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Success Factors for Road Management Systems

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Over the last 20 years most road agencies have implemented some form of computerized road management system (RMS). The purpose of these systems is to assist the road 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.

This Note describes the different factors associated with 'successful' RMS implementations. It is a summary of the report 'Success Factors for Road Management Systems'. The full report is available for download from www.road-management.info.

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1 What is a Road Management System?

The major functions of the road management process can be categorized as:

- Planning;
- Programming;
- Preparation; and
- Operations.

A road management system (RMS) is concerned with road monitoring, planning and programming. Major activities include:

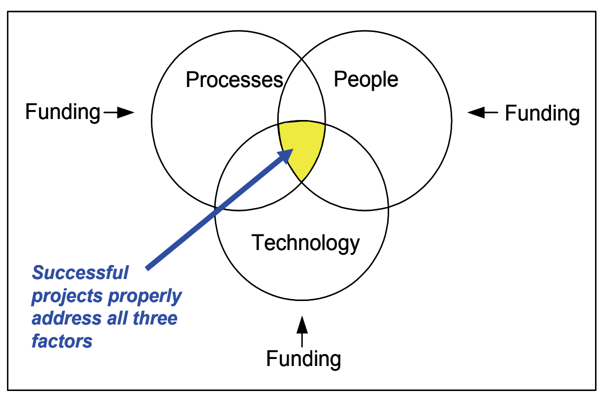
- Needs Assessment;
- Strategic Planning, including budgeting for development and asset preservation;
- Development, under budget constraints, of multi-year works expenditure programs; and
- Collection of Data. All of the above activities need data. Major data items include road inventory, condition,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

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 road planning and programming. Associated with the RMS are appropriate business processes to use the RMS to execute the business needs of the roads agency.

2 Processes, People and Technology

As shown in Figure 1, like any system, an RMS relies on three fundamental components: Processes, People, and Technology. There must also be a commitment to adequate funding. If any of these are lacking, the system will not be successful.

Figure 1: Processes, People, Technology and Funding



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. For an RMS to be successful, the importance of each component must be clear.

Executives and managers need to be demonstrably committed to the system, both in their relations with external stakeholders and internally in their agency through good management principles. Policies should explicitly state the goals and objectives of the organization in regard to road asset management, and procedures should detail exactly how the RMS will be used to achieve these goals.

Ideally, a separate organizational unit would have explicit responsibility for the system and data, and would be staffed with well-qualified and trained personnel who are pro-active in developing and expanding the system. 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*.

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

This note analyzes each of the key areas above, and identifies the factors that contribute to successful implementation of Road Management Systems.

3 Processes

The RMS must play an active role in the agency's business. This requires appropriate functionality, and ensuring that it fits into the organization's business processes.

3.1 The Annual Report/Business Plan

Most agencies have a statutory requirement to prepare an annual report or business plan. If the RMS contributes to this report, it will help ensure its sustainability.

The Annual Report 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.

- **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.

The RMS should be capable of supporting all of the above areas.

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 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.

3.3 Asset Value

'Asset Value' is an important concept in monitoring infrastructure. Agencies should have clearly defined goals and objectives to maintain or to increase asset 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·

Asset value can be measured relatively easily using data that is normally readily available within a road agency. This data includes inventory, condition, and cost 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.

3.4 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. 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.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 model.

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 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.

3.5 Implementation of RMS Programs

An indication of the role of the RMS in an agency is the degree to which the RMS 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.

All RMS would benefit from having a mechanism for monitoring the rate of program implementation.

4 People

4.1 Institutionalization

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 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.

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. Many countries outsource data collection, for a variety of reasons as discussed later. 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.

In addition, an agency should also have a set of training materials with which to train its own staff. Organizations often 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, but without development and handover of training materials, this cannot happen successfully.

4.3 Continual Quality Improvement

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.

Road 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 covered in this note—data collection, training, road network modeling, and hit-rate analysis.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.

5 Information Technology

5.1 IT Management

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.

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*.), hardware and software replacement, warranty and maintenance agreements, support *etc*.

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. Any in-house developers of applications can also concentrate on one database environment instead of multiple.

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 the organization. This will increase costs, and decrease efficiencies thereby influencing the likely success of any IT project, including 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;
- **Customization:** The time to develop new ideas may take longer, since the software supplier has a responsibility to existing clients; and
- **Cost:** Many agencies have difficulties in funding support and maintenance agreements[1].

A well-chosen COTS package from a good software supplier is **always** preferable to bespoke development. There are many such packages on the market in the areas of road and asset management as well as road planning. Some key features of these systems that should be included in any requirement or specification for RMS are given in Box 1.

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

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.

5.5 Functional Requirements for an RMS

Box 1 summarizes **some** of the key functional requirements for any RMS. A full list is given in McPherson and Bennett (2005). It should be noted that this 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 functions in Box 1 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.

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.

5.6 System Acceptance Testing

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. Few road 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. Formal acceptance tests reduce the possibility of bugs in the system, and can minimize any ease of use issues.

5.7 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 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 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.

