Experiences in Implementing New Maintenance Management Systems

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The Highway Development and Management Tool, HDM-4, was in the beta testing and pilot trial phase during 1998 and 1999. The Finnish National Road Administration (Finnra) has been testing the programs, with all early versions providing feedback for further development at the University of Birmingham. Now that Version 1.0 of the program has been released, Finnra's experts are using it in international projects in Europe, Asia, Africa, and Oceania. Two projects, which were conducted in totally different environments, are described and evaluated. Case 1 was carried out in Northwest Russia in 1999, in cooperation with local road authorities and consultants from Ramboll, DHV, SPEA, and Finnra. This pilot was one of the first carried out in northern freezing climates. Case 2, an ongoing Finnra project in Papua New Guinea, started in 1998. Its goal is to establish a road asset management system for the National Road Administration in Papua New Guinea. The project also includes road inventory surveys based on Global Positioning System and international roughness index measurements. The main output of Case 1 is a highway rehabilitation master plan (HRMP), which was prepared for attracting investors to participate in developing the road network in Northwest Russia. The main output for Case 2 is to inventory the road network, establish a road databank, establish a road asset management system with geographic information system, and create an HRMP for 5 years. These cases and all the phases of implementation of the new management system are evaluated. The most important goal of the projects is to ensure that local experts are fully capable of using the system. Training played an important role in every step, and training strategies were ambitious. The major lessons learned during the projects were as follows: (*a*) the time needed for implementation of a new system should not be underestimated; (*b*) quality of data is a key issue; (*c*) the need for personal contacts with local experts during the project is high; and (*d*) training should be organized in all phases of the project.

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The Highway Design and Maintenance Standards Model (HDM-III) developed by the World Bank has been used for more than two decades to combine technical and economic appraisal of road projects. The International Study of Highway Development and Management has been carried out to extend the scope of the HDM-III model and to produce the Highway Development and Management Tool (HDM-4).

The scope of this new tool has been broadened considerably beyond traditional project appraisals to provide a powerful system for the analysis of road management and investment alternatives in various technical, economic, and environmental circumstances, including cold climate areas, which were omitted from the previous versions of the HDM.

The analysis methodology in this project has followed HDM-4 project analysis. Project analysis is concerned with the evaluation of one or more road projects or investment options. The application analyzes each road link or section with user-selected treatments, with associated costs and benefits projected annually over the analysis period. Economic indicators are determined for the different investment options.

Project analysis is used to estimate the economic or engineering viability of road investment projects by considering the following issues:

- Structural performance of roads;
- Life-cycle predictions of road deterioration, road works effects, and costs;
- Road user costs and benefits; and
- Economic comparison of project alternatives.

The model simulates, year by year, the road condition and resources used for maintenance of each road section, under each strategy, as well as the vehicle speeds and physical resources consumed by vehicle operation. After physical quantities involved in construction, road works, and vehicle operation are estimated, user-specified prices and unit costs are applied to determine financial and economic costs.

Relative benefits against a base case (do nothing or do minimum) are then calculated for different alternatives, followed by net-present-value and rate-of-return computations. The sections can then be sorted by net present value of benefits or by internal rate of return to produce a ranking list of the most beneficial candidates for investments.

The benefits of maintenance are mainly accrued from improved road roughness, which is the main factor affecting vehicle operating cost (*1*).

CASE 1: NORTHWEST RUSSIA

Study Area and Main Objectives of the Project

Northwest Russia includes the regions of Arkhangelsk, Kaliningrad, Kirov, Leningrad, Murmansk, Novgorod, Pskov, and Vologda. It also includes the city of St. Petersburg and the republics of Karelia and Komi as well as the autonomous Okrug of Nenets. Northwest Russia covers about 10 percent of Russia, both its population and its territory.

The study area includes the oblasts of Arkhangelsk, Leningrad, Murmansk, Novgorod, and Pskov as well as the republics of Karelia and Komi. The major city in the area, St. Petersburg, situated in the eastern part of the Gulf of Finland with a population of 4.8 million, is not included in the study area, nor are the Kaliningrad and Kirov oblasts. The autonomous Nenets also is not included. The total study area is 1.7 million km^2 and has a population of 9.2 million (see Figure 1).

