If any of these components are lacking, the system will not be successful. The best technology in the world will ultimately fail if implemented in an environment where there are no people to run it, or where the processes are not in place to utilize it.

In theory, for an RMS to be successful, the importance of each component would be clear. Executives and managers would be demonstrably committed to the system, both in their relations with external stakeholders and internally in their agency through good management principles. Policies would explicitly state the goals and objectives of the organization with regard to road asset management, and procedures would detail exactly how the RMS would be used to achieve these goals.

It is very likely that a separate organizational unit would have explicit responsibility for the RMS and data, and would be staffed with well-qualified and trained personnel who are proactive in developing and expanding the RMS. Apart from the key process of asset management, a number of other subsidiary processes would contribute, including budgeting, financial management, human resource management, and IT management. These subsidiary processes would be essential in ensuring sustainability of the system in terms of data collection, staff training and development, hardware and software maintenance etc.

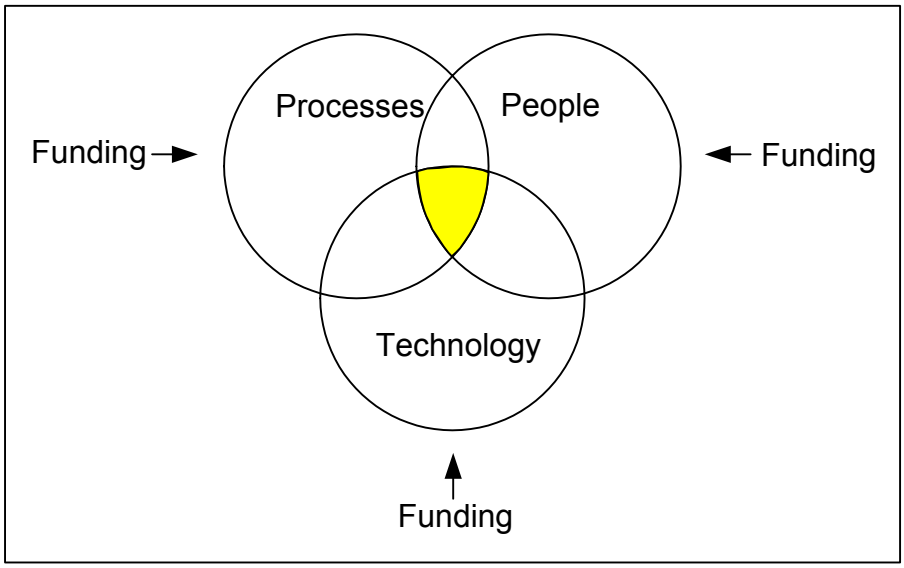



**Figure 2.2: Processes, People, Technology and Funding**

The data collection equipment and IT hardware and software would be fit for purpose, would be *used*, would be maintained, and covered by some sort of maintenance agreement and replacement strategy.

This project was designed to assess the success of the participating agencies in all of the above areas.

# 3 The Role of the RMS in the Business Process

**Key Success Factor:**
**The RMS Must Have an Active Role in the Road Agency**

The RMS must be viewed as an integral component in the highway agency's monitoring and planning process. The outputs from the RMS should be used to prepare Annual Reports as this helps ensure that the data are collected regularly and the system is applied.

## 3.1 The Annual Report/Business Plan

The agencies which have most successfully implemented an RMS have made it an integral element of their business process. The RMS is used to establish needs, set priorities, and regularly monitor and report on the road network condition.

One of the clearest indications that an RMS is successfully being used in an agency is the presence in its Annual Report/Business Plan of key indicators and analyses that are produced directly from the RMS.

**Annual Reports**

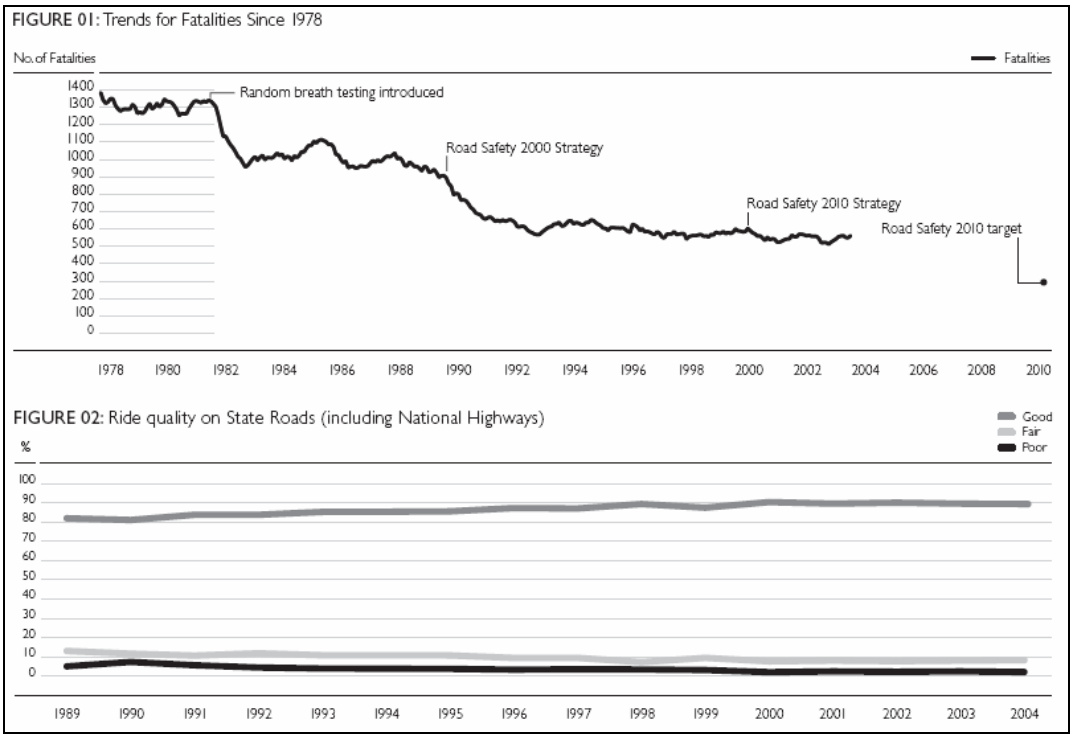
Most agencies have a statutory requirement to prepare an annual report. Those which have adopted a formal 'Business Plan' approach have been the most successful at implementing their RMS. This plan sets out the existing performance and also forecasts future investments. Elements typically include:

- **Key Performance Indicators (KPI):** Indicators by which the agency assesses its performance, for example the average condition of the network, number of km of pavements maintained, *etc.* Regular data collection provides the basis for many of the KPIs.
- **Five-Year Goals:** The goals reflect the overall objectives of the agency, and should be consistent with their long-term Strategic Plan. This is usually prepared by the planning and programming module of the RMS.
- **Annual Asset Management Plan:** The annual asset management plan describes the specific activities that are required to achieve the agency's goals, including detailed annual work programs. This will include asset management plans for pavements and structures as well as identifying areas where new roads and/or capacity improvements are required.
- **Financial Plan:** The financial plan will describe the current and future sources of financing road maintenance (Road Maintenance Fund, government funding, international donor assistance *etc*.) and disbursement schedules.

Figure 3.1 is an example of the way in which an RMS is used to prepare information in different agencies annual reports.

| Level of service and standard | Actual 2001/02 | Actual 2002/03 | Target 2003/04 | Actual 2003/04 |
|---|---|---|---|---|
| | Percent | | | |
| Percent of network classified as smooth | 99 | 99 | 97 | 99 |
| Percent of expectation of smooth travel | 99 | 99 | 97 | 99 |
| Percent of network <20mm ruts | 99.9 | 99.8 | 99 | 99.6 |
| Percent of network with good skid exposure above threshold level | 99 | 99 | 98 | 99 |
| Percent of network with texture greater than 0.5mm | 99.5 | 99.6 | 98 | 99.5 |

Source: Transit (2004)




Source: RTA (2004)

**Figure 3.1: Examples of RMS Outputs Used in Annual Reports**

Some examples of annual reports available from road agencies are:

- **New South Wales RTA:** www.rta.nsw.gov.au.
- **South Africa National Roads Agency:** www.nra.co.za.

- **Transit New Zealand:** www.transit.govt.nz.
- **UK Highways Agency:** http://www.highways.gov.uk.

## 3.2 Needs Assessment

One of the key objectives in implementing an RMS is to provide justification for budget, and to help direct limited funds towards those areas where the return on investment will be greatest.

A 'Needs Assessment' is an unconstrained[1] analysis of the needs of the road network. It is performed in order to calculate the real costs of maintaining or improving the value of the asset, or to bring it up to some agreed level of service if there is an existing maintenance backlog. It is unconstrained by budget, therefore it helps to develop a strategy for the agency. It may also be used by the agency as a justification for budget requests, which generally arise from a constrained analysis. Agencies working with international donor agencies should ideally be able to undertake both of these types of analyses.

As can be seen from Table 3.1, of the 17 agencies surveyed which have the systems capability to perform a full needs assessment, 11 perform it on their complete network, with another two performing it on a partial network. Thus, only about half the agencies know the overall network maintenance needs. Four agencies that apparently have the systems capability do not use it to establish the network's needs.

For example, in the case of Indonesia, they only use the Indonesia Road Management System (IRMS) to calculate needs for those roads which are candidates for funding by donors; other roads under their jurisdiction are not processed through the IRMS.

For those countries which claim to perform needs analysis, they often indicated that it was purely for internal use and was not used as a mechanism to request additional funding. In the case of Costa Rica (CONAVI), the agency indicated that the actual needs are actually about three times higher than requested, but the budget is prepared for the expected budgetary level.

The three provinces in China also provide interesting case studies. It appears that preventive maintenance is not seen as contributing to economic development, therefore the provinces do not attempt to get funding for it and hence do not perform a needs analysis. It was indicated in one case that they would rather let the roads deteriorate until they required rehabilitation, so that they could get funding from other budget categories. The China Pavement Management System (CPMS), although available for all provinces to use, was not actually fully used in any of the three case studies. One

[1] There are two types of analyses typically conducted. "Unconstrained" analyses assume an infinite budget. They therefore give the total investment needs for a network based on the target network performance (*eg* the amount of funds required to ensure the network has an average roughness of 3.5 m/km IRI). While hypothetical, they do give an indication of the total needs. "Constrained" analyses are more practical insofar as they establish the work program given the available budget.

reason quoted was that the budget is insufficient for the minimum level of maintenance so there was no benefit from running a sophisticated system.

Unpublished studies conducted in China external to this project have suggested that the current funding runs at about one-third of the budget required to maintain the network in its current condition.

## 3.3 Asset Preservation Budgets

A common problem in many countries is an under-investment in road maintenance/asset preservation. When a country is engaged in a major road construction program there is a tendency to divert funds away from maintenance (see China discussion in previous section). However, many studies have found that in the long-term this leads to a need for increased maintenance expenditure over that which would have arisen had funds been available earlier.

One sign of the effective use of an RMS in an agency is through the appropriate allocation of funds to asset preservation. Indeed, in some instances over time the proportion of funds available for asset preservation should probably increase[1].

An analysis of budgets (see Figure 3.2[2] and Table 3.1) showed wide disparities in the allocation of budget to asset preservation between countries[3]. The difference appears unrelated to the amount of time in which the RMS has been in operation. Only Chile, New Zealand (Transit NZ), and Vermont Agency of Transportation budget more than 45% on asset preservation. The three Chinese provinces budget the lowest, with Henan at 9.5 %, Hubei at 9.7% and Fujian at 16.9 %.

Analysis of historical budgets showed few instances where there has been a marked increase in the allocation of budget for asset preservation:

- **Chile:** (see Figure 3.3) managed to increase the proportion of expenditure on asset preservation even during a period when the total budget was decreasing due to severe budget constraints. This is a sign of a successful application of an RMS as well as a recognition by national authorities of the importance of maintenance.

[1] It is recognized that there can be problems with this type of analysis. At different stages of development countries will have significant investments in new construction. Thus, the percentage of the total budget used for maintenance will decrease. Unfortunately, the practice in many countries is to undertake capital works at the expense of maintaining the existing network.

[2] Papua New Guinea and New Zealand Papakura District Council have been omitted since there was no new construction funded by the agencies since 2000.

[3] It should be noted that countries often used different criteria to differentiate between preservation and new construction. Also, it is known that some countries, at various times, have included major rehabilitations as new construction in order to get projects approved for particular sources of financing.

## Table 3.1: Analyses and Budget Levels By Road Agency

| Agency | Year of System Implement-ation | Approximate Year of Planning / Programming Capability | Needs Analysis | Needs Met | Hit Rate Analysis | Annual Budget ($US million) | | | | Percentage of Budget for Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Total Budget | | | Maintenance 2005 | |
| | | | | | | 2003 | 2004 | 2005 | | |
| Argentina (Santa Fe) | 2002 | 2002 | Yes | 70 - 80% | No | | 54 | | N/A | |
| Bangladesh | 1996 | 2000 | Yes | 100% | Planned for 2006 | 431 | 458 | 438 | 100 | 21.8 |
| Botswana | 1993 | 1996 | Yes | 50% | No | 68 | 360 | 87 | 21 | 24.4 |
| Burkina Faso | 2000 | 2000 | Yes | 50% | Calibration test sections only | 32 | 24 | 120 | N/A | |
| Cameroon | 2000 | 2006S | Operates on only 60% of the network | | No | | | | | |
| Chile | 1980 | 1985 | Yes | | Yes | 370 | 440 | 269 | 159 | 36.1 |
| China (Fujian) | 2002 | No | No | | No | | | 606 | 103 | 16.9 |
| China (Henan) | 2003 | 2003N | No | | No | | 1250 | 1313 | 125 | 9.5 |
| China (Hubei) | 2003 | No | No | | No | 871 | 938 | 955 | 93 | 9.7 |
| Costa Rica | 1998 | 1998 | Yes | 80% (but estimated 30% since they do not expect they will get the true value from government) | No | 105 | 94 | 100 | n/A | |
| India (Rajasthan) | 1996 | 1996 | No | 80% | Not done | | | | Still checking data | |
| India (NHAI) | System Being Developed | - | - | 100% | - | 173 | 160 | 212 | 53 | 24.9 |
| Indonesia | 1985 | 1990S | Operates on only 40% of the network | | Preliminary | 237 | 353 | | 109 | 30.9 |
| Mozambique | 1997 | 1997 | No | Estimated 60 – 70% of needs met | No | | 90 | | 28 | 31.1 |
| New Zealand (TNZ) | Late 1980's | 1998 | Yes | 100% | Yes | 3 | 3 | 3 | 3 | 100.0 |
| New Zealand (PDC) | Early 1990's | 2003 | Yes | Maintenance Backlog would be eliminated by 20% budget increase | Yes | 402 | 480 | 526 | 236 | 44.8 |
| Papua New Guinea | 2000 | 2004 | Yes | 20% | Yes (although no statistics available) | 93 | 100 | 133 | 133 | 100.0 |
| Tanzania | 2001 | 2002N | No. Option was available but not used systematically | Estimated 40% | No | 130 | 141 | 212 | 47 | 22.1 |
| Uruguay | 1999 | 1999 | Yes | 80% | No | 59 | 55 | 67 | 18 | 26.9 |
| USA (VTrans) | 1995 | 1995 | Yes | 80% | Yes | 72 | 85 | 86 | 53 | 62.1 |

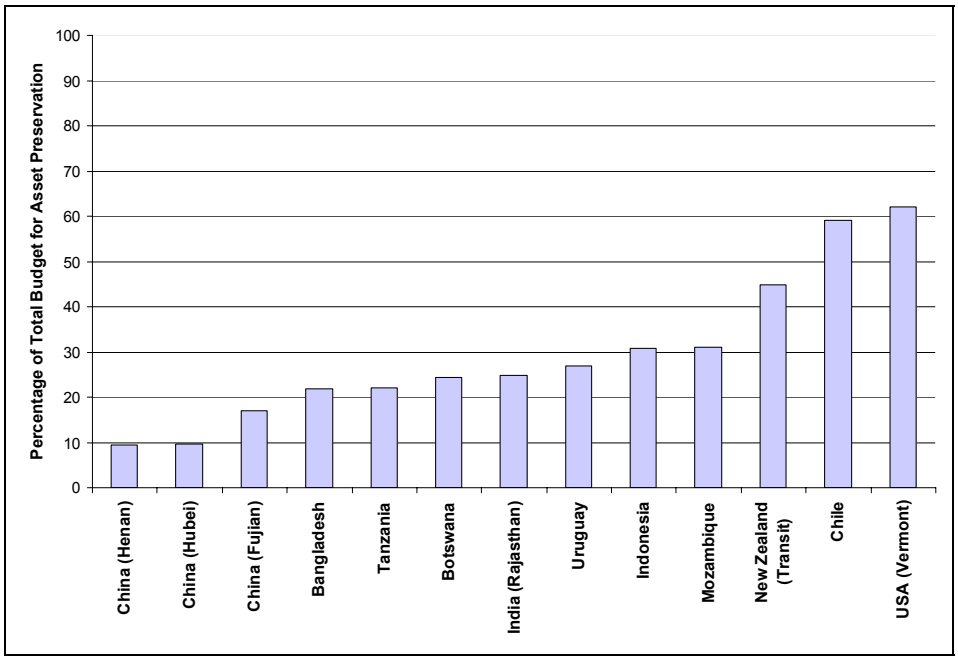



**Figure 3.2: Percentage of Budget for Asset Preservation**

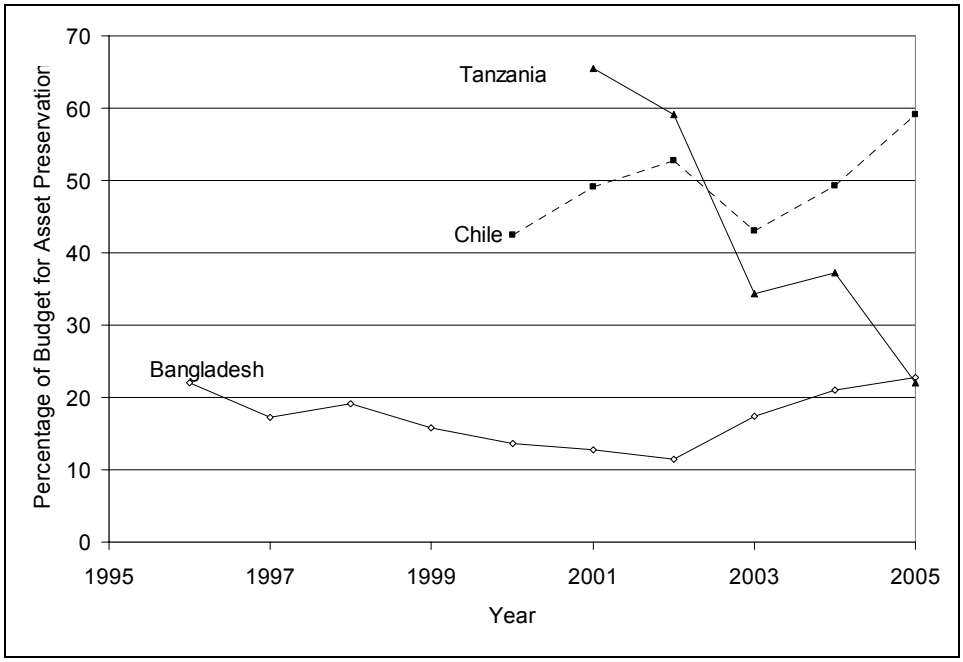



**Figure 3.3: Asset Preservation Budgets Over Time**

- **Bangladesh**: There was a major backlog of reconstruction and upgrading which meant that even though the overall budget increased steadily, the budget for asset preservation initially declined. However, the government is committed to asset preservation as evidenced by the recent increases in budget.

