A Periodic Maintenance Management System for Low-Volume Roads in Niger

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The establishment of a management system for preparing periodic maintenance programs in Niger is discussed. The Ministry of Public Works in Niger realized that a rational system was needed to develop a maintenance program to safeguard the investment in the road system. This system would have to be tailored to Niger, a poor country with a sparse but expansive road network and an extremely limited number of engineers and technicians. A Road Maintenance Unit was therefore established with the objectives of monitoring the condition of the network and the volume of traffic using it, and developing periodic maintenance programs based on this evaluation. A description is provided of the methods and techniques that were used to accomplish these objectives.

The establishment of a management system for preparing periodic maintenance programs and budgets in Niger is discussed. Niger is a landlocked country in West Africa that extends from the northern fringe of a rain-fed agricultural region into the heart of the Sahara desert. The population of about 6 million is growing at a rate of 3 percent a year. Nearly 90 percent of the population is concentrated along the southern border in the 12 percent of the land that is arable. It is one of the poorest countries in the world with a per capita GNP of about $200, and an economy dominated by subsistence agriculture. Adequate transportation is critical to Niger. Large stretches of nearly empty land exist between population centers. High transportation costs limit the competitiveness of Niger's products on the world market, make imported items expensive, and add to the cost of delivering services to distant urban centers and the scattered rural population.

The road network in Niger is 9800 km long; 3160 km of the roads are paved. Traffic volumes are low; outside urban areas, the highest traffic volume is less than 1,000 vpd, and only 546 km or 17 percent of the paved roads carry more than 300 vpd.

The road network is relatively new; the first one-lane paved roads were built in the 1960s. In the 1970s, all of these roads were widened to a two-lane width. A two-lane standard is now employed throughout the network. The paved roads are therefore at a point at which extensive periodic maintenance is required for the first time. The Public Works Department (PWD) grew into existence over the same 25-yr period. The Ministry of Public Works realized that a rational system was needed to develop a maintenance program to safeguard the investment in the road system. However, this system would have to be tailored to Niger, a poor country with a sparse but expansive road network and an extremely limited number of engineers and technicians.

A Road Management Unit (RMU) was therefore established in the PWD with two objectives: to monitor the condition of the network and the volume of traffic using it, and to develop periodic maintenance programs for the network on the basis of this data. The RMU must perform three major tasks to accomplish these objectives: collect data, on a continuous basis, on both paved and unpaved roads; create and maintain a data bank; and develop annual medium and long-term periodic maintenance programs, including cost estimates and economic justifications. This task includes analyzing the data, making forecasts, and applying decision criteria (Figure 1).

DATA COLLECTION

The immediate goal of the RMU was to produce credible periodic maintenance programs. In view of the limited human and financial resources available, data collection was confined to the parameters that were necessary to achieve this goal. The RMU and PWD are, however, dynamic organizations and additional tasks will be added in the future when interest in them becomes apparent.

Some data, called office data, can be collected without field visits, such as the definition of the network, historical information on each road link, and quarry locations. In Niger, the PWD is officially responsible only for "classified" or national highways. However, partly because the PWD is the only organization with maintenance capabilities, and partly because the official classification system is out of date, the PWD actually maintains more than the classified network. The maintained network, therefore, includes paved and unpaved national, regional, and rural roads, all of which are managed by the PWD. A reference system of nodes and links was defined for this network. Each link is homogeneous as much as possible from the point of view of traffic and class of road.

Other office data include the history of each link in the network, such as the dates of original construction, major resurfacing, and strengthening; quarry locations; and quality and quantity of available materials. Long stretches of road in Niger are far from suitable road building materials and transport is a major element of maintenance costs.

The collection of data by field survey was not the responsibility of any existing PWD unit. The RMU therefore established, trained, and administered its own survey crews, three for traffic counts and one for road inventory and condition surveys.

Traffic Counts

Traffic data are collected by manual and automatic counts by three crews based in regional centers. The count program is in operation 11 months each year. The manual counts last for either 3 or 7 days; the 3-day counts include a local market day. These counts include a classification of vehicles into five types.