The main output of the pilot trial was a highway rehabilitation master plan (HRMP) for the federal and local road network of Northwest Russia, which was prepared for attracting investors to participate in developing the road network there. In the HRMP, the road projects were prioritized with the HDM-4 program. Prioritizing in HDM-4 was done in the project analysis part of the program. Project analysis is based on comparing the benefits

FIGURE 1 Study area map, population, and population density (Case 1).

and costs of an individual project. With this process every project has a benefit/cost ratio, and the priority list implements the most beneficial projects first. Outputs of the project were

- Systems and procedures for the collection, analysis, dissemination, and application of road-related data;
- Trained staff for these systems and databases;
- An assimilated highway management model, the HDM-4 program in Road Directorate 9 (RD9), and the subjects; and
- A regional highway rehabilitation master plan for 2000 and later.

Following is a list of detailed project activities: (*a*) review of road organization setup and current data collection methods, (*b*) identification of the significant road network and division of the network into sections, (*c*) development of a road traffic database for the road section data, (*d*) introduction and installation of HDM-4, (*e*) calibration of HDM for prevailing conditions, (*f*) data compilation and data quality control, (*g*) preparation of a highway rehabilitation master plan and support for an investors' conference, (*h*) reporting, and (*i*) training and knowledge transfer.

The HDM-4 work of the project consisted of the following phases. These phases basically are done in every process in which the goal is to produce a priority list of projects with a maintenance management system: (*a*) data collection procedures and data compilation, (*b*) data input, (*c*) road characteristics, (*d*) road condition data, (*e*) traffic data, (*f*) construction and maintenance history, (*g*) calibration, (*h*) training, (*i*) analysis, and (*j*) evaluation of results. These phases are described below.

Data

Data Collection Procedures

Data collection for HDM-4 was done with the assistance of regions and republics. The input of RD9 also was significant. Because the data collection from existing data was done in the winter, the new measurements were not carried out. Thus there is a need for new measurements in the future, when local authorities update the master plan. The submitted data consisted of compiled existing road condition and traffic information data, as well as road construction and maintenance history information when it was available. For the data not available, the road authorities in each subject drew current best estimates.

In a country where a road data bank (RDB) is already functioning, these data could be transferred directly from the RDB to HDM-4. If there is no RDB, it is possible to use the HDM-4 program as an RDB. It is vitally important that the road condition data and traffic information data be updated regularly because the outputs of any maintenance management system are based on basic data in the program. If the input data are not correct, the results are not usable. The process of data collection is illustrated in Figure 2.

Data Input

The HDM-4 experts of the project carried out the data input for the HDM-4 program. In the future, the concept is that local experts in the regions and republics will accomplish the data input. Data inputting was done manually because it was not possible to transfer the data directly from the RDB. The first phase of data input was sectioning of the road network for the HDM-4 program. This was done in every oblast and republic based on homogenous sections. When the sections were input to HDM-4, the road condition, traffic information, and construction and maintenance history information were input to every homogenous road section. The sections are specified by road name, road number, section address, and information on section nodes.

In selecting the section break points, the following guidelines were followed. A road was broken into sections in main intersections, where a major change in traffic volumes is possible. A section was further broken if the section seemed to become too long. In subjects, the number of sections varied from 41 to 120 (Murmansk, 41; Karelia, 60; Arkhangelsk, 118; Leningrad, 120; Pskov, 50; Novgorod, 60; and Vologda, 60).

After revision of sectioning, the total number of sections in the HDM-4 program was 678. The data were manually input into HDM-4 as they were submitted or as they were read from the database (excluding the roughness transformations). In the future, data retrieval should be developed to be as easy as making a query over an Internet connection.

Road Characteristics

To keep the data collection effort at a reasonable level, only the main road characteristics were requested from