- **Tanzania**: Due to a large capital works program, the percentage of the total budget allocated to maintenance has been decreasing over time. However, the maintenance budget has been relatively constant. There will be a need to increase the maintenance budget to accommodate the higher maintenance costs of the recent road improvements.
- **New Zealand** (Transit NZ) and **Vermont** have both had the proportion of asset preservation budget remain relatively constant throughout the reporting periods, at around 45% and 60% respectively.

Although historical data were not available for China Fujian Province budgets around 14.5% for Asset Preservation, with Henan and Hubei at 9.5% and 9.7% respectively (see Table 3.2).

**Table 3.2: China Provincial Asset Preservation Percentages**

| Province | Asset Preservation as % of Total Budget | Highway Maintenance Budget ($ / km) | Highway Length (km) | | | % Paved |
|---|---|---|---|---|---|---|
| | | | Paved | Unpaved | Total | |
| Fujian | 14.5 | 2,847 | 15,400 | 20,600 | 36,000 | 42.8% |
| Henan | 9.5 | 1,786 | 19,000 | 51,000 | 70,000 | 27.1% |
| Hubei | 9.7 | 1,032 | 34,298 | 55,376 | 89,674 | 38.2% |

In China, funding for asset preservation mainly comes from road user license and registration fees (the total revenue is shared by the Highway Administration Bureau (HAB) and municipal/city road administration offices on different ratios). All three provinces receive similar ratios. Fujian is close to the coast with a stronger economy than Henan and Hubei so it is therefore able to budget more for asset preservation. Clearly asset preservation is not carried out on a needs basis in comparison with road construction, but rather is a function of the money available.

## 3.4 Asset Value

'Asset Value' is an important concept in measuring the value of infrastructure. It is used as a key performance indicator, and agencies have defined goals and objectives to maintain or to increase that value over time. Asset value also provides a mechanism to compare the value of investments in different types of infrastructure either within an agency or within a country[1].

Asset value can be measured relatively easily using data that is normally readily available within an RMS. This data includes inventory (pavement type and width), roughness, and costs of new construction, rehabilitation and repair. Schliessler and Bull (2004) present a simple technique for estimating asset value. The literature contains a number of examples of more detailed approaches.

[1] Saarinen, et al., (1997) describe how this is done in Finland

Of the case studies, only New Zealand (both TNZ and Papakura District Council) and Uruguay explicitly mentioned asset value as an indicator. Figure 3.4 is an example of the asset values reported by Transit New Zealand in their annual report (Transit, 2002). Vermont is also moving more towards an 'asset management' approach to help monitor the value of state investments.

| | Actual | | | Previous Year | | |
|---|---|---|---|---|---|---|
| Description | Replacement Cost ($M) | Accumulated Depreciation ($M) | Depreciated Replacement Cost ($M) | Replacement Cost ($M) | Accumulated Depreciation ($M) | Depreciated Replacement Cost ($M) |
| Roads | 11,145 | 1,463 | 9,682 | 10,320 | 1,418 | 8,902 |
| Bridges | 2,831 | 1,187 | 1,644 | 2,692 | 1,122 | 1,570 |
| Other | 806 | 186 | 620 | 757 | 173 | 584 |
| **Total** | **14,782** | **2,836** | **11,946** | **13,769** | **2,713** | **11,056** |

Source: Transit (2002)

**Figure 3.4: Example of New Zealand Asset Value Reporting**

In Finland (not included in the case studies), the Finnish National Road Administration (FINNRA) has been collecting data for asset value calculations since 1950: like New Zealand, asset value is used in its balance sheet.

## 3.5 Accuracy of RMS Forward Work Programs

Most RMS are used to prepare annual forward works programs. These predict the future maintenance needs for the network, usually on section-by-section basis[1]. A key issue to be considered in the RMS is how realistic the predicted maintenance program reflects the actual maintenance requirements. In other words, is the system producing the correct results?

Correctness may be defined in terms of:

- The type of maintenance treatment being recommended;
- The extent and location of that treatment; and,
- The recommended year for implementation.

Prior to any agency implementing an RMS for planning purposes it needs to ensure that the predictions are sensible in the local context. This is done using a 'hit-rate' (*ie* the number of correct predictions) analysis.

[1] There are two types of analyses commonly conducted. A "Project" analysis determines the maintenance treatments required for specific sections of roads. These typically are short-term analyses, covering 1 - 5 years in the future. A "Strategic" analysis is a higher level analysis which deals with hypothetical road networks, usually a matrix of the number of total kilometres in the network with given condition. These are typically used for longer-term predictions (5 – 10 years or more).

## Using the RMS in the Planning Process

One agency reported that a major advantage of implementing the RMS was the institutionalization of a process which was generally accepted to have improved the planning and programming of road investments. The process included:

- Creating and maintaining a reliable database on the road network inventory and condition;
- Using the data with the RMS analysis engine to rationally and objectively develop draft work programmes;
- Field inspection to assess and refine the work programmes; and,
- Confirmation that the proposed plan was the appropriate way forward.

The process resulted in a good quality approach to road management.

Transit (2001) describes the New Zealand approach to hit-rate analysis. Each section has the maintenance needs predicted. The sections are then assessed based on visual surveys and other engineering experience. Comparing the predictions with the assessments, there is one of four mutually exclusive outcomes:

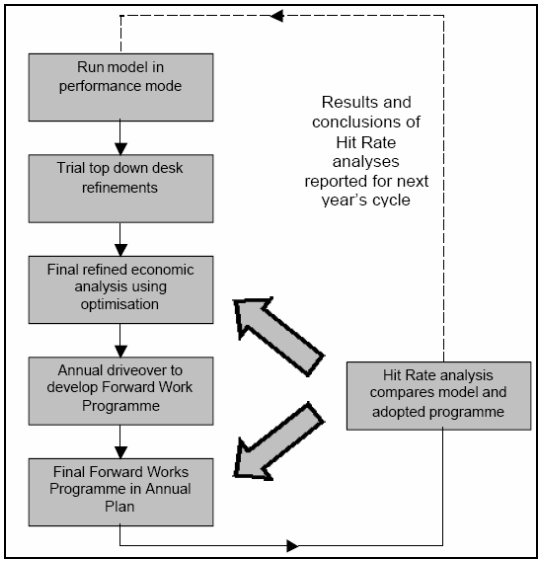
- **Correct Hit**: The RMS predicts the appropriate treatment in the assessed year[1] (right time/right treatment);
- **Incorrect Hit**: A different treatment is predicted (wrong treatment);
- **Coarse Hit**: From years 6 – 10 of the planning period the same or a different treatment is predicted +/- 2 years of the assessed year; and,
- **Miss**: None of the above (wrong time).

Figure 3.5 shows the New Zealand hit-rate analysis approach. As a result of applying this approach the following was learned:

- Predictive model calibration is carried out mostly at network level. That means that all roads in the network are assigned the same calibration factors. This resulted in hit-rates on the order of 50%. Where separate calibration exercises were performed on sub-networks, hit-rates of up to 80% were achieved.
- Localized differences in material quality and strengths accounted for many of the calibration differences.

[1] In New Zealand if the treatment is +/- 1 year of the expected date then it is considered a correct hit. This is a sensible approach given the uncertainties of data and predictive models.

- Outputs are not reliable enough (*ie* 50% accurate) to have a serious impact to funding allocation process.
- Lack of real data on pavement strength heavily influenced the predictions.
- There were data updating issues, specifically where the system had not been updated with recent treatments.




Source: Transit (2001)

**Figure 3.5: New Zealand Approach To Hit-Rate Analysis**

Table 3.3 shows that of the 17 agencies interviewed who have advanced planning / programming capability in their systems, only four (New Zealand Transit, New Zealand PDC, Chile, and Vermont Agency of Transportation), perform an explicit hit-rate analysis and were able to produce results of that analysis.

The Planning Policy Section in Indonesia recently conducted a survey in one Province to try to determine the accuracy of IRMS model results. They estimated a hit-rate of only 30%. The main reasons for apparent lack of accuracy are data quality (on inventory, condition, and traffic). It was also stated that the Directorate was not collecting axle load data, yet there is some concern on vehicle overloading.

It is important to appreciate that there will never be a 100% agreement between predictive models and assessed maintenance needs. Often, predictive models take into account factors such as economic evaluation, budget limitations, *etc*. which are usually omitted from engineering assessments. There are also often problems with data, the system may not take into account all issues (*eg* traffic safety considerations) and there are the basic limitations with any statistical pavement deterioration model.

**Table 3.3: Agencies Performing Hit-Rate Analysis**

| Agency | Implementation of Planning / Programming Capability | Hit Rate Analysis |
|---|---|---|
| Argentina (Santa Fe) | 2002 | No |
| Bangladesh | 2000 | No. Planning on doing one in 2006 after condition data updated in 2005 |
| Botswana | 1996 | No |
| Burkina Faso | 2000 | Calibration test sections only |
| Cameroon | 2006 | No |
| Chile | 1985 | Yes |
| China (Fujian) | No | No |
| China (Henan) | 2003 | No |
| China (Hubei) | No | No |
| Costa Rica | 1998 | No |
| India (Rajasthan) | 1996 | Not done |
| India (NHAI) | 1997 | System being Developed |
| Indonesia | 1990 | Preliminary |
| Mozambique | 1997 | No |
| New Zealand (TNZ) | 1998 | Yes |
| New Zealand (PDC) | 1998 | Yes |
| Papua New Guinea | 2004 | No |
| Tanzania | 2002 | No |
| Uruguay | 1999 | No |
| USA (VTrans) | 1995 | Yes |

However, by instituting a robust feedback mechanism which identifies areas where the model's predictions are significantly different to assessed needs, the overall accuracy and relevance of the predictions is improved. Experience from New Zealand has shown that improvements to data quality and regional calibration can increase the hit-rate accuracy to over 80%. However this requires a program of continual quality improvement in the agency (see also Page 24).

**An RMS Requires Ongoing Commitment**

Adopting an RMS requires an major commitment from the road agency. This commitment needs not only to be for the initial implementation, with appropriate calibration, but also to ongoing refinements, often through operational research. There needs to be full ownership of the system, its models and its outputs along with the necessary expertise to undertake the necessary improvements over time. A lack of commitment will lead to dissatisfaction by the users, and potentially an abandoning of the RMS.

## 3.6 Implementation of RMS Work Programs

An indication of the role of the RMS in an agency is the degree to which the RMS work programs are actually implemented. Due to budget, technical and logistical factors, even if the predicted forward works program was 100%

accurate, it would not be 100% implemented. However, if the RMS is an integral part of the planning process, and is giving sensible predictions, then a substantial portion of the predicted program would normally be implemented.

Most agencies were able to give estimates of the implementation rates, however in very few agencies is the actual implementation of the RMS program measured. Few (if any) Project Monitoring Systems are geared towards this. Some of the survey responses are listed below:

- **Africa:** "The intention was that HDM-4 should be used for developing the Annual Works Program. However this never took off, and computer models are not applied systematically today. Some HDM-4 estimates have been made, but there is no evidence that this has been used in the programming. Some regions are applying multi-criteria analysis, but there is no consistency between regions."
- **Africa:** "Some socio/political analysis/influence is exercised; however this process is not documented."
- **Americas:** "There seems to be a communication problem between the planning agency and the executing agency. The policies and criteria used in the planning exercises are in many cases different from those used by the executing agency for selecting and scoping projects."
- **Americas:** It is estimated that 70 – 80% of the treatments from the PMS are actually implemented, although there is currently no feedback mechanism from the RMS systems to keep a systematic record.
- **Asia:** "There is no way of knowing whether the plan coming from the [RMS] is actually implemented or not, mainly because so many other external factors come into play after [the RMS analysis], but also because the [RMS] does not keep a copy of the plan, it gets overwritten with next year's plan."

It is clear from the review that most RMS would benefit from having a mechanism for monitoring the rate of program implementation.

## 3.7 Processes – Key Success Factors

Based on the evidence from the case studies, the implementation of an RMS by itself is not seen as having a positive effect on shifting budget towards asset preservation. Even where systems are in place and where the total budget is increasing, budget is still often targeted more at network development rather than asset preservation.

### Funding

Part of the commitment to sustaining an RMS includes ensuring that there is sufficient funding to operate the system, keep the software and hardware up to date, and to collect the data. Reliable, and sufficient, funding of the RMS activities is a key success factor.

If agencies are not confident that they will get additional funding for maintenance, then they do not appear to perform a full Needs Analysis, and do not try to use such analysis to try to get additional funding or to divert funding from new construction to asset preservation.

The general conclusion is that unless an agency has an asset management 'mindset', then allocation of budget and funds will likely be driven by political will for new development rather than taking a holistic approach to balancing new roads against maintaining asset value.

It can be difficult to gauge the extent of the mindset and commitment of an agency to focus on asset management. Some key indicators would be the extent to which their annual reports discuss needs and asset value, rather than simply reporting the work performed in the last reporting period. Asset value is a relatively simple indicator to calculate and helps focus attention on the issues. Commitment to a system can also be demonstrated by the availability in the agency of hit-rate analysis data, along with resultant measures being taken to improve quality. Continual quality improvement in all parts of the process is vital.

## Important Factors for Successful Implementation

- **Funding:** Have annual budgets in place for data collection and operation of the RMS. Even if this initially requires donor funding support, there should be a phased increase in local budgeting to ensure that the RMS is self-funding within a given timeframe.
- Introduction of an RMS by itself is not a guarantee that it will be used, or that it will be successful. The agency must also follow basic asset management principles. Strong involvement of executives and managers prior to and during the implementation of the system is ***absolutely necessary***.
- Clear and explicit RMS planning and programming cycle/schedule developed with clear deadlines of and correlation between main tasks
- Annual Reports/Business Plans should be prepared, using 'Asset Value' and other Key Performance Indicators derived from the RMS. This is an executive and managerial responsibility. It also helps put focus on the RMS itself, since it provides the data and improves the chances that budget and funds are available to run the system.
- Institutional support consisting of high ranking decision-makers fully-committed to the asset management/asset preservation 'philosophy'.
- Regular briefings should be given to ministers and other high government officials on the importance of asset preservation, and what is being done to make sure that the preservation of the road infrastructure is dealt with satisfactorily.

(Continued) …

- Have specific and realistic key performance indicators, targets to measure asset value and to preserve/enhance that value. Monitor those targets, and assess at the end of each year whether they have achieved them or not, and take appropriate action. By publishing this information in Annual Reports, they are accountable to it.
- Have policies and procedures in place for data collection, and for quality assurance of that data.
- Technical (internal and/or external) auditing must be carried out on data and systems, and the recommendations acted on.
- A program of Continual Quality Improvement is also critical. No system is static. All systems can be improved.

# 4 People

**Key Success Factor:**
**The RMS Must Be Fully Institutionalized and Supported**

There must be sufficient budget allocated to operate the RMS and collect the necessary data. There must be an organizational unit established to manage, monitor and continually improve RMS implementation. This organizational unit must be appropriately staffed, have clear job responsibilities, and must have clear reporting responsibilities to upper management and executive level.

## 4.1 Institutionalization

In the context of this report, institutionalization means '*to make part of a structured and well-established system*'. Aspects considered to be important in institutionalization of an RMS are those that are similar for any management system. They should include:

- Establishment of an organizational unit with specific responsibility for the system;
- Establishment of a budget for the operation of the entire system, including all staffing, equipment, data collection (contract or in-house), field travel, *etc.;*
- Presence of appropriately qualified personnel, with good management skills, with access to and control over their budget;
- Specific and detailed job responsibilities for all aspects of the system;
- A program for continual quality improvement;
- Clear management reporting; and,
- A regular audit of all elements and the taking of corrective actions where necessary.

What is apparent from the survey is that very few of the agencies interviewed in developing countries can really be said to have 'institutionalized' their systems to the degree to which they can be considered successful and, above-all, self sustaining. The New Zealand and USA systems were well institutionalized and supported.

To illustrate this, the surveys found:

- 12 agencies out of 21 were unable to provide copies of job descriptions for their staff in the unit responsible for operation of the RMS.
- 10 agencies out of 21 indicated they had no formal Data Quality Assurance procedures (this is covered in more detail on Page 52).

- 12 agencies out of 21 indicated they do not do any formal hit-rate analysis (indicating a lack of checking of results and therefore lack of effort towards continual improvement).

Other examples suggesting a lack of institutionalization were responses such as:

- **Africa:** staff reported that one of the contributing factors to a lack of institutionalization was "ambiguous job descriptions with overlapping tasks… it has not been clear who was doing what".
- **Africa:** "The Pavement Management Section (which is responsible for the RMS) comprises five positions, but all were vacant at the time of the survey" (Botswana, Roads Department),
- **Americas:** "Approximately ten staff members were trained and almost all have left the group" (Argentina, Santa Fe)
- **Asia:** "The inventory updating was not completed … because the person making the efforts left on a 5-year leave"

## Outsourcing to Assist Institutionalization

The Botswana Department of Roads (DOR) shows that outsourcing can be effectively used to offset problems with staff availability affecting institutionalization.

Although all five positions in the Pavement Management Section were vacant at the time of survey, the DOR still clearly uses the output of their RMS in the planning/programming and also uses the data in the database (as printed in the reports) on a day-to-day basis. This is in spite of DOR appearing not to be able to operate the system (except for inputting data), nor to produce GIS maps.

Their solution has been to use a consultant to undertake data collection, prepare and publish the data, and operate the RMS. The DOR successfully procured such services in 1996, 1999 and 2002.

It could be argued that Botswana realizes that it cannot cope with the demands of maintaining an operational RMS on a day-to-day basis, and prefers instead to go for a 'minimalist' approach where it works with updates of data every 3 years. Such an approach might be valid for an agency having difficulties institutionalizing an RMS and where there is continuity of consultant inputs.