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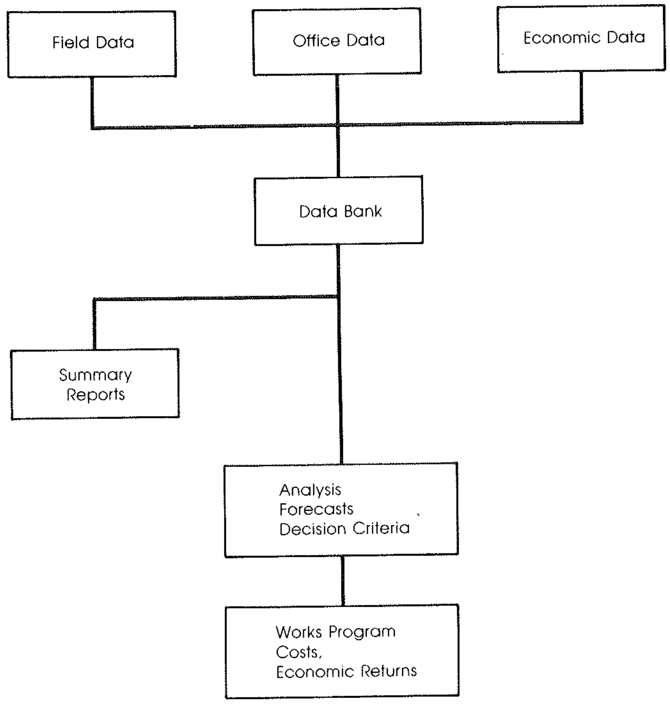

FIGURE 1 Functions of the Niger Road Maintenance Unit.

Automatic counts are performed only on paved roads. The RMU has 12 counters, eight of which are electronic and are read by a portable microcomputer (an Epson HX20) onto cassettes. They are used with magnetic loop detectors. The other four are of an older electromechanical type and are used with pneumatic tube detectors.

Road Inventory and Condition Surveys

Pentakilometer (5-km) markers were placed on all paved roads and they are generally accurate. However, road improvements that shorten the alignment can upset the accuracy of all subsequent kilometer markers. An independent kilometer reference system was therefore established, and the existing kilometer posts were incorporated into it. Most unpaved roads do not have pentakilometer posts. Distances on these roads were measured with a precise odometer (Halda Twinmaster), and special markers were placed.

A windshield survey is a conventional, detailed visual analysis that is performed in a car and, when necessary, on foot. Distances are recorded with the precise odometer, and the roadside kilometer markers were incorporated into the measurements. The following three groups of data are recorded:

- Road characteristics, such as pavement width, right and left shoulder width, presence of village or junction location, and type of drainage structure;
- Roadside condition, such as right and left ditches, right and left shoulders, and cut or fill section; and
- Pavement condition, such as condition of surface treatment, cracking, and deformation.

The pavement condition characteristics are recorded on a scale of 0 to 5, from excellent to bad, for the surface treatment, and 0 to 3 for the extent of cracking and deformation. Data collected for unpaved roads are width, presence of corrugations, gravel loss, potholes, rutting, depressions, and crossfall.

One axle load survey has been performed using portable scales, and the RMU has also introduced in-motion weighing on an experimental basis using a piezo-electric cable. The cable is positioned in a transverse slot in the pavement, which is then filled with epoxy. The passage of an axle produces an electric signal that varies with the load, and the reading is stored in an electronic control box. The reading is calibrated using standard loads. The cable needs a stable platform for accurate measurements. Because the pavements in Niger were relatively light and flexible, the RMU decided to install the cable in the center of a 30-m-long Portland cement concrete slab. Arrangements were therefore made with the financing agency, the European Development Fund, to include the slab in an ongoing contract to widen and strengthen a section of the main east-west highway. The electronic recording system produces a histogram of the number of passing axles in five classes: 1 to 5, 5 to 9, 9 to 13, 13 to 16, and more than 16 metric tons. The legal limit for a single axle in Niger is the usual Francophone one of 13 tons, or 28,600 metric lbs. If the experimental installation is successful, similar installations might be made on other sections of the paved road network.

The French APL 25 longitudinal profile analyzer was chosen to measure road roughness. The local crew was trained in its use by a technician from the French Central Roads and Bridges Laboratory. The APL 25 records results on a standard cassette, which is directly read by a digital cassette reader for automatic input to the RMU's computer. The software, in addition to expressing the road roughness on the normal CAPL 25 scale, converts the results into the International Roughness Index scale, which is used as a standard input to the World Bank's Highway Design and Maintenance Model (HDM). Complete surveys of the paved road network in Niger were performed in 1985 and 1986.

Economic Data

Three groups of economic data are collected: the unit costs of construction, rehabilitation, and maintenance, for both periodic and routine maintenance, by contract or by force account; vehicle operating costs; and macroeconomic and traffic forecasts.

DATA INPUT AND STORAGE

The RMU was instrumental in introducing electronic data processing to the Ministry of Public Works. A list of equipment was determined in 1984 and the following items were chosen at that time:

- A Victor S1 computer with 512 kbytes of memory and two floppy disks with 1.2 Mbytes of memory,
- An Alpha 10 computer with 2 x 10 Mbyte cartridges (Bernouilli Box),
- A Hewlett Packard 7475A Plotter, and
- An Epson LQ 1500 printer.