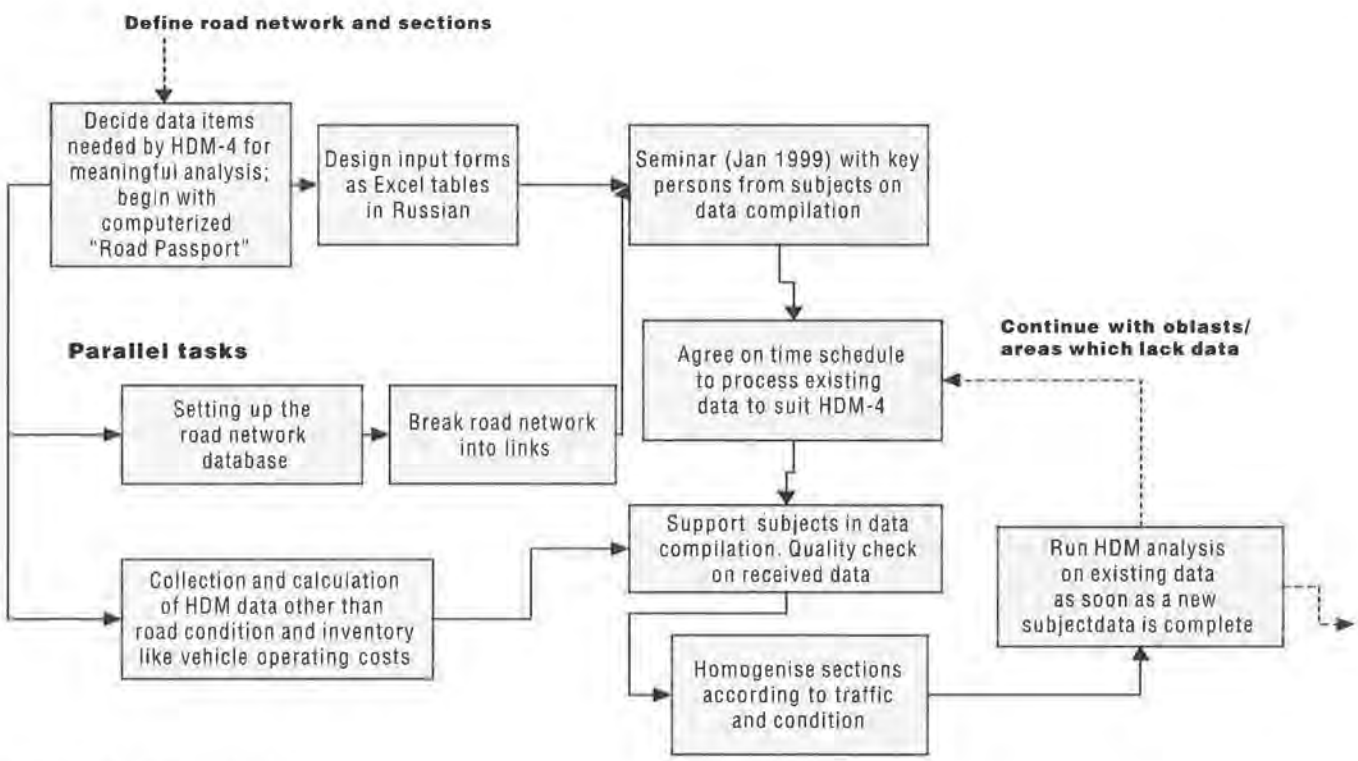

FIGURE 2 Data collection process.

the subjects. The characteristics listed below are enough for a preliminary analysis:

- Administrator of the road section (federal, territorial, municipal);
- Width of the road in meters;
- Number of lanes;
- Surface class (bituminous, unsealed, concrete);
- Surface material (description of the material and/or surfacing method used);
- Pavement type (technical information on combination of subgrade and pavement);
- Descriptions of thickness and so on, depending on surface class;
- Flow type, one-way or two-way traffic;
- Length of section in meters;
- Curvature (light or heavy);
- Hilliness (light or heavy); and
- Pavement history (information on past construction and maintenance operations).

Additional information, such as information about accidents, was requested, using the accident costs in the cost/benefit calculation. These figures were not submitted in full and therefore were not used in the HDM analysis. Basically the accidents should also be one part of the analysis. The cost of accidents is also a topic that must be considered before using accident information in the analysis.

Road Condition Data

All the road condition data were not available, and it was not possible to measure the condition of sections to make the compilation of data as easy as possible. Therefore defects were classified using a four-level scale, where "A" meant excellent condition and "D" bad condition. The classes were used when no measured data existed, as was the case for most of the territorial network. The condition data items that were requested are listed below.

- Roughness, either as international roughness index (IRI) (millimeter/meter) or as a value or an estimated class A–D; and
- Defects, either as a value or an estimated class A–D:
  - Cracking as percent of pavement area,
  - Raveling as percent of pavement area,
  - Potholes (number of potholes per kilometer),
  - Edge break (meters per kilometer),
  - Rut depth (millimeters),
  - Benkelman beam deflection or falling weight deflectometer deflection, and
  - Survey year.

Roughness describes the class of ride quality, which quantifies the subjective feeling of persons travelling along an uneven road.