One danger with outsourcing lies in consultants underbidding, particularly for data collection. In some countries the unit rates for data collection were so low that it was not possible to provide quality data at that cost. The same can apply to consultants operating the RMS: if the price is too low they will not be able to perform an adequate analysis.

One of the most positive directions comes from Chile, which is in the process of acquiring ISO certification for quality management of their RMS, including data collection.

Also on the positive side, in terms of career progression, the Bangladesh RHD encourages employees to pursue higher studies (Masters in highway, traffic and transportation and structures). Several officers have obtained higher qualifications (Masters) in the respective subjects.

## 4.2 Training

As a minimum, the training portion of an implementation project for of an RMS should cover:

- Principles of network referencing;
- Roles and responsibilities;
- Data collection policies and procedures;
- Network-level versus project-level data;
- Accuracy and tolerance on data;
- Data quality assurance;
- System operation;
- Reporting; and,
- Auditing.

It is also important that basic contract management skills are available in order to manage data collection procurement[1]. The ability to prepare a Terms of Reference, evaluate proposals, negotiate contracts, administer and quality assure a data collection contract requires strong management abilities, skills and experience that are often taken for granted in an RMS implementation. Training in these areas is also seen as a necessary part of the total picture. This is discussed further in Chapter 6 in relation to data collection.

Although the survey asked about number of days of staff training per year, it is difficult to make any assessment based on the responses. Most agencies claimed that their staff received 5 – 10 days training per year. Most training, especially that provided by traditional consultancy projects, is usually carried out 'on-the-job'. Also, it is difficult to quantify and assess the amount of client involvement in any implementation project. For RMS which are developed (either in-house, or by consultants), there is often a lot of client involvement in specifying the RMS requirements which may not be seen as 'training' as such, but nevertheless ensures that the client staff are more familiar with the RMS software during the design and development stages.

[1] Data collection is either done in-house or procured from consultants. The general trend, especially in countries with weak technical skills in an agency, is to outsource data collection to consultants.

Several agencies remarked that there had been projects in the past where 'training' was carried out in the last weeks before the consultant left. This is another indicator that 'institutionalization' has not fully taken place.

One surprising aspect from the surveys is that few, if any, implementation projects actually produced training materials for the client. In many cases, organizations claim that staff retention is a problem, also staff are often moved into different job areas or promoted. It is therefore important that training materials are available, and that the client's staff are trained to deliver new training if and when it becomes necessary. Many clients opt for a 'train-the-trainer' approach in implementation of systems, often to cut expensive consulting time from the implementations. However, without development and handover of training materials, this cannot happen successfully. There is also often a problem with long-term retention of the trainers.

For those agencies which have implemented off-the-shelf systems (see Page 29), this is not so much of an issue:

- Training material is often available 'off-the-shelf'; and/or,
- Software suppliers usually run regular courses and/or user conferences which client staff can attend (for a fee).

It is much more difficult in the case of bespoke[1] development to acquire additional training, even only one year after project implementation, simply because the original consultant development staff have moved on and the consultant company may have no staff available with knowledge and experience. Costs of additional training for bespoke systems therefore tend to be higher.

It is therefore necessary for organizations to develop, with the aid of the implementing consultant if necessary, a set of training materials which can be used in a classroom situation for new staff (or, as refresher training for existing staff) and that ownership and copyright of these materials resides with the client. Without the latter, there could be disputes over modifying, updating or even using the training materials without the involvement of the original consultant.

### Users Groups

RMS implementations are often complex, and there can be a wide number of users with different levels of expertise trying to apply the RMS. Countries which have established user groups or forums for sharing experiences have found that this is very beneficial to the adoption and application of the RMS.

## 4.3 Continual Quality Improvement

[1] Individually or custom-made software. Typically, software consulting companies develop software specifically for the client. Commercial-off-the-shelf (COTS) software is readily available and is usually customized.

Quality management is vital to the success of any business enterprise. The continual improvement of the organization's performance should be a permanent objective of the organization (ISO, 2000). Quality is an institutional responsibility, rather than the responsibility of any one particular individual or office.

What is noticeable from many of the case studies is that those agencies that have successfully employed RMS for a number of years have, during the course of their implementations, initiated programs of continual quality improvement. This has been apparent in many of the areas discussed in this report – data collection, training, road network modeling *etc.* It is most apparent in the hit-rate analyses that are conducted, and quite often the research that is undertaken by the agencies into understanding and refining their road deterioration models.

The key issue is that no system, and no organization, is static. Continual effort is required to improve it at all times. This requires drive and dedication from the agency, and particularly from the individual staff involved.

## 4.4 Institutionalization and Training – Key Success Factors

There are obviously many different aspects to institutionalization and training. However, too often in road management systems implementations, *training* has been regarded as sufficient for ***institutionalization***. This is not the case.

Institutionalization firstly requires an asset management mindset (see the previous chapter). There must also be in place a number of subsidiary processes including budgeting, human resource management, and IT Management, as discussed elsewhere in this report.

**Important Factors for Successful Implementation**

- There should be an organizational unit established with specific responsibility for the RMS.
- There should be a budget for the operation of the system, including all staffing, equipment, data collection (contracted or in-house), field travel, quality assurance etc.
- There should be clear job descriptions for the various activities, and a career path for those in the unit.
- There should be a continual training and development program (and budget) for staff to deal with staff turnover and re-training where necessary. This should potentially include Master's or other post-graduate degrees which will increase the attractiveness of working in this area.
- There should be training materials available. For bespoke systems the copyright should reside with the agency.

(Continued) …

- Jobs should be filled with appropriately qualified personnel, with good management skills, and with access to and control over their budget.
- Job responsibilities should explicitly include:
  - Management of the Road Network Referencing System – control, verification, education and dissemination to other stakeholders.
  - Data Collection – planning, management, supervision and coordination.
  - Data Quality Assurance – verification and checking of all data.
  - Management Reporting – reporting and presentation to management.
- Strong contract management skills are necessary, especially for agencies that contract out portions of data collection.
- The agency should follow good basic management principles, covering procedures, records, auditing *etc*.
- There should be a commitment to Continual Quality Improvement.

# 5 Information Technology

**Key Success Factor:**
**The IT Components Must be Appropriate**

Information Technology (IT) is becoming increasingly complex, as the demands for sharing information between applications and users grows. Any medium to large organization should have a strong IT division and an IT strategy to ensure that the benefits of IT are realized. The RMS implementation should fit within the overall IT strategy of the agency, and should be properly supported from an IT perspective.

## 5.1 IT Management

Management of IT is a challenge to all organizations, not only road agencies. Hardware and software develop so quickly that systems can easily become obsolete in the space of 3 – 5 years. Also, system complexity rises at an ever-increasing rate.

Road agencies also tend to spend an increasing share of their budget every year on IT. As the budget expands, and as IT becomes more and more critical to the organization, there comes a point where it is necessary to have an overall IT strategy backed up by strong IT management principles.

It is considered vital that any sizeable organization implementing any form of management system, such as an RMS, should have a separate IT Division. If there is no Division with overall responsibility for IT, then it is likely that there will be a lack of IT policy, lack of a strategy for development and use of IT across the organization, and a piecemeal approach to IT implementation. All of these can lead to loss of sustainability on the IT side.

Key responsibilities for IT Divisions should include:

- IT Budgeting;
- IT Procurement;
- Network Administration;
- Systems Administration (including data backups);
- IT Security;
- Development of IT Architectures;
- User Awareness and Training; and,
- User Support.

The survey (see Table 5.1) found:

- Five agencies out of the 21 surveyed have no separate IT Division; and,
- Of the remaining 16 agencies, six report significant numbers of vacancies in their IT Division.

**Table 5.1: IT Divisions in the Agencies**

| Agency | IT Division | Number of Network Users | Number of IT Staff | Number of Vacancies |
|---|---|---|---|---|
| Argentina (Santa Fe) | Yes | Unknown | 4 | "Several" |
| Bangladesh | Yes | 300 | 10 | 15 |
| Botswana | Yes | 200 | 3 | 0 |
| Burkina Faso | Yes | 50 | 4 | 0 |
| Cameroon | No | - | - | - |
| Chile[1] | Yes | 2,000 | 9 | 0 |
| China (Fujian) | Yes | 400 | 9 | 10 |
| China (Henan) | Yes | 10,000 | 5 | 0 |
| China (Hubei) | Yes | 800 | 6 | 0 |
| Costa Rica | Yes | 900 | 5 | 0 |
| India (Kerala) | - | - | Several engineers doing IT support | - |
| India (Rajasthan) | No | - | 1 engineer doing IT support | - |
| India (NHAI) | Yes | - | 7 Staff plus 22 Consultant personnel on contract | - |
| Indonesia | No | 100 | - | - |
| Mozambique | Yes | 150 | 4 | 0 |
| New Zealand (TNZ) | Yes | N/A | 20 | 5 |
| New Zealand (PDC) | No | N/A[1] | 0 | 0 |
| Papua New Guinea | Yes | 100 | 14 | 5 |
| Tanzania | No | 120 | 2 | 0 |
| Uruguay[1] | Yes | 500 | 10 | 3 |
| USA (VTrans) | Yes | 1,300 | 41 | 3 |

From this it can be deduced that 50% of the agencies in the survey are significantly short of basic IT staff (by their own standards).

The total number of staff in the IT Division is also indicative of the types of function they perform. It is difficult to envision that any IT Division with three or less staff can manage and maintain a computer network for more than 100 users, let alone perform all other IT functions adequately.

[1] Papakura District Council in New Zealand outsources all IT work and has two staff to manage the outsourced activities.

Significantly, in at least two cases, the agency stated that their IT Division does not really bother itself with the needs of the Planning Division; they are more concerned with other business functions such as financial management. There is a general impression in IT Divisions of road agencies around the world that Planning Divisions do not perform a critical business function, and therefore are not given high priority in terms of IT funding and support.

The ratio of Users to IT Staff varies considerably across the agencies (see Figure 5.1). IT Staff (apart from their other functions) should provide in-house support for applications and technology. The higher the ratio, the less support can be offered. In road agencies where a common complaint is lack of computer-literate personnel, lack of in-house support and training can be a major problem.

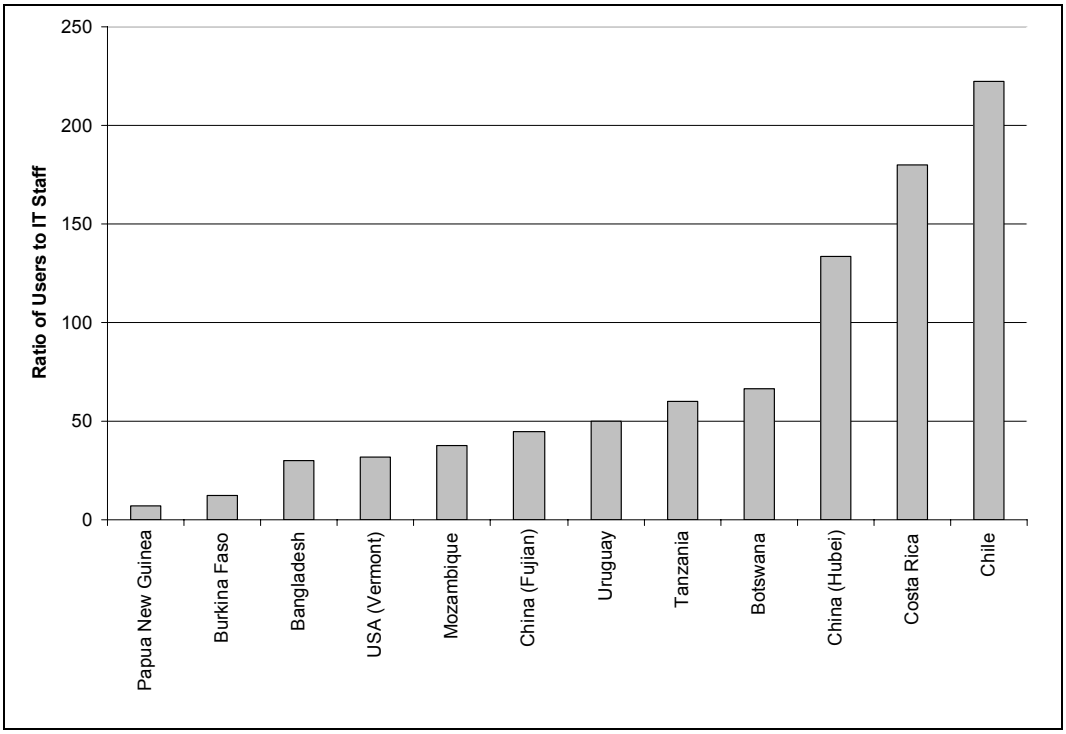



**Figure 5.1: Ratio of Users / IT Staff**

## 5.2 IT Budgeting

IT Budgets should cover procurement of all new hardware and software, operation of the network (including costs of leased lines *etc.*), warranty and maintenance agreements, support etc.

Very few agencies in the survey have an explicit IT budget (or, can even report on how much is spent on IT). Much of IT procurement in the road agencies involved in the case studies comes through 'projects', and hence tends to be piecemeal and not part of an overall agency strategy or plan. Issues related to this are discussed below under IT Architectures.

Table 5.2 shows the responses from the surveys. Only about half of all agencies interviewed were able to provide reliable figures.

**Table 5.2: IT Budgets by Agency**

| Agency | Approximate IT Budget[1] | IT Budget / Total Budget (%) |
|---|---|---|
| Argentina (Santa Fe) | "Very Small" | Not Known |
| Bangladesh | $150,000 | Estimated need 1 - 2 % |
| Botswana | Recurrent/maintenance budget BWP $55,000 Annually Development budget, $90,000 annually | Negligible |
| Burkina Faso | $100,000 for Staff and $10,000 for misc. expenses (no investments) | 1.33% |
| Cameroon | Not Answered | Not Answered |
| Chile | $200,000 | Not Answered |
| China (Fujian) | $250,000 + Project requirements | ~ 0.2 % |
| China (Henan) | Not Available | ~ 0.1 % |
| China (Hubei) | $125,000 + Project requirements | ~ 0.1 % |
| Costa Rica | $10,000 | < 10 % |
| India (Kerala) | Not Available | Not Available |
| India (Rajasthan) | Not Available | ~ 3.0% |
| India (NHAI) | Not Available | ~ 3.0% |
| Indonesia | Project-based | Not Known |
| Mozambique | $5,000 | Negligible |
| New Zealand (TNZ) | IT is outsourced as much as possible | Not Known |
| New Zealand (PDC) | IT is outsourced as much as possible | Not Known |
| Papua New Guinea | $300,000 | < 1% |
| Tanzania | $105,000 includes hardware and purchase of standard software | Negligible |
| Uruguay | < $100,000 | Negligible |
| USA (VTrans) | $ 3 million | ~ 1 % |

Note: 1/ All costs are estimates in $US to nearest $5,000. Converted from local currencies 10/2/05.

As far as the IT Budget as a percentage of total budget, for most agencies it is negligible. Recent work in Bangladesh has suggested that IT budgets for government agencies should be between 1 – 2 % of the total agency budget. An exception was India where both the National Highways Authority of India and Rajasthan PWD indicated that they spend about 3% of their agency budgets on IT.

## 5.3 IT Architectures and Standards

A 'Technology Architecture' is a series of principles, guidelines or rules used by an organization to direct the process of acquiring, building, and maintaining its IT resources. It acts as a framework within which the IT

infrastructure can be established, and should support the applications and data which are required by the organization to support its business needs.

The benefits of establishing a technology architecture are:

- **Control of diversity, and establishment of standards within the organization.** Diversity increases technology and support costs, and can obstruct interoperability, information sharing and system integration.

- **Easier procurement process.** An architecture eases and speeds up the procurement process because only appropriate products will be considered. Economies of scale can also be applied, both to major expenditures and also to supplies.

- **Clarifies long-term goals and provides a building-block to respond to environmental changes**. An architecture increases the order and predictability of future technology upgrades and expansions.

- **Increases the stability and reliability of network services.**

For example, if an agency maintains three separate database systems, then it requires that database and systems administrators have advanced skills in three separate packages. It usually also means that licensing fees on the whole are significantly higher than if a site-license or enterprise license was procured. Also, three separate support and maintenance agreements are required. Upgrades to a newer version of the database management system (DBMS) are also much easier to plan and implement. Also, any in-house developers of applications can also concentrate on one database environment instead of multiple environments.

The same principle applies to all hardware, system software, and application software. As another example, it is not uncommon for agencies to have three or four different anti-virus packages installed on their computers. This can cause untold extra work on systems administration, as well as contributing to gaps in the defense against viruses.

Without a formal technology architecture for the organization, and without proper control of all procurements, it is likely that there will be piecemeal IT implementation within any organization. This will increase costs, and decrease efficiencies thereby influencing the likely success of any IT project, such as an RMS.

## 5.4 Use of Commercial Off-the-Shelf (COTS) Software

In industry, most large organizations have a policy of using commercial off-the-shelf software (COTS) if at all possible, rather than developing bespoke software, (either in-house of through consultancy projects). The potential advantages of COTS over bespoke software are:

- **Cost:** they are usually much cheaper to buy than to develop from scratch;

- **Independence:** The client is not tied to one particular consultant since many may offer implementation support for the application;
- **Timeframe:** it can be implemented more quickly in the organization (*ie* it does not have to be developed first);
- **Experience:** it has usually been implemented in a number (sometimes many hundreds) of other client organizations for a number of years, and has therefore been subject to rigorous user testing in addition to the normal in-house testing of the software supplier;
- **Functionality:** it often provides more useful functionality than the client originally considered;
- **Ongoing Development:** there is usually continual upgrades of the software as the supplier responds to other client requests for enhancements; and,
- **Exchange of Ideas:** there are often user conferences held by the supplier at which ideas and experiences can be shared with other users.

There are also potential disadvantages including:

- **Requirements:** the functionality may not be *exactly* what is required, so some workarounds may be needed;
- **Institutionalization:** Associated with requirements, bespoke systems may have more institutional acceptance since the usually better reflect the current processes;
- **Customization:** the time to implement new ideas in the software may take longer, since the software supplier has a responsibility to other clients;
- **Cost:** many agencies have difficulties in funding support and maintenance agreements[1]; and,
- **Upgrades:** The timing of upgrades is controlled by the software developer, and agencies are often compelled to follow this schedule to ensure future system maintenance.

A well-chosen COTS package from a good software supplier is **almost always** preferable to bespoke development. There are many such packages on the market in the areas of road and asset management as well as highway planning. Some key features of these systems that should be included in any requirement or specification for RMS are given in Table 5.4 on Page 34.