Put simply, in the long term, support and maintenance agreements usually reduce the total costs of ownerships of systems.

[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.

Box 1
Some Key Functional Requirements for an RMS

- **Terminology and Local Language:** All Screen Labels, Menu Items, and Reports should be configurable to the local language and terms.
- **Road Network Referencing**: Different network referencing schemes should be supported.
- **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.
- **User-Defined Items and Attributes**: Should allow the user to define the types of 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.
- **Multi-Media Storage and Display**: Should allow storage and display of multi-media objects (*eg* photographs, video clips *etc*.) as attributes of inventory items.
- **Security**: Allow security setup so that different users may have access to different application modules and data activities.
- **Integration with GIS**: The RMS should integrate with GIS to allow display of inventory and condition data against maps of the road network.
- **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 any attribute of any database item over time.
- **Audit Trail**: All data changes should be audited, including time of change, username responsible for making the change, and value of previous data item.
- **Other Asset Inventory**: Should permit storage of, or cross-references to, other major assets such as bridges and other structures.

5.8 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 with data integrity. Recent literature has shown that 70% of all software development effort is now focused on systems integration.

Some 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.

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 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.

6 Data Collection

6.1 Introduction

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

Data are 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' (IQL). Bennett and Paterson, (2000) describe the IQL concept in detail.

However failure of the RMS due to 'data collection' is not seen as 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;
- There are no quality assurance procedures;
- 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 an RMS.

6.2 Location Referencing

The ability to manage data on road networks depends on an accurate and viable Location Referencing system. Most countries have in place some sort of linear referencing system, whereby roads (or sections) are uniquely identified, and where data are referenced to distance from the start of the section in a defined positive direction. Normally too, there is some system of kilometer posts or other distance markers which are fixed markers at known points on the section, which enables referencing of other items (*eg* traffic signs) as a relative distance from these markers. The ability to collect and report on data relative to those fixed markers is particularly important in helping field staff locate items of interest. Collection of data against those markers can also significantly reduce the cumulative error that can be built up if measurements are taken from the start of the section.

6.3 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.

The basic types of data 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.
- **Location 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 a GIS.

Policies for collection and update of these data 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 quality or detail, 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.

6.4 Data Collection Process

In terms of the process by which data are collected, there are essentially two choices an agency can make: to collect the data in-house or 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 may be 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 may have 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 countries use a specialist project with consultants or contractors to start the data collection, and during this time the agency's staff are trained in the use and operation of the equipment. After the project the staff continue the data collection.

Other agencies make a policy decision to completely out-source specialist surveys. Consultants or contractors who work full-time with the equipment, use 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 out-sourcing data collection was to reduce the ability of agency staff to manipulate data for their own purposes. If this approach 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.

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 below.

6.5 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 and accuracy and frequency of data collection).

QA on the client side is necessary irrespective of whether the data are collected in-house or not.

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.

Even agencies that have been contracting out 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 quality assurance procedures, including issuing multi-year data collection contracts with the same contractor to get continuity on the survey teams, as previous analyses had shown variations between consultants.

It should be noted that QA applies to the entire data collection and data reduction process. Road data are 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.

6.6 Data Collection Contract Management

Although it is recommended for some agencies to consider adopting policies to contract out data collection see 6.4 above), if such policies are adopted 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 neglected, are given in Box 2.

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.

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 are 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 and GIS skills.

Box 2
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 all sorts of 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.
- 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.

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 quality assurance 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 RMS projects 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 quality assurance 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 are 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 quality assure this data itself, then it should hire an independent contractor or consultant to do it on their behalf.

6.7 GIS Data Collection

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

Even for road network data (which is often the only spatial dataset that a road organization is responsible for), it is often difficult for a road agency to keep it current. 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 factors in Box 3 should be addressed regarding GIS data collection.

Box 3
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 are much more likely to be shared, and taken out of context, than most other road data.
- In particular, agree 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 standards should be agreed upon 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.

7 Conclusions

What makes an RMS successful? In addition to funding, there are three key factors: Processes, People and

Technology. If any of these are weak or fail then the RMS will be compromised.

Some agencies successfully consider all three factors, but many do not. The focus of too many projects is on the technology element, with insufficient attention given to the institutionalization of the system and the necessary support systems.

The major success factor in the implementation is therefore **institutionalization** (processes and people) rather than technology, although the latter is also important. It is essential to ensure that there are specific items in a Terms of Reference to deal with institutionalization, at the very highest level. Instead, the focus has usually been on technology. Too many Terms of Reference 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 is completely inadequate.

Project specifications and Terms of Reference 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, at present technology dominates.

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

7.1 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. 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 make sure 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 achieved them or not, and take appropriate action. By publishing this information in Annual Reports, the agency is accountable for 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 the RMS is self-funding within a given timeframe.
- 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.

7.2 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, including 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:

- 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.
- 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.

7.3 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 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 or external hosting of their systems where possible, but this depends on the technical capabilities of the private sector and the road agency's 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 McPherson and Bennett (2005). 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).
- 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.
- 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.

8 References

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