A comparison of the data supplied by the subjects with existing kilometer-based data on federal roads was made. This comparison made it possible to assess which parts of the sections have such significant differences in condition data that they need to be analyzed separately. Subjects were asked to supply information on found discrepancies possibly caused by the latest maintenance actions or by incorrect data in the database.

The roughness of the data submitted by RD9 has been measured using a bump-integrator, according to the standard VSN-21-84 or according to GOST norms. The VSN was transformed into the standard IRI values. For future preparation of the road master plan, the condition measurements should be done regularly.

Traffic Data

Traffic data were requested in the form of average annual daily traffic. These data were chosen because they usually are available in all road authorities. European Union experts also knew that, with the current method of traffic data collecting, there could be no reliable estimates for seasonal variation.

The traffic flow was divided in three vehicle classes in the HDM-4. The first class consists of cars and light trucks with a maximum weight of 6 tons. In practice all these cars are two- or three-axial. The second class includes trucks weighing 6 to 10 tons and buses. The third class includes all vehicles with a weight of more than 10 tons. These classes were aggregated from the current data collection forms to represent the typical composition of traffic.

Traffic data sources were

- Information from the automatic traffic counters,
- Information from the federal highway administration database, and
- Estimations of local experts.

The traffic data, especially the number of heavy vehicles, appeared to be very different from the traffic data used in the Western countries. In several link sections, the majority of traffic flow is of heavy vehicles, which is rare in Western countries, where car ownership is more common. It is expected that the development of car ownership will change the flow type in upcoming years.

History of Construction and Maintenance of Road Sections

Information about construction year and other maintenance operations years also should be input in the HDM-4 program. This information was basically available. It includes last reconstruction or construction year, last rehabilitation year, last resurfacing year, and last preventive treatment year for each road section.

Calibration of HDM-4 for Northwest Environment

Internationally accepted default models for climate, road deterioration, maintenance effects, and road user effects are included in the prerelease HDM-4 package. These models have to be calibrated to local circumstances. In the calibration phase of this study, the lowest level (1 of 3) of calibration was carried out, which included the collection of road data from existing sources, with no additional data collection. HDM-4 default values were adopted for data items not available, and the calibration of the most sensitive parameters with best estimates and desk studies was executed (*2*).

The calibration in the project was based on information from local experts and from the road condition data. The problem was that the historical data on road conditions were not available for every section. Therefore it was somewhat problematic to check the deterioration of the roads.

The first calibration was done for the models available in the beta 3.0 version in June 1999. Thus the results of HRMP reflect that situation and not the situation of the models in the prerelease version at the end of July 1999, or any more recent version of the HDM-4. Therefore the calibration of all models always must be checked before the next analysis.

Results

The main result from the HDM-4 run was a priority list of projects. The projects are prioritized by benefit/cost (B/C) ratio. Benefits are based on savings in vehicle operating costs and in travel time. With this indicator, it is possible to get listed maintenance works from the HDM-4 program in every section. The program gives the costs of every operation, and it is also possible to include a budget limit.

In the project, the proposal for the master plan consists of nearly 900 km of the road network. Common to all prioritized sections is that they show high economic benefits. In most cases, the benefits of the rehabilitation are several times larger than the planned invested costs. Results are illustrated in Table 1.

The work plan also included a requirement that all subjects comment on the presented proposal for the HRMP. The expertise of the local experts in defining the needs of road rehabilitation is needed to approve the results of economic analysis. The comments were compared with the HRMP results. In most cases, the subjects agreed with the results, although some individual differences were found. These were mainly due to missing data or misinterpretation of data.

TABLE 1 Results in Karelia Republic

Road Section	Beginning and End Kilometers	Length (km)	Cost (thousands of rubles, 1991)	Net Present Value/ Capital Costs
Territorial roads				
A128, Hiitola–Sortavala	73–91	18	134	5.72
A128, Hiitola–Sortavala	208–260	52	2,423	5.47
Total		70	2,557	
Federal roads				
M18, Spb–Murmansk	425–430	5	374	4.86
M18, Spb–Murmansk	435–478	43	11,924	4.42
M18, Spb–Murmansk	384–397	13	3,586	4.27
M18, Spb–Murmansk	367–384	17	4,648	3.91
M18, Spb–Murmansk	347–363	16	971	3.70
Total		94	21,503	

Training

Translation of the system into Russian was one of the key issues of the project. It was only a preliminary version of the translation, however, and the translation work was still ongoing in January 2000. Without translation, the training would have been impossible.