Careful review and assessment of off-the-shelf packages and the suppliers is essential. This needs to consider the financial stability of the company, the technical capabilities of the system, and the product's direction. Of particular

[1] Support and maintenance agreements are usually in the order of 12 – 20% per annum of the original cost of the software. However, that cost must be compared with the cost of consultants developing enhancements for bespoke systems.

importance is **prior to procurement** conducting a 'Gap Analysis' which establishes the system's functionality and features relative to the agency's operating procedures. There may be differences which necessitates either changes to the procedures or refinement of the software.

Table 5.3 shows that 13 out of the 21 agencies surveyed developed (or are in the process of developing) their own software (all through consultancy contracts, except for Chile, which was developed in-house). As shown later in Table 7.1, overall satisfaction was found to be higher with COTS than custom developed software.

**Table 5.3: Developed or Off-the-shelf Software**

| Agency | Year of System Implementation | Developed or Off-the-Shelf |
|---|---|---|
| Argentina (Santa Fe) | 2002 | Developed |
| Bangladesh | 1996 | Developed |
| Botswana | 1993 | Off-the-shelf |
| Burkina Faso | 2000 | Off-the-shelf |
| Cameroon | 2000 | Off-the-shelf |
| Chile | 1980 | Developed (in-house) |
| China (Fujian) | 2002 | Developed |
| China (Henan) | 2003 | Developed |
| China (Hubei) | 2003 | Developed |
| Costa Rica | 1998 | Off-the-shelf |
| India (Kerala) | (under development) | Developing |
| India (Rajasthan) | 1996 | Off-the-shelf |
| India (NHAI) | (under development) | Developing |
| Indonesia | 1985 | Developed |
| Mozambique | 1997 | Developed |
| New Zealand (TNZ) | late 1980's | Off-the-shelf |
| New Zealand (PDC) | 1998 | Off-the-shelf |
| Papua New Guinea | 2000 | Developed |
| Tanzania | 2001 | Developed |
| Uruguay | 1999 | Developed |
| USA (VTrans) | 1995 | Off-the-shelf |

For agencies that have existing developed systems, it is often quoted that they do not wish to change from their bespoke system because they would lose the past investment. However, that investment would not necessarily be lost by any future move to a COTS package. Normally with an RMS, the *data* represents 70 – 80% of the cost of implementing the system. If the data can be brought across to the new system (which should be a requirement of any implementation project), then much of the investment that has gone into the original system is retained.

Also, from the case studies, it is noted that in at least four separate cases systems *developed* by one consultant have been either replaced or substantially modified by later consultants. Each consultant claimed that the source code was either not available, or not current, that there was no formal systems documentation, and that few if any normal coding standards or

conventions had been applied. Often, this was discovered after the project had commenced so gave rise to increased costs and variation orders.

Technically, if the client goes down the route of employing a consultant to develop software, the aspects above should be explicitly covered in the contract, and the client should enforce handover of code and documentation in a suitable format and to agreed standards and conventions. Unfortunately, given that most road agencies are not equipped to develop coding standards or to monitor their implementation, the consultant is often free to do whatever he wishes.

In terms of functional requirements, Table 5.4 summarizes the key functional requirements for any RMS. It should be noted that this table is provided as a guide only. It is not intended to be en exhaustive list of functionality required for every RMS, and in fact some agencies may decide that they may not wish to have all the features listed. However, as their experience with an RMS grows, agencies tend to find that they need more and more in-built functionality and features. Most reputable COTS systems support more than 90% of the listed functions to some degree. The exact way in which these functions are implemented may differ, so it is always worth having detailed discussions with suppliers and other users to gain a better understanding of the working of the systems prior to procurement. It is also necessary to combine functional requirements with technical requirements, to match the architecture of the agency – *ie* operating systems, RDBMS, GIS, and other applications.

**Table 5.4: Key Functional Requirements for an RMS**

| Key Functional Requirements for an RMS |
|---|
| ❑ Terminology and Local Language. All screen labels, menu items, and reports should be configurable to the client conventions in the local language.<br>❑ Road Network Referencing. Different network referencing schemes should be supported. These should include linear distance from the start of the road section, linear distance from the start of a road, as well as distance from known location referencing points.<br>❑ Road Network Numbering Rules and Conventions. Network Numbering Schemes particular to the client should be able to be enforced by the RMS.<br>❑ Network Editing. Should permit splitting and joining of road sections, also modification of road section lengths, while preserving integrity of all data stored against the affected sections[1].<br>(Continued)… |

[1] This is one of the most often overlooked features of RMS and can lead to excessive maintenance efforts by the agency. Roads change over time and the system must be designed to automate the process of maintaining and updating the data to a very high degree.

## Key Functional Requirements for an RMS

- Network Auditing. Any changes to the road network definition should be audited, and the RMS should allow review of these changes.
- Multi-Media Storage and Display. Should allow storage and display of multi-media objects (*eg* photographs, video clips etc.) as attributes of inventory items.
- User-Defined Items and Attributes. Should allow the user from the GUI (Graphical User Interface) to define the types of inventory / condition data to be stored, and to define what attributes are to be stored against each type of inventory. There should be no restriction on the number and type of items or their attributes.
- Data Level Security. Allow security setup so that users may only have update privileges for sub-networks in different geographical or administrative areas. Also, for different users to have different levels of access depending on the type of data.
- Function Level Security. Allow security setup so that different users may have access to different application modules.
- Staging Area for Data Loading. Should permit data to be loaded into a temporary staging area for verification of data, prior to making it available to other users within the application.
- Integration with GIS. The RMS should integrate with GIS to allow display of inventory and condition data against maps of the road network. The exact type and method of integration can vary widely, from embedded GIS in the application front-end, to simple ability to export data for manipulation in an external GIS.
- Reporting. Reporting should be flexible, and the interface must enable the user to define his own reports from the GUI without reprogramming of the application.
- Automatic Sectioning. An automatic sectioning function to collate and summarize data for analytical purposes. The user should be able to define the sectioning criteria using any of the key inventory or condition data.
- Data Transformations. Sectioned data need to be transformed to the automatically generated sections using different criteria.
- Trend Analysis. Should allow production of reports/graphs showing trends in average condition (or any attribute of any database item) over time, for part of a section, a whole section, part of a route, or a whole route.
- Template Survey Forms. Should allow production of template forms for use by the client for performing surveys. These template forms should be based on actual network inventory.

(Continued)…

**Key Functional Requirements for an RMS**

- Schematic Line Diagrams. Should allow production of schematic line diagrams showing selected sections and inventory items with selected attributes.
- Purging of Data. Should allow purging of historical inventory and condition data to an archive database, and subsequent retrieval of that data if required.
- Audit Trail. All data changes should be audited, including time of change, username responsible for making the change, and value of previous data item.
- Application Programming Interface. Allow other applications to retrieve data from the RMS via a programming interface. Ideally this should not take place through direct database access.
- Other Asset Inventory. Should permit storage of, or cross-references to, other major assets such as bridges and other structures. If bridges and other structures can be accommodated, then all above functional requirements should also apply to these assets.

Finally, many COTS packages manage both roads and bridges, as well as other infrastructure assets. There are many benefits to be gained from maintaining all asset inventory and condition data in a single system, not the least of which is that it enforces the use of a common network referencing system.

## 5.5 System Acceptance Testing

In the surveys, agencies often complained about 'bugs' in the software, or 'it is not user-friendly'. Fundamentally, the issue here is that clients often do not perform proper acceptance testing of the system. A set of acceptance tests should be agreed with the supplier/consultant at the start of the project, and these should be gone through formally when the software or implementation is completed. Very few agencies actually perform proper and thorough acceptance testing, often because their IT divisions are not fully involved in the implementation (see above), and also because the task of acceptance is delegated to junior staff. Since the agency will be using the RMS for managing their business it is essential that it be properly tested.

It should also be noted that acceptance testing for COTS software is often much more straightforward than acceptance testing for bespoke software. Major software suppliers have their own internal quality control and testing standards prior to release, also the software has usually been on the market for a significant period and any bugs or interface issues have usually been sorted out long ago. This is not to say that there are no bugs in COTS software, however in general, there are fewer. From recent experience in acceptance testing of software systems of similar complexity, acceptance

testing for COTS software took two days, while acceptance testing for a bespoke system developed by a consultant took three months.

## 5.6 Hardware and Software Support and Maintenance

Best-practice IT policy dictates the use of hardware and software maintenance agreements. By not having maintenance agreements, organizations run the risk of having obsolete systems within a very short time period, also of having to maintain staff skills in old versions of software. Maintenance agreements are cheaper than complete replacement of systems and re-training of staff every 4 – 5 years.

- **Hardware agreements:** These provide a guarantee of service and replacement of spare parts within agreed timeframes dependent upon business needs, and removes the need to have funds earmarked for purchase of spare parts (hard disks, new monitors *etc.*) whenever a breakdown occurs.
- **Software agreements:** These are necessary to obtain continued software support after warranty and upgrades without having to purchase new software licenses. They enable organizations to keep up-to-date with technology changes in an incremental fashion, as well as to avail of security patches which are becoming of growing concern across all software platforms and systems.

As shown in Table 5.5, of the 21 agencies surveyed, only three had software support agreements in place with the original supplier; only six had hardware support agreements in place with local hardware vendors.

## 5.7 Outsourcing of IT Functions and Systems

Maintaining any sizeable computer network across several offices, providing staff access to the internet, and perhaps also remote dial-up, requires dedicated skills and resources that were not necessary 5 - 7 years ago. There are literally hundreds of pieces of equipment that need to be maintained and monitored on a daily, sometimes hourly, basis to ensure that network services remain available (including servers, switches, hubs, routers, multiplexers, hardware firewalls, concentrators, PABXs and other communication devices). In addition, there are dozens of software tools required to manage and protect networks (including patch management software, anti-virus software, firewalls, bandwidth monitoring tools, bandwidth management tools, hardware and software auditing, and intrusion detection systems).

The complexity of the IT infrastructure, and the sophistication of tools necessary to administer it, is only going to increase in the coming years.

Given the increasing complexity of IT management, road agencies should generally consider outsourcing their IT functions and systems to the private sector. Outsourcing, if established properly, can provide the following benefits:

**Table 5.5: Software and Hardware Support Agreements**

| Agency | Software Support Agreement in Place? | Hardware Support Agreement in Place? |
|---|---|---|
| Argentina (Santa Fe) | No | No |
| Bangladesh | Development Ongoing | Yes |
| Botswana | No | No |
| Burkina Faso | No | No |
| Cameroon | No | No |
| Chile | N.A. (in-house) | No |
| China (Fujian) | No | No |
| China (Henan) | No | Yes |
| China (Hubei) | No | No |
| Costa Rica | No | No |
| India (Kerala) | Development Ongoing | No |
| India (Rajasthan) | Development Ongoing | Yes |
| India (NHAI) | Yes | Yes |
| Indonesia | No | No |
| Mozambique | No | No |
| New Zealand (TNZ) | Yes | Yes |
| New Zealand (PDC) | Yes | Yes |
| Papua New Guinea | No | No |
| Tanzania | No | No |
| Uruguay | No | No |
| USA (VTrans) | Yes | Yes |

- Experienced professionals with in-depth knowledge of hardware and software tools for complete network and systems management;
- Established procedures based on best-practice experience from the private sector;
- Agreed service level targets with agreed response times, with liquidated damages if not met;
- 24 x 7 coverage and support if necessary;
- Single point of contact for the agency – the contractor would be responsible for dealing with the multitude of hardware and software vendors, telephone companies *etc.*;
- Eliminates problems of staff recruitment and retention for network and systems administration;
- Faster response to problems without having to address issues such as lack of funding for travel, inability to procure small hardware items *etc.*;
- Proper capacity monitoring and planning for network bandwidth; and,
- Disaster recovery planning becomes the responsibility of the contractor, not the agency.

In addition to basic network and systems management outsourcing, some of the larger RMS software suppliers offer hosting services, whereby the supplier will host the client's system *and* data, and make it accessible to the client through some sort of secure Virtual Private Network (VPN).

Two agencies in the study that are already committed to outsourcing of IT functions are Transit NZ and Papakura District Council. Many of the Transit systems and data are already hosted on the software supplier's machines, and access to those systems and data is given to contractors and other external agencies.

Obviously, outsourcing of IT functions cannot happen in all countries, and is very dependent on the presence of strong local private companies. It can also give rise to serious problems if there is a lack of accountability. However, road agencies should perform regular reviews of the local IT environment to determine whether this may be a possibility.

## 5.8 Integration with HDM-4

Much of the IT-related discussion above relates to any agency and any system. This section discusses one aspect particular to RMS implementations, which is the integration of the RMS with HDM-4, the Highway Development and Management tool. HDM-4 is a tool for economic optimization of maintenance of road networks and has been adopted or applied in many different countries for economic analysis and prioritization. HDM-4 can operate with Strategy, Program and Project analysis. It utilizes road network inventory and condition data, traffic data, and economic data to feed a series of road deterioration models and cost models, and to formulate candidate work programs for road networks.

A number of bespoke software development projects have been undertaken in recent years to create 'interfaces' between the RMS and HDM-4. In the case studies reviewed, there have been attempts in Argentina, Bangladesh, Chile, Papua New Guinea, Henan Province in China, Tanzania, and Uruguay. Developments are also being planned for Cameroon, Costa Rica, Mozambique.

Several agencies in the surveys had problems with the interfaces between their RMS and HDM-4, and these are instructive for those planning future interfacing. They also apply to interfacing the RMS with other third-party applications.

Problems with interfaces are not surprising, given a review of several Terms of Reference for projects included no more than a one-line statement saying, "*The Consultant shall integrate the client's Road Management System with HDM-4*". Such a Terms of Reference is not a precise specification of the task, and is usually the cause of severe misunderstandings between the client and consultant as to the extent of the work. Quite often too, consultants underestimate the complexity of the task, and submit proposals without a clear understanding of the task and the resources needed to complete it to the client's satisfaction.

An interface between an RMS and HDM-4 may include any or all of the following:

- An Automatic Sectioning function to create 'homogeneous' sections for analysis in HDM-4 based on inventory and condition data;
- A generic interface which allows the user to define the rules for the above-mentioned automatic sectioning. This can include specification of which data items to use, what transformations to apply to the individual data items (*ie* average, minimum, maximum, dominant, weighted average), minimum and maximum lengths of sections *etc.*;
- Transformations of inventory and condition data to get it into terms understood by HDM-4 (this may also include manipulation of road construction types to match the set of surface types supported by HDM-4);
- An ability to bring in default data where one or more data items is missing, and to highlight in the reporting which data items have been defaulted;
- Preparation of HDM-4 Input files for Work Standards, Traffic Classification and Growth Rates;
- Averaging and Preparation of data for Strategy Analysis (as opposed to Program Analysis); and,
- Import to the RMS of the results of the works program generated by HDM-4 so that they can be related back to the real road network and displayed in tabular or map-based reports. Depending on how complex the system is, and what it is intended for, this may also require the RMS retaining a copy of the road network definition passed to HDM-4, so that if any changes occur to that network between the time of passing the data and getting the results, then they do not prevent the results being imported.

Each of these is complex to program, and the graphical user interfaces are often similarly complex to use. An advantage to COTS packages with an existing HDM-4 interface is that they will already have addressed most, if not all, these issue.

From the client perspective, he often believes that he will receive a 'press-the-button' interface to 'Export Data' and 'Import Data', however what he usually gets is often a convoluted and complex interface that can (depending on various factors) take hours to run even with today's hardware, often with many steps requiring manual intervention.

It is **essential** that Terms of Reference should be more precise when it comes to interfacing the RMS with other applications. This will raise client awareness of the issues, and will enable the consultant to get a clearer understanding of the client's needs prior to bidding.

## 5.9 Geographic Information Systems

Many road agencies employ some sort of Geographic Information System (GIS) to enable mapping and analysis of their road networks. 13 out of the 21

agencies in this study already use GIS, with an additional three agencies already planning for future GIS implementations.
GIS implementations can range in complexity from simple stand-alone desktop software on a single PC, to a full enterprise-wide GIS accessible to all users and even to the public, in which data from different agencies are integrated together.

To a large extent, many of the issues previously discussed in relation to IT, also apply to GIS, *ie* management, budgeting, hardware and software maintenance agreements, and support.

However, GIS in road agencies also has its own peculiar problems since it usually relies on data provided by other agencies (including land use, other transport networks, environmental data, socio-economic data *etc*). It can be relatively easy to go into an organization and set up a demonstration GIS for an agency. The difficulty lies in keeping the data current, of implementing standards, and in promoting sharing of data among agencies if there are no formal rules in place already[1].

Issues regarding collection of GIS data are discussed in the following chapter on data collection (see page 57).

## 5.10 Web-Enabled Systems

Many RMS Terms of Reference call for 'web-enabled' RMS. However, a call for a web-enabled RMS should be carefully assessed against several criteria to ensure that this is (i) required, and (ii) properly scoped. Some of the key issues are:

- **Target audience:** is this for internal (intranet) or external (internet) use? Or both? The answer has ramifications for the IT infrastructure since the network management, systems management and IT security considerations need to be thought through. Does the agency really have sufficient IT infrastructure, skills and budget to support this properly? What IT security measures are in place (*eg* anti-virus protection, patch management, firewalls, intrusion detection systems *etc*)? Is the computer network properly designed and partitioned? Are relevant security settings properly established on all servers? What staff and procedures are required to review and monitoring all of the above? Can these really be managed 24 x 7?

- **Functionality:** Which particular functions of the RMS should be web-enabled? Many functions of an RMS (such as modifying network referencing, loading of bulk data, and complex reporting) do not lend themselves well to a web interface, and besides should normally be open to only a small number of highly trained individuals. Usually, only simple reporting is be 'web-enabled' to make the data more easily

[1] The complexity of establishing an inter-agency data sharing policy, which could also include private sector data, should not be under-estimated. It is necessary to have in place formal agreements covering who will provide what data, when it will be updated, how the updated data will be made available and, importantly, pricing. Many agencies assume that data held by other agencies will be made available for free, or at a nominal cost, which often does not prove to be the case.

accessible to large numbers of occasional end users (either inside the agency, or outside).

- **Mapping:** Should maps be posted on the internet? If so, should they be dynamic or static? A dynamic map interface requires a higher order of magnitude of GIS infrastructure software, hardware, and systems expertise to keep it operational.

Opening systems up to the internet also leads to misunderstandings of data. Few RMS properly incorporate the concept of 'metadata' which gives the background to the data. What *exactly* does the data on the web mean? What is its accuracy or tolerance? What is its update frequency? When was it collected? Who collected it? How reliable is it? External users tend to assume that data on internet websites are accurate and up-to-date. Putting data on a website with no clear policies or statements relating to its accuracy can be highly misleading and may open the agency up to criticism.