Training is the most important phase in implementing a new maintenance management program in a new country. If the consultant executes all the work without clear commitment to the project by local authorities, the benefits of the project are not sustainable. A proper training program and an on-the-job training consultant ensure that, when the current project is completed, the local authorities can continue running the program each year and get the most benefit from it.

In this project the training was implemented with several training seminars and sessions. The main training was carried out in an HDM-4 training session in the Pavlsovsk Training Center in St. Petersburg in September 1999. In that seminar, all the local experts who would be responsible for year-to-year programming with HDM-4 software were present. The seminar's main goal was to make sure that the local experts had adequate knowledge of how to use the program. This was done with normal presentations and especially with case studies, in which the trainers input the data by themselves and ran project analysis cases, just as they will when carrying on their year-to-year planning work in their road organizations.

Naturally, more training and practice are needed in the future in order to ensure sustainability. Establishing an HDM-4 user group in this area was discussed and recommended.

Case 2: Papua New Guinea

Introduction

The Finnish National Road Administration (Finnra) has been responsible for the implementation of a road asset management system (RAMS) project in Papua New Guinea since October 1998. The project is financed through a grant by the Asian Development Bank and will be completed in September 2000. This presentation was prepared when approximately 70 percent of the project had been implemented and, therefore, contains results that are only preliminary in nature.

The road asset management system established under the project is the foundation for systematic and sustainable management of Papua New Guinea's road network and contains basic data on the physical characteristics of roads, traffic data, and cost data. These data are supplemented by regular condition surveys as well as a system for planning maintenance operations and carrying out economic analysis. RAMS also provides illustrative methods for presenting data to decision makers. RAMS is subordinate to national development plans, which set forth all policy and strategic issues, set maintenance and development objectives, and indicate the financial resources that are available.

The national government is responsible for all roads classified as national roads, and provincial governments are responsible for provincial roads. In some provinces the provincial governments may engage the Department of Works (DoW) to undertake maintenance on their behalf. DoW has three major divisions or sections: Design and Major Contracts, Operations, and Corporate Services.

Data Collection

On the basis of a list of classified roads provided by DoW, the network was subdivided into geographical locations and assigned to survey teams. Each road section was listed on a survey form that provided the survey team with the road name, road number, length, and physical features (such as rivers or other permanent landmarks) for starting and ending sectional surveys. Road sections had a planned length, typically ranging between 5 and 15 km.

In the field, the survey teams liaised with DoW provincial staff to revise the survey forms to take into account any recent developments and changes. The equipment was set up and calibrated, the survey was mobilized, and computer file numbers and other relevant information were recorded on the forms. These survey forms were later used in the office to cross-reference and quality check input data.

Two procedures were used for data collection. The preferred and by far the quickest procedure was to use vehicle-mounted Roadmaster equipment. Surveys were accomplished at a speed of 20 to 70 km/h, and data were directly input into the onboard computer. In some locations, due to inaccessibility (bridge washouts, poor road conditions) or simply because of remoteness and the difficulty of securing a survey vehicle, a manual method was used. The manual method collected the same data as the Roadmaster but used handheld Global Positioning System (GPS) equipment and visual roughness and surface condition measurements. Results were tabulated manually for later transfer into the road condition database (RCDB). The same survey form was used in both methods.

The Roadmaster survey equipment consisted of the following components: central unit, roughness sensor, odometer, GPS receiver, road-condition coding keyboard, laptop PC, and connecting cables. The equipment was transported to survey locations by air, installed on four-wheel-drive vehicles, and calibrated. Installation and calibration took approximately 1 day at each location. Survey data were stored on diskettes and sent regularly to the head office for postprocessing. Postprocessing of survey data consisted of editing, analysis, and transformation of the coordinate system.

All survey data collected by the project included GPS data that were recorded on location at 1-s intervals and provide accuracy within a range of 50 m.

The project used two types of GPS equipment. The first type is a GPS receiver that is integrated into the Roadmaster survey equipment mounted on survey vehicles. The second type is a handheld unit that is used to collect location data on small, isolated networks and remote locations and to carry out any supplementary surveys. This approach ensures that important roads are surveyed at a steady pace with minimum delay due to transporting and setting up equipment at new locations.