'Web-enabling' of systems is another example (similar to the case of HDM-4 integration) where there may be severe misunderstandings between client and consultant/supplier as to what is really meant. The real requirements should be stated explicitly in TORs, and the client needs to make sure that the IT infrastructure is able to support what they wish to do.

## 5.11 Systems Integration

Large agencies that have been using IT for a number of years eventually find it necessary to integrate their systems, otherwise they end up with many different databases containing the same information, or references to information held in other databases. After a while, manual procedures can no longer cope.

For road agencies, often the road database is separate from the bridge database, which is separate from the traffic database, which is separate from the routine maintenance management system database, which is separate from the GIS *etc.* All of these systems should ideally use a common referencing system (*ie* the road network). Any changes to this common referencing system will involve the same changes to multiple databases, and when changes are made to one database but not another, then problems start to occur in terms of data integrity. Recent literature has shown that 70% of all software development effort is now focused on systems integration.

The major software suppliers have recognized this, and many RMS have the ability to store information on a number of different types of asset (roads, bridges, signs, traffic data *etc.*). This has several potential advantages, including savings on database licensing costs, a larger user base with which to exchange knowledge in the agency, but most importantly enforces data integrity between all these systems because they are forced to use the same referencing system. Ideally too, all of the above systems would also use the same GIS system and the same GIS data without having to share it manually across different divisions of the same organization.

## Web-Enabling Data Access/Collection

One area of increasing interest to Highway Agencies is the web-enabling of the data collection component of an RMS. This would allow different units in the field to collect data and then remotely update a central database via the internet. This can be achieved in one of several ways:

1. Several of the larger COTS RMS software suppliers provide solutions to host the database in their offices, and to allow clients access to that database across the internet. This usually runs via a bandwidth compression tool so that internet access over even relatively slow lines can be achieved. Thus, a single central database for an agency would reside at the software supplier's office. Anyone with proper security access rights could access it remotely[14] through an internet connection from anywhere in the world. All the functionality of the client's software would be available to the remote user, including editing and analysis tools.
2. A similar system to Option (1) above could be set up in the agency's head office. Any database application could be made available to any specified user across the internet. The problem is that you need a good computer network infrastructure (including some fairly high specification servers) in the head office to run the database application, good systems administration staff to maintain the servers, bandwidth compression tool, firewall, anti-virus protection, intrusion detection software *etc.* There also needs to be a good database administrator to manage and monitor the application. If you do not have the head office infrastructure and support in place, then the system may never work properly and might never be fully operational.
3. There may be private hosting services in the country outside of the agency, or for that matter anywhere in the world, who could host perform (2) above on behalf of the agency. This would potentially be cheaper than (1), and more robust than (2), but would require a good local private company and a hosting agreement.

In summary, Option (1) is probably safest but also the most expensive. It is also only available for the higher-end applications that are quite complex to use and hence also require a great deal of training. Option (2) can be used for any database-type application, but requires a good network infrastructure and head office computing support. Option (3) is probably much less expensive than option (1), but requires an informed client and a reliable hosting company, which in theory could be located anywhere in the world.

Many of the major RMS also provide APIs (application programming interfaces) to allow other applications to integrate with them. Common functions include the ability to reference data to the road network (even if

[14] The remote access is usually done using a laptop computer. While PDAs have been used on some projects, this is usually for simple data collection. PDAs have limited reporting capability so it is not practical to do reporting and querying against the database.

held in another database system), and to retrieve information (such as inventory and condition) for use by a second application.

More and more agencies are moving towards integrated systems. This makes it even more critical when planning an RMS implementation to choose the correct software package in terms of its functional and technical requirements. The ability of a system to be able to store information on *any* asset, as well as exchange data between other systems, is becoming more important. This should also be built into Technical and Functional Requirements for systems.

## 5.12 IT - Key Success Factors

**Important Factors for Successful Implementation**

- There should be an IT Division.
- TORs should explicitly reflect the IT support in the agency, they should not implement a system in isolation from the IT strategy of the agency. If necessary, assistance must be provided to define an IT strategy and to implement it.
- Road agencies should consider outsourcing / external hosting of their systems where possible given their local environment and according to their overall organizational policies.
- Any sizeable organization procuring IT should have a Technology Architecture, or explicit technology standards and directions. This is important to avoid a profusion of different infrastructure software (operating systems, databases, GIS *etc.*) with all the attendant support issues; it is also important in helping to define a replacement / upgrade strategy for hardware and software. There are also distinct economies of scale that can be achieved through centralized procurement of hardware and system software.
- All IT implementations should use commercial off-the-shelf (COTS) products wherever possible.
- For any future implementation of an RMS, a set of functional and technical requirements should be drawn up. Functional requirements should include the functions that the software should perform. From the wealth of experience available, it is relatively easy to determine generic functional requirements of an RMS to suit a road agency of a given size. Key functions that should be in any system are given in Table 5.4 on Page 34. Technical Requirements should describe the technology environment within which the RMS will fit (*ie* hardware, operating systems, databases, GIS, and other applications). This should relate to the agency's Technology Architecture as discussed on Page 30.

(Continued)…

- Terms of Reference requiring 'integration' other applications, such as HDM-4, with an RMS should be more precise, to raise client awareness of the issues, and will enable the consultant to get a clearer understanding of the client's needs prior to bidding.
- Agencies should develop and adhere to a long-term IT budget strategy that includes costs of hardware and software maintenance agreements (in addition to hardware replacement strategies). One of the comments from a case study in Asia was "*The system has not been upgraded since its initial installation (in 1996) and it shows its age. It was the first MS Windows-based version of this system and is not very user friendly*". This is a classic case of what can happen if there is no long-term IT strategy.
- The real requirements for web-enabling of systems should be more carefully assessed, and explicitly stated in Terms of Reference. The client also needs to make sure that their IT infrastructure (including hardware, systems software, databases and GIS) is able to support what they wish to do with a web-enabled system.

# 6 Data Collection

**Key Success Factor:**
**Data Collection Must Be Appropriate and Sustainable**

Only the key data that are required for use in decision-making should be collected and stored in the RMS. These data should be collected at the minimum level of detail with the most appropriate data collection technology given the constraints and capabilities of the agency. Where possible, data collection should be outsourced.

There must be explicit data collection policies and procedures for the agency, in a manner understood by all involved with data collection.

There must also be strict data quality assurance procedures in place so that all system users have confidence in the data and analyses provided to them.

## 6.1 Introduction

Data (*ie* inventory, condition, traffic, environmental, and cost data) is vital to the success of any RMS. Without good data, it is not possible to conduct proper analyses or monitor the road network. Problems with data is one of the main causes of failure of an RMS.

Data is also expensive. Each data item requires time, effort, and money to collect, store, retrieve, and use. The first rule of data collection is that data should never be collected because 'it would be nice to have the data', or because 'it might be useful someday'. There have been several papers advising on the necessity to collect only what is needed, and to collect it at the required Information Quality Level[15].

What is apparent from the case studies is that those agencies that are committed to RMS, and have most successfully implemented RMS, **all** have explicit policies and procedures for data collection, and a management structure committed to implementing them.

Failure of the RMS due to 'data collection' is not a failure of the data collection itself, rather a failure to properly institutionalize data collection. Specifically,:

- There are often no explicit data collection policies;
- Budgets are not made available for data collection;
- Staff are not properly trained or monitored;
- The quality assurance procedures are missing or inadequate;

[15] The Information Quality Level (IQL) concept was introduced by Paterson and Scullion (1990). Bennett and Paterson (2000) expand on the original concept and apply it to HDM-4.

- There is no auditing; and,
- There is no replacement strategy for specialist equipment or vehicles.

All of these areas need to be specifically addressed in implementation of a data collection program for any RMS.

As an example of the above, the following are some experiences with data collection, both from the case studies and the recent experiences of the study team:

- **Africa:** "Procedures for updating data exist, but are not enforced /implemented. Data collection should be done through the provinces. Originally it was planned that the provincial officers should undertake the data collection; but this was later outsourced to local consultants. It was planned that some of the provincial staff should be transferred to the consultants to ensure that the consultants would have the capacity and knowledge to undertake the surveys; however this never materialized."
- **Africa:** The condition of the network was reported by the provincial staff to be better than it actually was to escape sanctioning for poor performance.
- **Africa:** "Network level data collection has been undertaken at intervals by international consultants. However the results of these surveys have never been input into the [RMS], nor have the data been collected using the formats applicable for the [RMS]."
- **Americas:** The agency required that the vendor supplying data used the vendor's quality assurance practices but did not have their own practices. It was subsequently found that large sections of data were unusable since the equipment had failed and the vendor's practices did not identity the problem.
- **Asia:** The specialist staff trained to analyze the data from the multi-function data collection vehicle have emigrated and there is nobody available who can fully operate the equipment or manage the data.
- **Asia:** The project procured an expensive multi-functional data collection vehicle from overseas. It has not been used for over five years since the vehicle broke down and parts were unavailable.
- **Asia:** The client procured three specialist bridge-inspection vehicles through a project at a cost of over $100,000 but they were never made operational due to the client's inability to fund the $100 annual registration fee for each vehicle.
- **Asia:** The vendor provided late data of poor quality. Some data sets were resubmitted three or four times after the client's team identified problems. This resulted in a large extra workload for the client but since the contract did not include a clause for liquidated damages for late submission of quality data, the client had no recourse on the vendor.

- **Asia:** The client's staff in provincial areas were responsible for collecting data. They submitted inflated traffic count data since they knew that this increased the likelihood of projects in their area being selected in the annual program.

These are clearly not issues with data collection, but of institutionalization. Even though there are may be policies and procedures, there must be budget made available, and there should be follow-up by management (which implies regular management reporting and auditing), to ensure that data are actually collected according to policy and are valid.

## 6.2 Data Collection Policies

Policies for data collection can be quite simple. They should describe at a high level the type of data that will be collected, its frequency, and its level of detail (or, IQL). They should also describe the process by which data will be collected (*ie* in-house, or by contract). Policies such as these give the organization clear guidance on their duties and responsibilities, and also serve to communicate with other agencies when it comes to discussing sharing of data.

**Extent of Data Collection**

The case studies found in a number of instances that the RMS was not designed around the full range of roads managed by the agencies. For example, several agencies had substantial portions of their network comprised of rigid pavements but the RMS data tables and decision framework was limited to flexible bituminous pavements.

It is therefore essential that the agencies have a good general knowledge of their road network prior to the implementation of any RMS and associated data collection technologies. This will serve as a guide in system development and establishing data collection policies.

### 6.2.1 Data Types, Updating Frequencies and Quality Levels

The basic types of data that are collected by road agencies are:

- **Road inventory data**. These are typically collected in a once-off exercise. They are then updated when changes are made to the road. It is common to verify/update the data every five years or so. This may include video.
- **Pavement condition data**. These may be collected at different frequencies, depending on the road class. Main roads and major highways may be monitored at more frequent intervals, often 1-2 years, while minor roads may be monitored at 2 – 5 year intervals. The frequency needs to be sufficient to identify major changes which will influence road maintenance decisions.

- **Traffic data**. Traffic volume data are usually collected through a set of permanent traffic count stations around the country, supplemented by short term counts (typically seven days for traffic volumes) at other locations. Axle load data are usually collected at a relatively small number of representative static locations around the road network.
- **Locational data**. Coordinate data on the road network itself and/or point locations for location reference markers (*eg* kilometer posts), and perhaps also structures. These are usually incorporated into GIS.

## Example of Survey Frequencies: Roughness Data

Road roughness is one pavement condition attribute measured by most highway agencies. It provides a good indicator of the structural and functional condition of the pavement.

The frequency of the surveys varies between countries, and depends partly on the size of the network and the logistics. For example, in Botswana the main road network is essentially a loop of approximately 3,000 km around the Kalahari desert so this could be surveyed in about a month. On the other hand, the Philippines has 45 islands with 18,000 km of National Roads so it takes over a year with a single vehicle, and this excludes some smaller islands because it is logistically too difficult to survey them.

The general practice is to survey the primary (or high-traffic) roads frequently, and the lower-traffic roads less frequently. The following are some examples of survey frequency for primary roads:

- **Botswana:** Every three years;
- **Costa Rica:** Every two years;
- **New Zealand:** Annually;
- **Papua New Guinea:** One third of the network every year; and,
- **South Africa:** Every two years; maximum three years;

Most agencies collect all the above data types to a degree (although some agencies may not implement GIS). Often, this is done in a single project funded by a donor usually part of implementing the RMS. A major problem, however, in many of the agencies surveyed was that there were few explicit policies and procedures for updating of data. Thus, agencies were making decision on old, out of data or incomplete data.

For example, it is not uncommon for a basic road network inventory to change by up to 10% each, due to new road construction, road realignments, road widenings, and road transfers (between agencies). However, some organizations in the survey do not update their road inventory on a regular basis (*eg* as new roads are opened, or widened) so that even the basic asset inventory in the system (which is the cornerstone of the whole asset

management principle) in some cases was five years out of date. Users either within the agency, or in external agencies, rapidly lose confidence in the data when they realize that some of the roads they are familiar with are not reported in the RMS database. Loss of confidence in the data leads to loss of confidence in the RMS, and can easily cause failure of the RMS implementation.

Policies should be explicit, and should guide management in ensuring that there is sufficient budgeting and staff made available for the activities required to implement these policies. More data, collected at a higher level of detail or quality, requires more budget and more people. Any implementation project for an RMS should explicitly quantify these relationships in terms of costs, and get up-front agreement with executives and managers that these levels of budget and staff are sustainable in the medium to long term. Equipment also needs to be considered, as discussed in the next section.

### 6.2.2 Data Collection Process

In terms of the process by which data are collected, there are essentially two choices an agency can make. One is to collect the data in-house, the other is to contract out the collection. The choice depends very much on the individual agency, and its ability to purchase, operate, and maintain any specialist equipment required.

Specialist equipment are used in surveys to collect data such as roughness, GPS, deflections, skid resistance and pavement structure. Operating this equipment places demands on an agency that are difficult to meet, such as:

- The capital cost of equipment is high so funds may be diverted from other, equally important, activities to fund the equipment;
- The agency has difficulties in funding, importing/acquiring and installing spare parts or to service the equipment (especially if the equipment's host vehicle is imported from overseas);
- The equipment requires specialist staff with a high degree of skills and training, which in a road agency may be used irregularly and therefore staff, skills and training tend to be lost over time; and/or,
- The requirements for calibration and checking which may not always be performed well by staff without full training and documented quality assurance procedures.

Many agencies can manage certain types of special survey equipment by themselves, and maintain the equipment and staff skills to do so. Often, these agencies used a specialist project with consultants or contractors to start the data collection, and during this time the agency's staff were trained in the use and operation of the equipment. After the project the staff continue the data collection. Thailand has successfully used this model for almost 15 years for roughness data collection, and Cambodia has recently used it.

Other agencies make a policy decision to completely outsource specialist surveys. Consultants or contractors who work full-time with the equipment, using highly skilled personnel, who strive to acquire or even develop latest

technology, and who follow approved calibration and validation procedures, are often in a much better position to collect good data. One reason identified for outsourcing data collection was to reduce the ability of agency staff to manipulate data for their own purposes. If outsourcing is used it is vital that the agency have in place their own data collection procedures, and the ability to claim liquidated damages for the submission of late or inaccurate data.

Table 6.1 shows the results of the survey regarding ownership of specialist data collection equipment by the agencies. Of the 21 agencies in the project, six stated that they ***do not*** own any specialist data collection equipment. In their cases, ***all*** data collection is undertaken by contract with specialist data collection providers.

Of the remaining 15 agencies that own specialist data collection equipment, some use a combination of in-house and outsourcing. The following points were noted:

- Five agencies *do not use* some major items of equipment that they own.
- Two agencies explicitly indicated that they had concerns over their own ability to calibrate and operate the equipment.
- Two agencies, although they had collected data, were unable to load it into their RMS for various reasons.
- 11 agencies reported *no warranty or maintenance agreements* on their equipment.

The recommendations are clear. Agencies that have difficulties in calibrating, operating, maintaining, and/or obtaining funding for warranties and maintenance agreements for specialist data collection equipment, should adopt and implement policies to contract out the data collection services.

This decision, of course, has ramifications in terms of institutionalization and training for management of data collection contracts, as well as data quality assurance, which are discussed in later sections in this chapter.

## 6.3 Data Quality Assurance

Agencies **must** have in place Quality Assurance (QA) procedures for data. The QA procedures must be consistent with the data collection policies of the agency, especially with regard to the Information Quality Level (including the accuracy and frequency of data collection).

QA on the client side is necessary irrespective of whether the data is collected in-house or outsourced.

It is not safe to *assume* that the consultant or data collection contractor will provide good quality data. There are many opportunities for error in the overall data collection process, even when dealing with automated data collection equipment and with experienced contracting firms. Equipment is being developed or upgraded all the time, and with each new development

comes a new set of problems. Also new or inexperienced contractor staff in the field may be unaware of, or forget to follow, equipment calibration procedures.

**Table 6.1: Specialist Data Collection Equipment and Warranties**

| Agency | Equipment | Equipment Warranty |
|---|---|---|
| Argentina (Santa Fe) | WIM, FWD, Weigh scales, Bump Integrator | None mentioned |
| Bangladesh | Benkelman Beam, ROMDAS, GPS, Axle Load Pads, DCP, Sampling Equipment, Survey Vehicle | None mentioned |
| Botswana | 11 Permanent Weigh stations | Servicing contract - every 3 months |
| Burkina Faso | 3 GPS (20 more to come), 3 Viziroute, 3 Bump Integrators, 2 Automatic Traffic Counters | None mentioned |
| Cameroon | 6 automatic traffic/axle-load stations | None mentioned |
| Chile | Combined IRI / Rutting / Video / GPS equipment, FWD, SCRIM, Grip Tester, Automatic Traffic Classifiers, WIM, Static Weigh scales | Yes, through local suppliers in Chile |
| China (Fujian) | RMS-200 (combined GPS, gradient, curvature data) | None mentioned |
| China (Henan) | None mentioned | - |
| China (Hubei) | None mentioned | - |
| Costa Rica | Bump Integrator | - |
| India (NHAI) | Proposing the procurement of several equipments including GPS, ROMDAS, Traffic Classifiers, Weigh-in-Motion etc. | None mentioned |
| India (Kerala) | Benkelman Beam, 5th Wheel BI; proposals are on to procure GPS, ROMDAS etc. | None mentioned |
| India (Rajasthan) | ARAN, 5th Wheel BI Units, Topographic Surveying Instruments, ROMDAS. | None mentioned |
| Indonesia | ROMDAS, Benkelman Beams | No |
| Mozambique | GPS Equipment | None mentioned |
| New Zealand (TNZ) | None – all data collection undertaken (including traffic data) by professional service providers | N/A |
| New Zealand (PDC) | None – all data collection undertaken (including traffic data) by professional service providers | N/A |
| Papua New Guinea | Road Master (Includes Roughness, GPS, Odometer, Keypad | Maintenance funded under foreign funded project (soon to end) |
| Tanzania | ROMDAS | No |
| Uruguay | Combined IRI / Rutting / Video / GPS equipment. Traffic Counters. Benkelman Beam. Deflectometer. | - |
| USA (VTrans) | Profilometer, FWD, ARAN vehicle | None mentioned |

As described by Bennett (2000), errors arise because of:

- **Random measurement errors**: If measurements are not repeatable this is usually because of random measurement errors.

- **Systematic measurement errors**: These arise due to instrument malfunctioning or improper calibration; and/or,
- **Operator errors:** These are the most common, for example with all types of surveys it is very easy to enter an incorrect link/section identifier[16], collect or store data in the 'wrong' direction, and/or fail to follow out the required daily checks on factors such as tire pressure, odometer calibration.

Often a contractor might use clerical staff in the office to consolidate and clean field data before submission to the client, and the lack of experience of those staff, and lack of supervision, can also lead to errors.

Even agencies that have been outsourcing data collection for many years, using experienced contractors, are continually looking at ways to improve data quality. New Zealand, for example, has recently introduced stricter QA procedures, including issuing multi-year data collection contracts with the same contractor to get continuity on the survey teams, as previous analyses had shown variation between contractors.

It should be noted that QA applies to the **entire** data collection and data reduction process. Road data is usually voluminous, and data needs to be controlled and managed carefully once it has been submitted to the client's office. Corrections or changes to data on the client side should be properly documented, if possible in the computerized RMS through automatic auditing capabilities. Also, regular audits should be carried out to ensure that the quality procedures are actually being followed. The results of audits should be documented, and actions followed up. Only by following such procedures can users (both internal and external) have confidence in the data, and hence have confidence in any analysis that goes with it.

Table 6.2 shows the extent of data QA procedures from the surveys. Only 50% of the agencies apply *any* formal quality assurance procedures to their data or their systems. There must therefore be concern over the quality of data in their systems.

Chile is another example of an agency that is committed to data QA. In general, it reports that satisfaction with the data is "fair to good". There has been much improvement but there are many things that still need to be better, especially in the timeliness of the information submission. More formal QA procedures are needed and they are being implemented. Efforts at improvement in quality include: new data collection manuals, ISO certification, inclusion of quality targets in the agency goals, and productivity bonuses for the data collection crews.

[16] One advantage to collecting GPS data at the same time as other data is that it forms an independent verification of the location where the data were collected. The vehicle's odometer should still form the primary data collection, but even uncorrected GPS data will confirm if an improper link/section identifier was used or the data collection was in the wrong direction.

**Table 6.2: Data Quality Assurance Procedures**

| Agency | Data Quality Assurance Procedures |
|---|---|
| Argentina (Santa Fe) | No |
| Bangladesh | Formal documentation/Manual |
| Botswana | No |
| Burkina Faso | No |
| Cameroon | No |
| Chile | Yes (applying for ISO certification) |
| China (Fujian) | Some formal documentation |
| China (Henan) | Some formal documentation |
| China (Hubei) | Some formal documentation |
| Costa Rica | No |
| India (NHAI) | Some formal documentation |
| India (Kerala) | No |
| India (Rajasthan) | No |
| Indonesia | No |
| Mozambique | No |
| New Zealand (TNZ) | Yes |
| New Zealand (PDC) | Yes |
| Papua New Guinea | Yes |
| Tanzania | Yes |
| Uruguay | No |
| USA (VTrans) | Yes |

## 6.4 Data Collection Contract Management

Although it is recommended for some agencies to consider adopting policies to outsource data collection (see page 53), if such policies are adopted, then there needs to be careful thought given to institutional capacity for the management of the data collection contracts.

Procurement and management of a nation-wide data collection contract on 10,000+ km of roads is a challenge for any agency. Some basic procurement principles, that are sometimes often neglected, are given below.

It must be recognized that the effort that has to go into management of a data collection contract is immense. Specialist skills are often necessary to understand the data and to be able to validate it. Spot-checks are often worthwhile as part of a quality assurance program. Dedication and resources can often be stretched to the limit as data starts arriving and has to be quality assured before payment is made.

**Table 6.3: Basic Principles for Data Collection Contract Management**

| Basic Principles For Data Collection Contract Management |
|---|
| ❑ Require the contractor to survey a validation network (minimum 100 km) prior to the full survey. This will help the contractor to sort out logistical and technical issues early on and before the full survey commences. This validation survey data should be completely processed and imported to the RMS where it is verified as suitable. This will (i) confirm that the data processing steps are in place to use the data, and, (ii) ensure that the client can review the submitted data on a timely basis.<br>❑ Require every data collection team of the contractor to perform the validation survey. If there are different teams, different vehicles, and different equipment, then all should be tested.<br>❑ Require the contractor to produce his own Quality Assurance Plan prior to the start of the contract. This should be approved by the client.<br>❑ It may also be useful to ask for the Contractor's Quality Assurance Plan as part of the proposal, and include evaluation of the Quality Assurance Plan in the technical evaluation.<br>❑ Require documentary evidence of calibration prior to, and during, the surveys.<br>❑ Require data to be *submitted* within a short time period after collection (less than 2 weeks if possible, and certainly not more than 1 month).<br>❑ Pay only for data approved, not for time, and not for data submitted. It will be necessary to agree upon the time-frame for approving data (usually 30 days or less) and to ensure that the client's staff are allocated sufficient time to check the data.<br>❑ Have a liquidated damages clause in the contract which can be used in the event of late submission or continued submission of poor quality data. |

The following client staffing estimates (for contract supervision, contract management and quality assurance of data) are made for typical data collection contracts of 10,000 km of road network.

- **Roughness Data:** 1 – 2 full-time client staff for the duration of the contract (which may be up to nine months, depending on circumstances and logistics).
- **Inventory Data**. Depending on the number of inventory items and their number of attributes, 2 – 3 client staff full-time for the duration

of the contract. If video data is being collected under the same contract, and where there is the ability to cross-check video with inventory, then estimate 3 – 4 client staff full-time.

- **GPS Data.** One client staff member full-time for the duration of the contract. Requires good GPS / GIS skills.

With experienced contractors, and a track record in the agency for data collection by contract, the staffing levels may be reduced, but not significantly. Some agencies procure a consultant to do the data collection contract management and quality assurance on their behalf.

A combined data collection contract with all three major types of data being collected at once, can obviously pose severe organizational difficulties for an agency. Any RMS implementation project that includes data collection should look to train appropriate numbers of client staff in the art and science of data quality assurance. Much of the data QA is best done in spreadsheets prior to uploading to the RMS, therefore good spreadsheet and database skills are often required, along with good analytical skills.

In contrast to the above approach, some projects for implementing RMS have the consultant collect and load data into the newly-implemented RMS, with little, if any, involvement of the client. This misses an opportunity for client's QA procedures to be developed and implemented for data collection. It is unlikely that after hand over of the system that the client's staff will have the skills to perform this process independent of the consultant.

It is often the case too that some data is very complex and difficult to interpret (*eg* FWD data requires specialist knowledge). It is strongly recommended that if the agency does not have the skills to QA this data itself, then it should hire an independent contractor / consultant to do it on their behalf.

## 6.5 GIS Data Collection

GIS data is treated separately here, since there are some special issues that apply to it, particularly because of the potential for sharing with other agencies.

Even for road network data (which is often the only spatial dataset that a road agency is responsible for), it is often difficult for the agency to keep it current. As mentioned earlier, it is not uncommon for a road network to change by up to 10% per annum, when new road construction, road realignments, road widening, and road transfers (between agencies) are taken into account. There must therefore be a policy relating to this data in the same way as applies to any other data (*ie* how often is it to be updated, and to what accuracy will it be collected).

When implementing GIS in a road agency, the following factors should be addressed regarding GIS data collection.

**Table 6.4: Key Points For GIS Data Collection**

| Key Points for Implementation of a GIS |
|---|
| ❑ Agree to the policies, standards and accuracies with internal stakeholders and with external stakeholders from other relevant agencies. Mapping data is much more likely to be shared, *and* taken out of context, than most other road data.<br>❑ In particular, agree on policies for updating the geographic representation of the road network, taking into account whether the agency has the ability to collect its own GPS data, or whether it needs to hire GPS contractors. There is also the possibility of getting road construction contractors to provide as-built drawings and/or GPS coordinates of new roads, although this does not help in the case of road conversions.<br>❑ Metadata [17] standards should be agreed on and implemented.<br>❑ Data quality standards should include data cleanup procedures, snapping of lines, closing of polygons *etc*. as well as domains of values for attribute data.<br>❑ Consideration should be given to versioning of data to allow historical spatial analysis. |

## 6.6 Data Collection - Key Success Factors

| Important Factors for Successful Implementation |
|---|
| ❑ Data collection equipment and approaches should be tailored to the capacity of the road agency.<br>❑ Only the key data that are required for use in decision-making should be collected and stored in the RMS.<br>❑ Data should be collected at the minimum level of detail with the most appropriate data collection technology given the constraints and capabilities of the agency.<br>❑ Data collection policies and procedures need to be formalized and should be readily available.<br><br>(Continued) … |

[17] Metadata provides information about the content, quality, condition, and other characteristics of data.

- If the agency has concerns about operation and maintenance of specialist data equipment in-house, then consideration should be given to outsourcing of the relevant surveys.
- Outsourcing surveys requires strong management and quality assurance of the contractor. There should also be liquidated damages in the contract in the event the contractor fails to provide quality data in a timely manner.
- Key principles for data collection contracts should be included in Terms of Reference.
- Strict data quality assurance procedures should be adhered to so that all system users have confidence in the data and analyses provided to them.
- GIS data needs to be managed in a more detailed manner than other road data since it is likely to be used by many parties outside the road agency.
- Continual improvement is necessary on all aspects of data collection, quality assurance, and data management.

# 7 Conclusions

What makes a RMS successful? Three factors: processes, people and technology – and sufficient funding. If any of these are weak or fail then the RMS will be compromised. The RMS must also have appropriate and reliable data

During the course of this project it was found that a few agencies had successfully considered all three factors, but most had not. The focus of too many projects was on the technology element, with insufficient attention given to the institutionalization of the RMS and the necessary support systems.

The project surveys asked agencies to rate their overall satisfaction with their RMS on a scale of 1 to 10, with 1 being 'completely unsuited to needs' and 10 being 'fulfils all current and anticipated future needs'. This question was directed not simply at the RMS software itself, but at the myriad of other factors including how it fits into the overall planning and programming process of the agency, usability of the system, the support from the software supplier (if any), hardware support etc. The results are shown in Table 7.1.

**Table 7.1: Overall Satisfaction with RMS**

| Agency | Overall Satisfaction[1] |
|---|---|
| Argentina (Santa Fe) | 7.5 |
| Bangladesh | 6 |
| Botswana | 7.4 |
| Burkina Faso | 8.5 |
| Cameroon | 6 |
| Chile | 7 |
| China (Fujian) | (not used) |
| China (Henan) | (not used) |
| China (Hubei) | (not used) |
| Costa Rica | 5 |
| India (NHAI) | (under development) |
| India (Kerala) | (under development) |
| India (Rajasthan) | (not used) |
| Indonesia | 6 |
| Mozambique | 5.5 |
| New Zealand (TNZ) | 8 |
| New Zealand (PDC) | 8 |
| Papua New Guinea | 5 |
| Tanzania | 6.7 |
| Uruguay | 8 |
| USA (VTrans) | 9.9 |

Notes: 1/ Overall satisfaction with the system – on a scale of 1 (completely unsuited to needs) to 10 (fulfils all current and anticipated future requirements)?

For those agencies actually using their systems, the average score for was 7. If one includes the four agencies that are not actively using their systems the average score drops to 5.5.

It is worth noting that the average score for bespoke systems is 6.5, while the average score for those using COTS is 7.5. However, the use of COTS software is no guarantee of success. In one agency, the original (COTS) system was not fully implemented or institutionalized so is no longer used. The opinion of the client was that the successful implementation of RMS required a dedicated group responsible for all activities, and there was no such group formed by the agency for the purpose. This resulted in expensive equipment lying unused, and eventually deteriorating until they were beyond repair. The personnel originally involved in the project were no longer available. The basic data and other documentation were also not available.

The major success factor in the implementation is therefore **institutionalization** (processes and people) rather than technology, although the latter is also important. The institution must see a need for the system and it must be supported from all levels, not just the technical team who will be responsible for the system.

It is therefore essential to ensure that there are specific items in TORs to deal with institutionalization, at the very highest level. Instead, the focus has usually been on technology. Too many TORs call for consultants to implement a system, and then give 'on-the-job training' and a high-level presentation to management at the end. This completely inadequate.

Project specifications and TORs should be more explicit, and the proposals should require Consultants to detail how they will address institutionalization in their project plan. Proposals should be scored on how well this is addressed, and it should attract a much higher weighting than the technology, especially since the technology is usually well established. Instead, the opposite is the case at present: technology almost always dominates.

Thus, for RMS implementations to be successful, future projects must reflect the findings of this project in these key areas:

## Processes

The introduction of an RMS by itself is not a guarantee that it will be used, or that it will be successful. The agency must also follow basic asset management principles. Strong involvement of executives and managers prior to and during the implementation of the system is absolutely necessary. If it is not seen as having value by the agency's higher management, they will not provide the necessary support and funding to maintain the system.

Some agencies developed the RMS without clearly defining what its role would be in the agency. In several instances it was done under the assumption that it would find its position in the agency when completed and introduced to the senior staff. This approach was contrasted by agencies where the role of the RMS was clear from the onset, and these are the agencies which were much more successful with their implementations.

It is therefore important to have:

- Business Plans, using 'Asset Value' and other key performance indicators derived from the RMS. This is an executive and managerial responsibility. It also helps put focus on the RMS itself, and improves the chances that budget and funds are available to run the system.
- Institutional support consisting of high ranking decision-makers fully-committed to the asset management/asset preservation 'philosophy'.
- Regular briefings given to ministers and other high government officials on the importance of asset preservation, and what is being done to ensure that the preservation of the road infrastructure is dealt with satisfactorily.
- Have specific and realistic key performance indicators and targets to measure their asset value and to preserve/enhance that value. Monitor those targets, and assess at the end of each year whether they have been achieved or not, and take appropriate action. By publishing this information in Annual Reports, the agency is accountable to it.
- Have annual budgets in place for data collection and operation of the RMS. Even if this initially requires donor funding support, there should be a phased increase in local budgeting to ensure that these activities are self-funding within a given timeframe.
- Have policies and procedures in place for data collection, and for quality assurance of the data.
- Technical (internal and/or external) auditing must be carried out on data and systems, and the recommendations acted on.
- A program of Continual Quality Improvement is also critical. No system is static. All systems can be improved.

## People

An RMS (including all computer systems, data, policies and procedures) should be driven by a dedicated group within the agency, probably in the planning division or equivalent. This dedicated group should actively seek to promote the system within the agency, especially to higher level management; raise awareness of the system; manage data collection; constantly look for ways of improving data collection procedures and data quality assurance; research off-the-shelf packages and systems on the market; create and maintain technical and functional requirements for planning and programming systems; and coordinate all efforts related to the RMS in terms of other applications.

To ensure that an appropriate staff environment exists:

- There should be an organizational unit established with specific responsibility for the RMS.

- There should be a budget for the operation of the system, including all staffing, equipment, data collection (outsourced or in-house), field travel, quality assurance *etc*.
- There should be clear job descriptions for the various activities, and a career path for those in the unit.
- There should be a continual training and development program (and budget) for staff to deal with staff turnover and re-training where necessary. This should potentially include Master's or other post-graduate degrees which will increase the attractiveness of working in this area.
- Jobs should be filled with appropriately qualified personnel, experienced with RMS, having good technical and management skills, and with access to and control over their budget.
- Job responsibilities should explicitly include:
    - Management of the Road Network Referencing System – control, verification, education and dissemination to other stakeholders.
    - Data Collection – planning, management, supervision and coordination.
    - Data Quality Assurance – verification and checking of all data.
    - Management Reporting – reporting and presentations to management.
- Strong contract management skills are necessary especially for agencies that outsource any data collection.
- The agency should follow good basic management principles, covering procedures, records, auditing *etc*.
- There should be a commitment to Continual Quality Improvement.

## Technology

RMS are demanding with regard to their IT requirements. It is important that the RMS implementation should fit within the overall IT strategy of the agency, and should be properly supported from an IT perspective.

- Terms of Reference should explicitly reflect the IT support in the agency, they should not implement a system in isolation from the agency's IT strategy. If necessary, assistance must be provided to define an IT strategy and to implement it.
- Road agencies should consider outsourcing / external hosting of their systems where possible, given their local environment and according to their overall organizational policies.
- Any sizeable organization procuring IT should have a Technology Architecture, or explicit technology standards and directions. This is important to avoid a profusion of different infrastructure software (operating systems, databases, GIS *etc*.) with all the attendant

support issues. It is also important in helping to define a replacement/upgrade strategy for hardware and software. There are also distinct economies of scale that can be achieved through centralized procurement of hardware and system software.

- All IT implementations should use commercial off-the-shelf (COTS) products wherever possible.
- For any future implementation of an RMS, a set of functional and technical requirements should be drawn up. Functional requirements should include the functions that the software should perform. From the wealth of experience available, it is relatively easy to determine generic functional requirements of an RMS to suit a road agency of a given size. Key functions that should be in any system are given in Table 5.4 on Page 30. Technical Requirements should describe the technology environment within which the RMS will fit (*ie* hardware, operating systems, databases, GIS, and other applications). This should relate to the agency's Technology Architecture.
- Agencies should develop and adhere to a long-term IT budget strategy that includes costs of hardware and software maintenance agreements (in addition to hardware replacement strategies). One of the comments from a case study in Rajasthan, India was "The system has not been upgraded since its initial installation (in 1996) and it shows its age. It was the first MS Windows-based version of this system and is not very user friendly". This is a classic case of what can happen if there is no long-term IT strategy.
- Terms of Reference requiring 'integration' other applications, such as HDM-4, with an RMS should be more precise, to raise client awareness of the issues. This will enable the consultant to get a clearer understanding of the client's needs prior to bidding.
- The real requirements for web-enabling of systems should be more carefully assessed, and explicitly stated in any Terms of Reference. The client also needs to make sure that their IT infrastructure (including hardware, systems software, databases and GIS) is able to support what they wish to do with a web-enabled system.