To aid the survey teams in standardizing survey procedures and maintaining quality control, a series of checklists was developed. These checklists covered equipment, daily diaries, and performance monitoring.

RAMS adopted the road-numbering convention used by DoW, which is well understood throughout the country.

The start and end of each section are visually recoverable and were fixed by coordinates and distances from known points. In addition to location data (coordinates) and length of each road section, data relating to surface condition parameters also were collected. The measurement of surface condition varied depending on whether the surface was sealed, gravel, or earth.

The surveys were carried out using two sets of Roadmaster road-condition survey equipment and measured the surface roughness and recorded the condition of the road. The equipment can be used on both sealed and gravel roads and also records distance data and GPS coordinates.

The Roadmaster apparatus contains the following components:

- Central unit (300 × 400 × 120 mm, plus connectors);
- Accelerometer (approximately 4 × 4 × 1 cm);

- Pulse detector connected to the speedometer cable;
- Keypad connected to the central unit;
- Power supply connection, 12 V (cigarette lighter connection); and
- Notebook PC (Compaq Armada 1572, P2330, 16 megabytes RAM, Windows 95 English).

Survey data were postprocessed in two stages. The first stage was carried out by the survey team and consisted of checking that road link numbers, numbers of sections, and lengths of sections were correct; that roughness values were within an acceptable range; that surface type was correct; and that GPS readings were logical. The survey team also recorded any special events that may have affected the results in a survey diary.

The second stage of postprocessing was carried out at DoW headquarters and consisted of verifying the consistency of all survey data files, automatic checking for possible duplication of sections, automatic opening of the Access "form," and updating of the section file.

Surveys of approximately 6093 km (82 percent) of national roads and 874 km of national institutional roads were completed by the end of September and covered all provinces. Throughout the 19 provinces, some 1303 km could not be surveyed because of access restrictions resulting from

- The road's isolated location on an island or inland;
- Poor road conditions or inclement weather;
- Security risk in the area; or
- Prohibited access because of impassable river crossings, landslides, or overgrowth through lack of use.

A summary of the lengths of classes of road in the network is shown in Table 2.

RAMS Components

A road asset management system is one of the most important tools a road authority should have in order to efficiently manage a nation's road network. Establishing an asset management system generally takes years and involves tasks that are often carried out by different units in an organization. Combining these tasks under a common asset management umbrella helps improve planning and decision making and efficient use of funds. When several systems are interconnected under a common umbrella, further improvements in compatibility and exchange of data among different parts of the system are also encouraged.

RAMS has been established using as much data from existing data banks as possible. DoW already has valuable information on the physical characteristics of roads and bridges, traffic volumes, road conditions, costs, and geographic location. This information was collected during previous studies and updated by regular data collection efforts. In addition to using existing data, the project carried out a comprehensive road condition survey that systematically collected geographic location and road condition data. The survey covered all national roads.

To successfully establish RAMS within the given time frame, the system has been designed with the precondition that all major software elements are standard off-the-shelf programs, and together they will form a package suitable for road asset management. The package contains all elements needed for operating data banks, planning maintenance activities, performing economic evaluation of projects, and reporting to decision makers.

RAMS (see Figure 3) runs on PCs connected to the DoW's local area network. Copies of all data have been saved on CD-ROMs and eventually will be saved on drives under the responsibility of the Information Technology Branch. This will ensure that important data are always saved as backup copies and that permitted outside users have access to all data.

RAMS uses a selection of popular off-the-shelf software as the basis of the system to ensure that program development and upgrades do not form a constraint to RAMS's sustainability. This also ensures that future user support on technical issues is available from a number of sources.

Microsoft Access is used for managing the road condition database, with some procedures being carried out under Excel. The RCDB established by RAMS contains data from existing data banks as well as the results from comprehensive and systematic surveys of all accessible national roads. Because surveys include the collection of GPS data, RAMS also provides updated maps of the road network. The RCDB links information from various sources and stores it into road sections, which are relatively homogenous stretches of road with a length

TABLE 2 Summary of Road Lengths by Class (Papua New Guinea)

Surface Condition	NR	NM	ND	TOTAL	NI
Sealed	1391	452	210	2053	164
Gravel	1716	1574	2053	5343	1074
TOTAL	3107	2026	2263	7396	1238

NOTE: Values given are in kilometers.