## Data Collection

Without reliable data sufficient to meet the needs of the user, the RMS will not succeed. For this reason, it is vital that the data collection equipment and approaches be tailored to the capacity of the road agency. In too many instances the initial RMS implementation collected too much data, at too high a level of detail, and this was not sustainable in the long-term either from a staffing or budget perspective. For this reason it is important that:

- Only the key data that are required for use in decision-making should be collected and stored in the RMS.
- Data should be collected at the minimum level of detail with the most appropriate data collection technology given the constraints and capabilities of the agency.

- Data collection policies and procedures need to be formalized and should be readily available.
- If the agency has concerns about operation and maintenance of specialist data equipment in-house, then consideration should be given to outsourcing of the relevant surveys. However, it must be recognized that for outsourcing to succeed there needs to be strong management and quality assurance of the contractor.
- Strict data quality assurance procedures should be adhered to so that all system users have confidence in the data and analyses provided to them. There should be liquidated damages clauses when using outsourced data collection to help ensure quality data.
- GIS data needs to be managed in a more detailed manner than other road data since it is likely to be used by many parties outside the road agency.

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# 9 Index

# Annex 1: Summary of Key Recommendations

This annex summarizes the key recommendations from the main text of the report.

## Processes

- **Funding:** Have annual budgets in place for data collection and operation of the RMS. Even if this initially requires donor funding support, there should be a phased increase in local budgeting to ensure that the RMS is self-funding within a given timeframe.
- Introduction of an RMS by itself is not a guarantee that it will be used, or that it will be successful. The agency must also follow basic asset management principles. Strong involvement of executives and managers prior to and during the implementation of the system is ***absolutely necessary***.
- Clear and explicit RMS planning and programming cycle/schedule developed with clear deadlines of and correlation between main tasks
- Annual Reports/Business Plans should be prepared, using 'Asset Value' and other Key Performance Indicators derived from the RMS. This is an executive and managerial responsibility. It also helps put focus on the RMS itself, since it provides the data and improves the chances that budget and funds are available to run the system.
- Institutional support consisting of high ranking decision-makers fully-committed to the asset management/asset preservation 'philosophy'.
- Regular briefings should be given to ministers and other high government officials on the importance of asset preservation, and what is being done to make sure that the preservation of the road infrastructure is dealt with satisfactorily.
- Have specific and realistic key performance indicators, targets to measure asset value and to preserve/enhance that value. Monitor those targets, and assess at the end of each year whether they have achieved them or not, and take appropriate action. By publishing this information in Annual Reports, they are accountable to it.
- Have policies and procedures in place for data collection, and for quality assurance of that data.
- Technical (internal and/or external) auditing must be carried out on data and systems, and the recommendations acted on.
- A program of Continual Quality Improvement is also critical. No system is static. All systems can be improved.

## People

- There should be an organizational unit established with specific responsibility for the RMS.
- There should be a budget for the operation of the system, including all staffing, equipment, data collection (contracted or in-house), field travel, quality assurance etc.
- There should be clear job descriptions for the various activities, and a career path for those in the unit.
- There should be a continual training and development program (and budget) for staff to deal with staff turnover and re-training where necessary. This should potentially include Master's or other post-graduate degrees which will increase the attractiveness of working in this area.
- There should be training materials available. For bespoke systems the copyright should reside with the agency.
- Jobs should be filled with appropriately qualified personnel, with good management skills, and with access to and control over their budget.
- Job responsibilities should explicitly include:
  - Management of the Road Network Referencing System – control, verification, education and dissemination to other stakeholders.
  - Data Collection – planning, management, supervision and coordination.
  - Data Quality Assurance – verification and checking of all data.
  - Management Reporting – reporting and presentation to management.
- Strong contract management skills are necessary, especially for agencies that contract out portions of data collection.
- The agency should follow good basic management principles, covering procedures, records, auditing *etc*.
- There should be a commitment to Continual Quality Improvement.

## Information Technology

- There should be an IT Division.
- TORs should explicitly reflect the IT support in the agency, they should not implement a system in isolation from the IT strategy of the agency. If necessary, assistance must be provided to define an IT strategy and to implement it.
- Road agencies should consider outsourcing / external hosting of their systems where possible given their local environment and according to their overall organizational policies.
- Any sizeable organization procuring IT should have a Technology Architecture, or explicit technology standards and directions. This is important to avoid a profusion of different infrastructure software (operating systems, databases, GIS *etc.*) with all the attendant support issues; it is also important in helping to define a replacement / upgrade strategy for hardware and software. There are also distinct economies of scale that can be achieved through centralized procurement of hardware and system software.
- All IT implementations should use commercial off-the-shelf (COTS) products wherever possible.
- For any future implementation of an RMS, a set of functional and technical requirements should be drawn up. Functional requirements should include the functions that the software should perform. From the wealth of experience available, it is relatively easy to determine generic functional requirements of an RMS to suit a road agency of a given size. Key functions that should be in any system are given in Table 5.4 on Page 34. Technical Requirements should describe the technology environment within which the RMS will fit (*ie* hardware, operating systems, databases, GIS, and other applications). This should relate to the agency's Technology Architecture as discussed on Page 30.
- Terms of Reference requiring 'integration' other applications, such as HDM-4, with an RMS should be more precise, to raise client awareness of the issues, and will enable the consultant to get a clearer understanding of the client's needs prior to bidding.
- Agencies should develop and adhere to a long-term IT budget strategy that includes costs of hardware and software maintenance agreements (in addition to hardware replacement strategies). One of the comments from a case study in Asia was "*The system has not been upgraded since its initial installation (in 1996) and it shows its age. It was the first MS Windows-based version of this system and is not very user friendly*". This is a classic case of what can happen if there is no long-term IT strategy.

(Continued)…

- The real requirements for web-enabling of systems should be more carefully assessed, and explicitly stated in Terms of Reference. The client also needs to make sure that their IT infrastructure (including hardware, systems software, databases and GIS) is able to support what they wish to do with a web-enabled system.

## Data Collection

- Data collection equipment and approaches should be tailored to the capacity of the road agency.
- Only the key data that are required for use in decision-making should be collected and stored in the RMS.
- Data should be collected at the minimum level of detail with the most appropriate data collection technology given the constraints and capabilities of the agency.
- Data collection policies and procedures need to be formalized and should be readily available.
- If the agency has concerns about operation and maintenance of specialist data equipment in-house, then consideration should be given to outsourcing of the relevant surveys.
- Outsourcing surveys requires strong management and quality assurance of the contractor. There should also be liquidated damages in the contract in the event the contractor fails to provide quality data in a timely manner.
- Key principles for data collection contracts should be included in Terms of Reference.
- Strict data quality assurance procedures should be adhered to so that all system users have confidence in the data and analyses provided to them.
- GIS data needs to be managed in a more detailed manner than other road data since it is likely to be used by many parties outside the road agency.
- Continual improvement is necessary on all aspects of data collection, quality assurance, and data management.

## Key Functional Requirements for an RMS

- Terminology and Local Language. All screen labels, menu items, and reports should be configurable to the client conventions in the local language.
- Road Network Referencing. Different network referencing schemes should be supported. These should include linear distance from the start of the road section, linear distance from the start of a road, as well as distance from known location referencing points.
- Road Network Numbering Rules and Conventions. Network Numbering Schemes particular to the client should be able to be enforced by the RMS.
- Network Editing. Should permit splitting and joining of road sections, also modification of road section lengths, while preserving integrity of all data stored against the affected sections[18].
- Network Auditing. Any changes to the road network definition should be audited, and the RMS should allow review of these changes.
- Multi-Media Storage and Display. Should allow storage and display of multi-media objects (*eg* photographs, video clips etc.) as attributes of inventory items.
- User-Defined Items and Attributes. Should allow the user from the GUI (Graphical User Interface) to define the types of inventory / condition data to be stored, and to define what attributes are to be stored against each type of inventory. There should be no restriction on the number and type of items or their attributes.
- Data Level Security. Allow security setup so that users may only have update privileges for sub-networks in different geographical or administrative areas. Also, for different users to have different levels of access depending on the type of data.
- Function Level Security. Allow security setup so that different users may have access to different application modules.
- Staging Area for Data Loading. Should permit data to be loaded into a temporary staging area for verification of data, prior to making it available to other users within the application.
- Reporting. Reporting should be flexible, and the interface must enable the user to define his own reports from the GUI without reprogramming of the application.

(Continued)…

[18] This is one of the most often overlooked features of RMS and can lead to excessive maintenance efforts by the agency. Roads change over time and the system must be designed to automate the process of maintaining and updating the data to a very high degree.

## Key Functional Requirements for an RMS

- Integration with GIS. The RMS should integrate with GIS to allow display of inventory and condition data against maps of the road network. The exact type and method of integration can vary widely, from embedded GIS in the application front-end, to simple ability to export data for manipulation in an external GIS.
- Automatic Sectioning. An automatic sectioning function to collate and summarize data for analytical purposes. The user should be able to define the sectioning criteria using any of the key inventory or condition data.
- Data Transformations. Sectioned data need to be transformed to the automatically generated sections using different criteria.
- Trend Analysis. Should allow production of reports/graphs showing trends in average condition (or any attribute of any database item) over time, for part of a section, a whole section, part of a route, or a whole route.
- Template Survey Forms. Should allow production of template forms for use by the client for performing surveys. These template forms should be based on actual network inventory.
- Schematic Line Diagrams. Should allow production of schematic line diagrams showing selected sections and inventory items with selected attributes.
- Purging of Data. Should allow purging of historical inventory and condition data to an archive database, and subsequent retrieval of that data if required.
- Audit Trail. All data changes should be audited, including time of change, username responsible for making the change, and value of previous data item.
- Application Programming Interface. Allow other applications to retrieve data from the RMS via a programming interface. Ideally this should not take place through direct database access.
- Other Asset Inventory. Should permit storage of, or cross-references to, other major assets such as bridges and other structures. If bridges and other structures can be accommodated, then all above functional requirements should also apply to these assets.

## Key Points for Implementation of a GIS

- Agree to the policies, standards and accuracies with internal stakeholders and with external stakeholders from other relevant agencies. Mapping data is much more likely to be shared, *and* taken out of context, than most other road data.
- In particular, agree on policies for updating the geographic representation of the road network, taking into account whether the agency has the ability to collect its own GPS data, or whether it needs to hire GPS contractors. There is also the possibility of getting road construction contractors to provide as-built drawings and/or GPS coordinates of new roads, although this does not help in the case of road conversions.
- Metadata [19] standards should be agreed on and implemented.
- Data quality standards should include data cleanup procedures, snapping of lines, closing of polygons *etc*. as well as domains of values for attribute data.
- Consideration should be given to versioning of data to allow historical spatial analysis.

[19] Metadata provides information about the content, quality, condition, and other characteristics of data.

## Basic Principles For Data Collection Contract Management

- Require the contractor to survey a validation network (minimum 100 km) prior to the full survey. This will help the contractor to sort out logistical and technical issues early on and before the full survey commences. This validation survey data should be completely processed and imported to the RMS where it is verified as suitable. This will (i) confirm that the data processing steps are in place to use the data, and, (ii) ensure that the client can review the submitted data on a timely basis.
- Require every data collection team of the contractor to perform the validation survey. If there are different teams, different vehicles, and different equipment, then all should be tested.
- Require the contractor to produce his own Quality Assurance Plan prior to the start of the contract. This should be approved by the client.
- It may also be useful to ask for the Contractor's Quality Assurance Plan as part of the proposal, and include evaluation of the Quality Assurance Plan in the technical evaluation.
- Require documentary evidence of calibration prior to, and during, the surveys.
- Require data to be *submitted* within a short time period after collection (less than 2 weeks if possible, and certainly not more than 1 month).
- Pay only for data approved, not for time, and not for data submitted. It will be necessary to agree upon the time-frame for approving data (usually 30 days or less) and to ensure that the client's staff are allocated sufficient time to check the data.
- Have a liquidated damages clause in the contract which can be used in the event of late submission or continued submission of poor quality data.

# Annex 2: Project Proposal and Terms of Reference

*This annex contains the terms of reference for the project.*

# Project Proposal

*The project proposal as approved by TRISP.*

**Title:** Success Factors for Implementing Road Management Systems

**Bank team leader:** Christopher Bennett

**Objectives:** The Bank has supported the implementation of road management systems in a number of different countries. While some have been successful and are used for the ongoing planning and prioritization of road investments, others have been expensive failures. The systems have not been sustained in spite of large investments of time, training and consultant funds. The objective of the project is to review a range of projects in different countries and to determine what were the factors that led to the systems being successfully implemented. At the same time, projects which were not successfully implemented will be considered. The output will guide those implementing projects to help ensure a positive outcome.

**Primary Audience:**

There are three groups who would find the document useful: (a) our client governments. They would be informed of the what policy and institutional factors need to be addressed in implementing road management systems, as well as technical issues. (b) Consultants who execute projects would have a set of core expectations that they would need to meet in delivering a system. (c) Task Managers and other Bank staff who are preparing projects would have key elements to be included in TORs as activities to maximize the likelihood of success.

**Deliverables/Format of knowledge product:**

The output will be a report which has the following components.

(A) **Institutional Factors**. This would cover the institutional factors necessary for successful implementation of road management systems. This covers aspects such as policies, staffing, skill mixes, use of outsourcing, *etc*.

(B) **Technical Factors**. Technical issues that need to be in every project to ensure success. For example, many systems are designed to work with existing roads but cannot easily handle new roads or changes to alignments.

(C) **Data Issues**. How to ensure that the data requirements are tractable.

(D) **Case Studies**. Some case studies of successful, and not so successful, projects.

(E) **Terms of Reference**. A sample Terms of Reference for a road management system.

**Justification - Knowledge/Learning Needs this Supports:**

Institutional strengthening is a key element of many Bank projects. In the road sector, the implementation of road management systems which offer objective analyses using data to determine investment priorities are one area that the Bank has been stressing. At the time of writing we have at least six road management system projects underway, or just starting, in China; two in Vietnam; one in Pakistan. Unfortunately, our track record of ensuring the success of these projects is not good and many high profile projects (such as the 4 States PMS in India) have fallen by the wayside. It is important to learn the lessons of these projects and to use the experiences to develop better Terms of Reference and offer guidance to Consultants.

**Methodology/Approach (including source of primary material):**

The approach will be as follows:

1. Identify countries to focus on. It is proposed to include China, India, Indonesia as well as countries in Africa and Latin America.
2. Identify projects in these countries which were both successful and unsuccessful.
3. Visit the agencies and through dialog learn what were the factors in the success and failure of the projects.
4. Combine that information with other experience from developed countries to prepare the recommendations.
5. Development of guidelines and ToR along with refinement based on feedback.

**Timing:**

8 months from start of project to complete first draft.

**Inputs and Budget:**

Team Leader – 3 man weeks
Researchers – 5 man-months
Other inputs from Bank and Consultants

# Principal Consultant

*The Principal Consultant had the primary responsibility for executing the project. He was supported by other consultants who conducted the field surveys.*

**Project Name:** P093595 - Success Factors for Implementing Road Management Systems

**Consultant Name:** Kevin McPherson

**Bank team leader:** Christopher Bennett

**Project Objectives:** The Bank has supported the implementation of road management systems in a number of different countries. While some have been successful and are used for the ongoing planning and prioritization of road investments, others have been expensive failures. The systems have not been sustained in spite of large investments of time, training and consultant funds. The objective of the project is to review a range of projects in different countries and to determine what were the factors that led to the systems being successfully implemented. At the same time, projects which were not successfully implemented will be considered. The output will guide those implementing projects to help ensure a positive outcome.

**Consultant's Activities:**

The approach will be as follows:

1. The consultant shall spend several days in Washington D.C. and meet with individuals at the Bank who involved with road management. On the basis of these meetings, in consultation with the Bank the consultant shall Identify countries to focus on. It is proposed to include China, India, Indonesia as well as countries in Africa and Latin America.
2. The consultant shall identify projects in these countries which were both successful and unsuccessful based on the Bank's Implementation Completion Reports and discussions with Bank staff.
3. The consultant shall design a survey framework to gather key information on the projects to assess the success/failure factors. This framework shall be agreed on with the Bank.
4. Visits will be arranged the agencies and through dialog learn what were the factors in the success and failure of the projects. It is anticipated that there will be several sub-consultants involved due to the wide geographical spread of the work. The consultant shall identify these individuals/firms and establish terms of reference for them. They will be contracted directly to the Bank but the consultant shall be responsible for the performance and quality of deliverables.
5. The consultant shall combine that information with other experience from developed countries to prepare the recommendations.

6. The consultant shall prepare a draft report which will be circulated for comment. The final guidelines and sample ToR will be prepared based on feedback.

**Deliverables:**

The output will be a report which has the following components.

(A) **Institutional Factors**. This would cover the institutional factors necessary for successful implementation of road management systems. This covers aspects such as policies, staffing, skill mixes, use of outsourcing, *etc*.
(B) **Technical Factors**. Technical issues that need to be in every project to ensure success. For example, many systems are designed to work with existing roads but cannot easily handle new roads or changes to alignments.
(C) **Data Issues**. How to ensure that the data requirements are tractable.
(D) **Case Studies**. Some case studies of successful, and not so successful, projects.
(E) **Terms of Reference**. A sample Terms of Reference for a road management system.

# Consultants for Conducting Surveys

*Under the management of the Principal Consultant, other consultants were used to conduct surveys of agencies in different parts of the world which could not be conveniently or efficiently visited by the Principal Consultant.*

**Project Name:** P093595 - Success Factors for Implementing Road Management Systems

**Bank team leader:** Christopher Bennett

**Project Objectives:** The Bank has supported the implementation of road management systems in a number of different countries. While some have been successful and are used for the ongoing planning and prioritization of road investments, others have been expensive failures. The systems have not been sustained in spite of large investments of time, training and consultant funds. The objective of the project is to review a range of projects in different countries and to determine what were the factors that led to the systems being successfully implemented. At the same time, projects which were not successfully implemented will be considered. The output will guide those implementing projects to help ensure a positive outcome.

**Background:** The lead consultant, Mr. Kevin McPherson, is responsible for preparing the report. He has designed a survey framework to gather key information on the projects to assess the success/failure factors. Visits will be arranged, both by the lead consultant and sub-consultants, to identified agencies and through dialog learn what were the factors in the success and failure of the projects. The lead consultant shall combine that information with other experience from developed countries to prepare the recommendations. It is anticipated that the report shall contain the following information:

(A) **Institutional Factors**. This would cover the institutional factors necessary for successful implementation of road management systems. This covers aspects such as policies, staffing, skill mixes, use of outsourcing, *etc*.

(B) **Technical Factors**. Technical issues that need to be in every project to ensure success. For example, many systems are designed to work with existing roads but cannot easily handle new roads or changes to alignments.

(C) **Data Issues**. How to ensure that the data requirements are tractable.

(D) **Case Studies**. Some case studies of successful, and not so successful, projects.