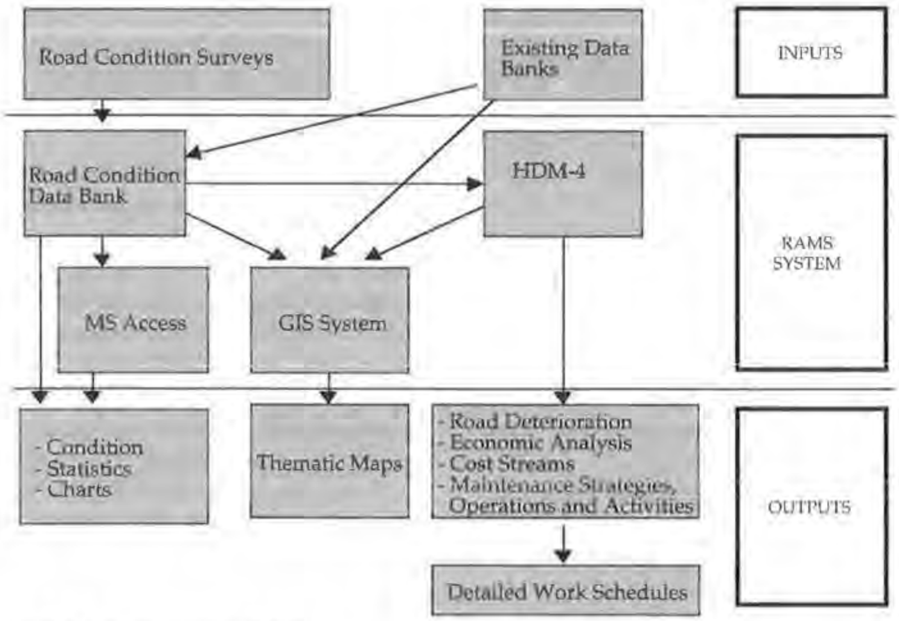

FIGURE 3 Diagram of RAMS.

generally varying between 5 and 15 km. The RCDB also contains information on maintenance standards and built-in automatic procedures for producing standard reports.

HDM-4 is used to evaluate alternative maintenance strategies and to carry out economic analysis to prioritize major development projects. Maintenance funds are severely limited in Papua New Guinea, and therefore maintenance planning must be carried out under a constrained budget. Program level analysis and planning with a constrained budget had not yet been carried out at the time this presentation was written. The RCDB has been developed to automatically provide HDM-4 input files on any or all road sections. The project has used beta versions of HDM-4 to ensure that data compiled by the project are compatible with data input requirements of HDM-4.

The role of HDM-4 applications is summarized in Table 3.

RAMS also includes a geographic information system (GIS) application that produces thematic maps based on GPS data collected during road condition surveys. The GIS system is used to illustrate RCDB data and to provide a practical means of presenting information to decision makers. After careful consideration, the consultant selected ArcView (including ArcExplorer) as the GIS software for RAMS. ArcView Desktop GIS is a common platform for thematic mapping, and ArcExplorer is a GIS application for occasional users and a platform for querying, reviewing, and displaying data.

Maintenance Planning

Road Network Classification

The project prepared initial classification criteria for reclassifying national roads based on their functional role. This classification serves as the basis for defining maintenance standards for each road section and assists in planning required maintenance operations. The classification is based on traffic volumes and existing administrative categories and therefore, in addition to indicating the

TABLE 3 Summary of the Role of HDM-4 Applications

Activity	Time Horizon	Responsible Staff	Spatial Coverage	HDM-4 Tool
Planning	Long term (strategic)	Senior management and policy makers	Network-wide	Strategy analysis
Programming	Medium term (tactical)	Middle level professionals	Sub-network	Program analysis
Preparation	Budget year	Technical staff	Project level	Project analysis

functional class (FC) of roads, also provides a basis for defining maintenance classes for roads. Unlike previous maintenance prediction systems used by DoW, RAMS prioritizes maintenance activities depending on the importance of the road. For this purpose, roads have been reclassified by functional class, depending on the volume of traffic they carry.

To further assist in prioritizing maintenance activities and setting appropriate maintenance standards, each road section has been assigned a maintenance standard (MS) on the basis of its functional class and pavement type as shown in Table 4.

Maintenance Operations

The network is typically in a very deteriorated state. For some years the level of budget support has been sufficient only to keep the road network open, regardless of deteriorating surface conditions. With reduced funding levels, the managerial and technical resources and capability of DoW have been allowed to deteriorate to such an extent that DoW now has difficulty spending the limited funds that are available.