**The Assignment:** This assignment consists of visiting [*a number of*] agencies in [*several countries*] (to be identified). You will be briefed by the lead consultant and provided a copy of the survey questionnaire. You will then visit the identified agencies and spend approximately 1-2 days at each agency discussing the issues arising from their road management system implementation. You shall write up the results of each visit and provide the information necessary to the lead consultant for him to prepare the report.

**Timing:**

The estimated input is [*to be defined*] man-days. Travel costs will be billed separately at cost. You are expected to start as soon as possible and complete the work to meet the reporting deadlines for the project.

# Annex 3: Questionnaire Used in Surveys

*This annex contains the questionnaire used by the consultants in the survey of road agency experience with RMS.*

## BACKGROUND INFORMATION

If possible, please give all answers for highways only, or indicate a % total spent on non-highways.

### Type of Organization

Please check appropriate box(es)

| National | Regional | District |
|---|---|---|
| | | |

| Governmental | Quasi-Governmental | Commercial |
|---|---|---|
| | | |

| Highways Only | Other Public Works (as % of total budget) |
|---|---|
| | |

### Infrastructure Managed by the Organization

| **Type of Infrastructure** | Highways (km) | Urban Roads (km) |
|---|---|---|
| Paved roads | | |
| Unpaved roads | | |
| Other roads managed | | |
| Other public roads | | |

| | Number | Approx Length (m) |
|---|---|---|
| Bridges | | |

### Number of Employees

| Permanent | Temporary | Seasonal | Total |
|---|---|---|---|
| | | | |

### Decentralization of Functions

Please check appropriate boxes

| Level / Functions | Planning | Design | Construction | Supervision |
|---|---|---|---|---|
| National | | | | |
| Regional | | | | |
| District / Local | | | | |
| Other | | | | |

## Total Annual Budget for Last Year

| Financial Year Period | Budget | Currency |
|---|---|---|
| | | |

# ORGANIZATIONAL ENVIRONMENT

## Fund Sources

Please indicate the main sources of revenue, with percentages if possible indicating source of funding:

| | Check or % |
|---|---|
| Road User Licences | |
| Road User Tolls | |
| Fuel Tax | |
| National Budget Allocation | |
| Others (please specify) | |

## Dedicated Road Fund

| | Yes | No |
|---|---|---|
| Is there a dedicated Road Fund? | | |

| If *Yes*, how is the Road Fund administered? |
|---|
| |

## Funding Levels

Please give actual Funding Levels for Road Construction and Asset Preservation / Maintenance for the past 5 years. (Note: please provide this in *actual* terms).

| | New Construction | Asset Preservation / Maintenance |
|---|---|---|
| Current Year | | |
| 2004 | | |
| 2003 | | |
| 2002 | | |
| 2001 | | |
| 2000 | | |

## Road Board

| | Yes | No |
|---|---|---|
| Is there a Road Board? | | |

| |
|---|
| When was the Road Board established? Year: |

| |
|---|
| What are the functions of the Road Board?<br><br>[*In particular, does it have Executive or Administrative powers? Is it fully operational? Does it require data and justification from the Highway Department before approving the programs? Also, please get the composition of the Road Board, including its chairman*]. |

# HUMAN RESOURCES

## Retention of Staff

| | Yes | No |
|---|---|---|
| Is retention of staff a problem in your organization? (Particularly for Planning, Engineering and IT functions) | | |

| | % |
|---|---|
| Approximate annual rate of staff turnover for the organization?<br><br>If possible, please break this down into<br><br>Engineering<br>Planners<br>IT Staff | |

If Retention of Staff is a problem, what are the main reasons:

| | Yes | No |
|---|---|---|
| Salary levels | | |
| Civil Service regulations | | |
| Others (please specify): | | |

| |
|---|
| Have there been any major initiatives to address this, or are you considering special measures to deal with it?<br><br>*[E.g. Do they hire consultants (local or otherwise) to help in production of plans and programs, and/or to manage the IT environment.]* |

## Staff Training

Please check appropriate box

| | 0 - 5 | 6 - 10 | 11 - 16 | 16 -20 | 20+ |
|---|---|---|---|---|---|
| On average, how many days of each employee's time are devoted to training every year? | | | | | |

## PLANNING

## New Construction Versus Asset Preservation

| | % of Annual Budget |
|---|---|
| What % of annual budget is spent on new construction? | |
| What % of annual budget is spent on preservation / maintenance of existing assets? | |

## Prioritization of Maintenance Needs

| |
|---|
| How do you prioritize and calculate the costs of Preventive maintenance needs? Please describe briefly the overall process. (Note: actual computer systems / road management systems are discussed later). |

## Percentage of Needs Usually Met by Government

| |
|---|
| On average, what percentage of the total needs are usually met by Government? If possible, please give figures for previous 5 years and, if possible, compare the costs of these needs versus the total Funding Levels given in B.3. |

# ROAD MANAGEMENT SYSTEM

## Road Management System Technical Description

| | Yes | No |
|---|---|---|
| Do you use a computerized Road Management System? | | |

If *Yes*, please give brief technical description (name of system, functionality, technical architecture – database, GIS, web-enabled etc.)

[*If possible, please try to get a copy of any System Overview diagram and/or User Manuals. Electronic copies preferable.*]

If *No*, please give description of how they make their investment decisions.

## Road Management System Implementation

Was the Road Management System purchased off-the-shelf? Or did a Consultant develop it as part of an implementation project?

| | Start Year | End Year |
|---|---|---|
| Please specify the duration of the Project | | |

## Use of Computer Models

To what extent do the results of any computer models get directly used in the Annual Work Program?

*[We are trying to determine whether the planning / programming systems are really being used and feed directly through to the Annual Work Program in a systematic manner. Even if they undergo some sort of socio-political analysis prior to the production of the plan, at least there should be a systematic method and record of decisions made].*

## Hit-Rate Analysis

Is any Hit-Rate analysis performed on the Preventive Maintenance Program?

*[Try to get a feel for whether they have done "hit-rate" analysis (in other words, have they checked that the results of the models they are using reflect the real condition of the road network). Are they able to produce statistics on comparison of say previous year's modeling results versus actual conditions this year?]*

## Users of the Road Management System

| | Office | No of Users |
|---|---|---|
| Please list the offices that use the Road Management System, and approximate number of users. | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| Total | | |

## Overall Responsibility

Which Organizational Unit has overall responsibility for managing / promoting the Road Management System within the organization?

### Detailed Responsibility for Management of the RMS

| |
|---|
| How many staff are in the Organizational Unit specified in 0 above? What are their Roles and/or Job Descriptions?<br><br>[*Please try to get copies of their roles and/or job descriptions to see whether they have separate people responsible for network referencing, contracting of data collection, roughness specialists, GPS specialists, etc.]* |

## Other Applications

| |
|---|
| Are there any other applications / systems operating in your organization that use data from the Road Management System? Please specify and give brief details.<br><br>[*This helps to determine whether the database is integrated with other computer systems in the Agency, or whether it is simply seen as a planning tool for use by the Planning Division. An accurate road inventory has potential uses in many other applications, and potentially the more uses and users of the data, the more pressure there is to keep it up to date*]. |

## Consultant Team Composition

| | Yes | No |
|---|---|---|
| a) Was there an expatriate Consultant team involved? How many technical staff? | | |
| b) Were there local Consultants involved? Please indicate approximate percentage of time for expatriate and local technical staff. | | |
| c) Were the local Consultants retained after the original implemented was completed? | | |

## Maintenance and Support - Software

| | Yes | No |
|---|---|---|
| a) Is there an Agreement in place for continued support and maintenance of the software? | | |

| |
|---|
| b) If so, what is the approximate annual cost as a percentage of the original software price? |

| |
|---|
| c) How is the support funded? Internally, or through a Lending Agency? |

| |
|---|
| d) When was the software last updated? |

| |
|---|
| e) How is maintenance and support provided (e.g. e-mail, telephone, supplier staff visits to the client)? How effective is it? |

## Maintenance and Support – Hardware

| | Yes | No |
|---|---|---|
| a) Is there an Agreement in place for continued support and maintenance of computer hardware? | | |

| |
|---|
| b) If so, what is the approximate annual cost? |

| |
|---|
| c) How is the support funded? Internally, or through a Lending Agency? |

## Maintenance and Support - Consultancy

| | Yes | No |
|---|---|---|
| a) Is there any provision for annual Consultancy support? | | |
| b) If so, has the Consultancy component been used? Has it been successful? Please describe briefly.<br><br>[*Duration / financing / any problems with continuity of consultant staffing etc. Try to determine whether it was successful or not in really moving the system forward, or just resurrecting it. There should be a Consultant report at the end of such work, please try to get a copy of the report and / or recommendations*] | | |

## Expansion of the System

Has there been any significant expansion of the use of the Road Management System since it was first implemented? Please give details.

[*Significant expansion, in terms of number of uses, new offices connected, possible Road Board connection etc. would show pro-active attempts by the agency to make it successful and to drive it forward. On the other hand, no expansion is an indication that no-one looking to drive it forward or expand the use of the data and the capabilities of the system]*

## Original Training in the Road Management System

Approximately how many days of training per staff member was given on operating the Road Management System during its initial implementation?

No of Days:

How many staff were originally trained in the operation of the system, and approximately what percentage still remain in their original positions?

## On-Going Training in the Road Management System

Does the Organization run any in-house training courses for use of the Road Management System? Who is responsible for delivering such training? Is there an Annual Training Program for new staff members, or for members who have perhaps transferred from other divisions / offices?

[*Please ask for evidence. E.g. if they have any statistics showing number of staff trained after the Consultant has left, or even a brochure of their annual training program showing a calendar entry for RMS training etc*]

## Satisfaction with the Road Management System (Detailed)

Please rate the following features of the Road Management System by placing an X in the appropriate box:

| | Not supported | Supported to some extent, but difficult or unfriendly, or does not do everything we wish | Good support, but still some areas we have identified that we would it to cover, or wish it could be implemented better | Excellent support – no areas that do not fulfil or exceed our requirements |
|---|---|---|---|---|
| a) Support to the overall Planning and Programming Process | | | | |
| b) Ability to cope with changes to our road network referencing system (e.g. additions of new roads, splitting of sections etc.) and to report on historical changes to the network | | | | |
| c) Ability to change the road classification system | | | | |
| d) Ability to store all existing data that we collect | | | | |
| e) Support for multi-media (text, photographs, video etc.) | | | | |
| f) Ability to add new data items and attributes without modifying the code / internal database structure | | | | |
| g) Support for GIS (Geographic Information Systems), including integration with any other GIS in the agency | | | | |
| h) Reporting (including ability to add new user-defined reports, export to standard spreadsheet packages etc.) | | | | |
| i) Reporting on trend data (e.g. condition of same road section over time) | | | | |
| j) Ability (or at least easy-to-follow procedures) for archiving of data | | | | |
| k) Application Programming Interface for potential integration with other applications. | | | | |
| l) Potential for operation in stand-alone scenarios (e.g. in remote offices with no or occasional network connection) | | | | |
| m) Data Security features – ability to apply security by type of data or geographically | | | | |
| n) Functional Security features – ability to apply security to different functions of the system (e.g. changes to the road network, changes to attribute definitions) | | | | |

## Satisfaction with the Road Management System (Overall)

[*Different users may have different opinions. Please try to ask the following questions of a range of different users in the organization, as identified in box E.5* ]

| |
|---|
| a) Are there any issues with the system itself? |

| |
|---|
| b) Do you keep a record of Maintenance / Enhancement Logs for the system (i.e. bugs and errors, as well as things that you would like to see added to future releases)? Are these successfully addressed by the support and maintenance agreement? Can we see the current list of issues and issues that may have been addressed in the past? |

| |
|---|
| c) Are there any plans to extend the system, or extend the use of the system to other offices? |

| |
|---|
| d) If there were plans to extend the system, would the client require original consultant assistance, or local consultant assistance? Both? Neither? |

| |
|---|
| e) Is the source code available to the client? (Normally, this should be available for systems developed on behalf of the client by a consultant) |

| |
|---|
| f) Would future expansion require external funding, or would the agency be able to fund it internally? |

| |
|---|
| g) Is the system extensible / expandable for future needs?<br><br>[*May be difficult to answer – may need to prompt them for example, if they decided to start collecting say structural pavement data, if it could be accommodated easily into the database without programming effort].* |

| |
|---|
| h) Overall satisfaction with the system – on a scale of 1 (completely unsuited to needs) to 10 (fulfils all current and anticipated future requirements)? |

# DATA COLLECTION

## Road Inventory Surveys

When was the last full Inventory Survey performed?
Year:

| | Method (In-house, Contractor) | Equipment (if any) | Cost |
|---|---|---|---|
| Inventory Survey | | | |

## Road Inventory – Items and Attributes

Can you supply a list of all types of Inventory Data collected (e.g. Surface Type, Carriageway Width, Culverts, Signs etc.) and their attributes?

[*This should be easily accessible to the client staff. If no-one can produce it easily, then it is an indication that no-one is taking responsibility for update of inventory data*].

[*Also, try to get a feel for whether all of the Inventory Items are actually used by anyone or by another system (such as a Routine Maintenance Management System), or whether they were collected as a one-off inventory with no actual usage.*]

## Road Inventory – Currency of Data

How up-to-date is the Inventory Data in the database? Are there clear policies / procedures for update of Inventory data? For example, what is the procedure for making sure that a change in the field (such as a road realignment, or a road conversion)?

[*Ask for a report from the system showing which Inventory data has been recently updated. Try to determine when the last update was made to the network (in terms of new sections, deleted sections, split sections etc)... Any road network would probably have an inventory change in the order of 2 – 3 % per annum. The system should be capable of showing dates of these types of change.*]

## Condition Data - Methods and Costs

Please indicate approximate annual budget, and the method of data collection, for the following activities.

| | Method (In-house, Contractor) | Equipment (if any) | Annual Data Collection Cost |
|---|---|---|---|
| Roughness Surveys (Network Level) | | | |
| Roughness Surveys (Project Level) | | | |
| FWD (Network Level) | | | |
| FWD (Project Level) | | | |
| Visual Road Condition | | | |
| Traffic Counts Network Level (Automated) | | | |
| Traffic Counts Network Level (Manual) | | | |
| Weighbridges / weighstations | | | |
| Road Centerline data (GPS, Surveys etc.) | | | |
| Video | | | |
| Others (please specify) | | | |
| Others (please specify) | | | |
| Others (please specify) | | | |

## Data Collection Equipment

Does the agency own any specialist Data Collection Equipment, e.g. Roughness Measuring Devices, FWD, GPS, Automated Traffic Counters, Video etc.?

[*Try to get a list of equipment, including make / model / age. Also indication of annual usage of the equipment].*

*[Also, very important – find out if there are any warranties on the equipment, any local support issues, how this is financed, and if the organization has successfully managed to get the equipment repaired or replaced spare parts recently].*

## Review of Data

Is it possible to review some data / reports from the Road Management System on any / all of the above (including Inventory data)?

[*Cursory examination of reports often determines whether the data are up-to-date or not, whether there is invalid data in the system (e.g. invalid IRI ranges), whether there is complete network coverage or whether it is only a small sample, etc. etc. Cross-validation of data sets (e.g. comparison of total length of paved network with total length of roughness) also gives an indication of whether there is complete survey data and rigorous checking on data entered.]*

## Quality Assurance

What Quality Assurance procedures are in place for ensuring the quality of data supplied?

[*There should be proper Quality Assurance Procedures Manuals for all of the above data. If there are none, or none to hand, then it is an indication that the data in the system may not be thoroughly checked. Please try to get copies of any manuals for Data Collection and/or Quality Assurance].*

## Satisfaction with Data

Are users generally satisfied with the quality of data (accuracy, timeliness etc.)?

[*There should be proper Quality Assurance Procedures Manuals for all of the above data. If there are none, or none to hand, then it is an indication that the data in the system may not be thoroughly checked and/or that users may not be satisfied with the quality of data].*

# INFORMATION SYSTEMS

## Organization

| | Yes | No |
|---|---|---|
| Is there a separate IT Division? | | |

If Yes, then:

| | |
|---|---|
| How many staff in your IT Division? | |
| How many vacancies in your IT Division? | |
| Has IT staff numbers increased over the last 3 years? | |

| | Please indicate the numbers of staff in each position |
|---|---|
| Junior Programmer | |
| Senior Programmer | |
| Analysts | |
| Hardware Support | |
| Software Support | |
| Data Administration | |
| Data Entry | |
| Other (please specify) | |

## Computing Environment

| | Client-Server | Stand-Alone PC |
|---|---|---|
| Please indicate your primary computing environment. | | |

## Computer Network

| | Yes | No |
|---|---|---|
| Do you operate a computer network? | | |

If Yes, then:

| | |
|---|---|
| What type of network is it (LAN, WAN, Leased Line, Dial-Up)? | |
| In which year was it installed? | |
| How many separate locations are connected? | |
| How many users are connected? | |

| | Regional | District | Local |
|---|---|---|---|
| Please indicate which types of office are connected. | | | |

## Major Applications

Please list briefly the major information systems being used in your organization:

| Name of Application | Main Purpose (e.g. Financial Management, Contract Management, Road Management, Bridge Management etc. ) | Developed By |
|---|---|---|
| | | |

## Information Technology Budget

| | |
|---|---|
| What is the average annual budget for IT over the past 3 years? (Please state amount and currency) | |
| What % is the IT budget of the total organizational budget? | |
| Who is responsible for budgeting of IT? | |

| | Please indicate a % of budget spent for each activity of your IT department |
|---|---|
| Hardware Maintenance | |
| Software Maintenance | |
| In-house development of new systems | |
| Purchase of off-the-shelf systems | |
| Data entry | |
| Data administration | |
| Other (please specify) | |

## Application Development

| | Please indicate the % of applications developed by each of the following groups over the last 3 years |
|---|---|
| In-house centralized | |
| In-house decentralized | |
| Consultants | |
| Off-the-shelf systems | |
| Other (please specify) | |

## Maintenance of Software Applications

| | In-House | Suppliers | Other (please specify) |
|---|---|---|---|
| Who maintains your applications? (Please check) | | | |

## IT Policy and Priorities

| |
|---|
| What position or level in the organization does the head of your IT department occupy (e.g. Director, Division Manager etc.)? |

## Internet and E-mail

| | Yes | No |
|---|---|---|
| Does your organization use Internet? | | |
| Does your organization use E-mail? | | |
| Does your organization have a Web page? | | |
| If Yes, please give the address: | | |

## Local IT Industry Capacity

| |
|---|
| a) Would a local IT Consultancy firm be able to develop / enhance / support the software? |

| |
|---|
| b) Would they able to design and implement methods of integrating the software with other applications in the Agency? |

| |
|---|
| c) Approximately how many local IT firms might be capable of providing the services discussed above? |