Even with full recognition of the importance of road maintenance funding, it is likely to take DoW 2 to 3 years to put in place an effective restructuring of the Maintenance Section and restoration of the managerial and technical resources and capabilities necessary to implement rehabilitation of the network.

Restoration of the whole road network to a "reasonable" condition will take time, maybe another 10 years. To allow for the progressive improvement of the network and to allow DoW to strengthen its capability in managing and implementing maintenance tasks, the maintenance plan should not be overly ambitious. Maintenance thresholds initially should be selected to ensure that the plan is fundable and can be implemented with the resources available. The following condition ratings have been selected based on a statistical analysis of the condition of the road network. In turn, these will yield intervention thresholds that will provide for rehabilitating the network at the rate of 30 million to 80 million kina per year over the next 5 to 6 years (additional to normal routine and periodic maintenance activities).

TABLE 4 Maintenance Standards Based on Functional Class and Pavement Type

Functional Class	Sealed Road	Gravel Road	Earth Road
FC1	MS1		
FC2	MS2		
FC3	MS2		
FC4	MS3	MG1	
FC5	MS3	MG2	ME1
FC6	MS4	MG3	ME2

Based on a statistical analysis of the network, the following intervention criteria and corresponding maintenance activities have been adopted by RAMS.

The specific maintenance activities used by RAMS are

- Sealing cracks and potholes,
- Edge and shoulder repairs,
- Overlay,
- Regraveling (resulting from bad conditions), and
- Culvert maintenance (small).

These activities are not subject to set frequencies or cycles and can be implemented by DoW provincial staff using simple planning procedures.

The major reconstruction activities used by RAMS are the following:

- Upgrading earth road to gravel road,
- Pavement reconstruction (single bituminous surface treatment 19 mm and double bituminous surface treatment 19 mm + 13 mm);
- Upgrading gravel road to sealed road (19-mm aggregate with no base and 19-mm with base);
- Earth road construction; and
- Sealed road construction (widths of 4.5 m, 5.5 m, 6.5 m, and 7.5 m).

These activities are not subject to set frequencies or cycles and can be implemented only after detailed planning and feasibility analysis.

The specified maintenance operations will be reviewed in May through July 2000 and may change significantly.

Training

Training within the project has focused on on-the-job training and formal training courses and seminars. Because staff in various organizations will use RAMS, training has been targeted at various levels in several government departments and provincial staff.

For RAMS operation and computer skills, training has concentrated on local counterpart staff who in turn will themselves act as trainers. To secure sustainability, it has been imperative that the counterpart staff be highly motivated and develop a responsibility for local ownership of the system. The counterpart staff also has been trained in road inventory and condition survey activities. Through these activities, the basic data for the management system are collected, and it is important that the staff running the system can judge the reliability of the information they collect. Training in road maintenance activities and principles also forms part of the training program.

Staff members from provincial DoW offices and the provincial administrations have participated in the actual road inventory and condition survey fieldwork. An ongoing training program in inventory and condition data collection has also been tailored to field personnel.

DoW, OoT, and ONPI staff have gained a better appreciation of modern management techniques related to roads and a clear understanding of the concepts involved as well as the benefits of adopting a more systematic approach to road management. A series of training workshops aimed at a broader DoW and ONPI participation has been organized.

Conclusions

The following conclusions were made during this first implementation of HDM-4 in Russia and Papua New Guinea.

• Time needed for implementation of a system should not be underestimated. Learning of any new topic will take time, and this requires a long enough project period.

• Use of a pilot version of any software in a real project is always risky. This project used a piece of software that was in its development stage. This evidently caused much delay and rerunning of analysis. However, valuable information for the future development of HDM-4 was gained.

• The need for personal contacts with local experts during the project is high. This project was run mainly from the central office in St. Petersburg. However, a more efficient, although more expensive, way of implementation would have involved more traveling to the subjects, in order to meet and discuss with the local experts closer to their own circumstances.

• The need for translation of the system to the local language was proved.

• Minimum calibration can be done everywhere, but a proper calibration of HDM-4 needs more time and more reliable local history, traffic, and condition data.

• The practical results of this project (i.e., HRMP) were applicable, but the interpretation of results has to be done very carefully. It should be noted that the first results can always incorporate errors, but those errors cannot be found without trial-and-error procedures.

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