Data are input manually by way of the keyboard, and automatically from the automatic traffic counters and the APL 25. In order to take advantage of other software now available, increase flexibility, and ease communication, the system is in the process of being updated with a new microcomputer that is IBM-compatible.

Data are stored in the following four files:

- Fixed inventory data, such as information on link start and finish, road length, pavement and shoulder width, and the presence of ditches, drainage structures, and cut or fill sections;
- Evolving inventory data, such as information on the condition of pavement surfaces, shoulders, and ditches that was collected by the windshield survey;
- Traffic data; and
- Road roughness data.

SUMMARY REPORTS ON DATA

The information in the four files can be output in summary form, including general information on each road section, summary traffic counts, and pavement condition. Data can also be output in map form on the automatic plotter. The characteristics shown by the variation in form or color of lines of the map can be representative of any parameters stored in the data bank. Data for the plotter come directly from the data bank, so the maps produced always reflect the latest input data.

DATA ANALYSIS

The first set of data was collected during 1985 and the beginning of 1986. These data were used in 1986 to develop the proposed maintenance programs for the years 1987 to 1989. Although it was originally intended that the RMU produce an annual program of periodic maintenance, the programs in Niger are funded with foreign aid. The time necessary to establish a program and the size of each program prevented the strict implementation of year-by-year programs. A 3-year program was therefore funded by several donors.

MAINTENANCE POLICIES

It was first necessary to establish a decision methodology. In 1986 the software that automatically read and input the APL roughness data was not yet available. Therefore, decision criteria were used from the three pavement condition evaluations of the windshield survey: surface treatment condition, cracking, and deformation. The first two are indications of surface distress, and the third of problems in the pavement structure below the surface. A two-dimensional decision grid was therefore developed in which increasing surface distress, defined as the sum of surface treatment condition and cracking, was plotted on the X-axis and deformation was plotted on the Y-axis. The types of maintenance intervention, which ranged from routine maintenance to strengthening the overlay and rehabilitating the road, were then related to the cells in the grid, as shown in Figure 2.

The thresholds and the different types of maintenance works in the decision grid were positioned on the basis of engineering judgment. The positioning of these thresholds was the subject of considerable discussion between engineers from the government and the World Bank. They considered engineering standards that were commonly used in Niger and West Africa, and the results of World Bank research in other parts of the world. Because the great majority of surfaces and pavements in Niger were in good condition, persons who conducted the windshield condition survey tended to rate the road severely. The grid therefore might need to be extended for use by other countries.

MAINTENANCE MODEL

A simplified version of the World Bank's HDM was developed by the Bank and consultants. The model is shown in schematic form in Figure 3. The inputs to the model are the road inventory (both fixed and variable conditions), traffic data, economic data, and the maintenance policy decision grid.

The model first adds default values for required HDM input data that are not collected in Niger, and transforms the Niger survey ratings for surface treatment condition, cracking, and deformation into HDM units. This provides the initial condition for the simulation, which is run with either a null or specified maintenance policy. The model predicts the condition of the road section at the end of the year, as a result of its initial condition and the effects of traffic and climate derived from the HDM equations that were calibrated to conditions in Niger. The predicted condition is then compared to the maintenance policies to determine if work would be required on a road section. If so, the maintenance quantities and costs for the sections are calculated. Then the updated road condition is calculated. This road condition then becomes the input for the second year of the simulation cycle, which is repeated for the total number of years of the analysis. The simulation cycle for Niger was 10 years.

The total vehicle operating costs over the road section for each year are calculated, depending on the forecasts of both traffic and road conditions. The total transport costs, which

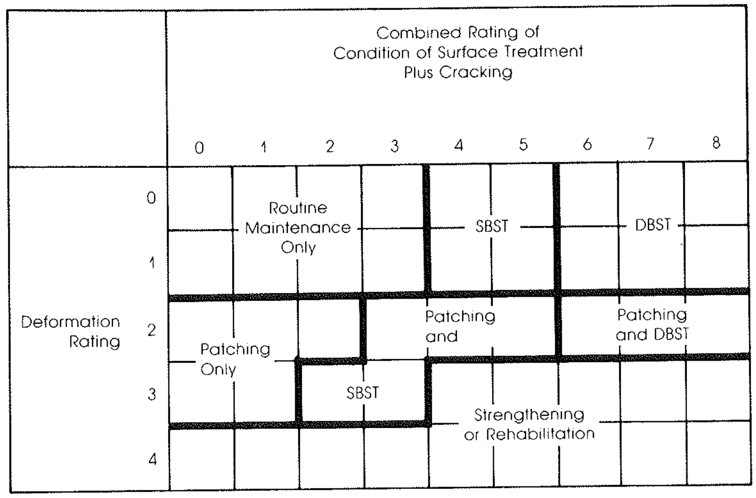

FIGURE 2 Maintenance policy decision grid.

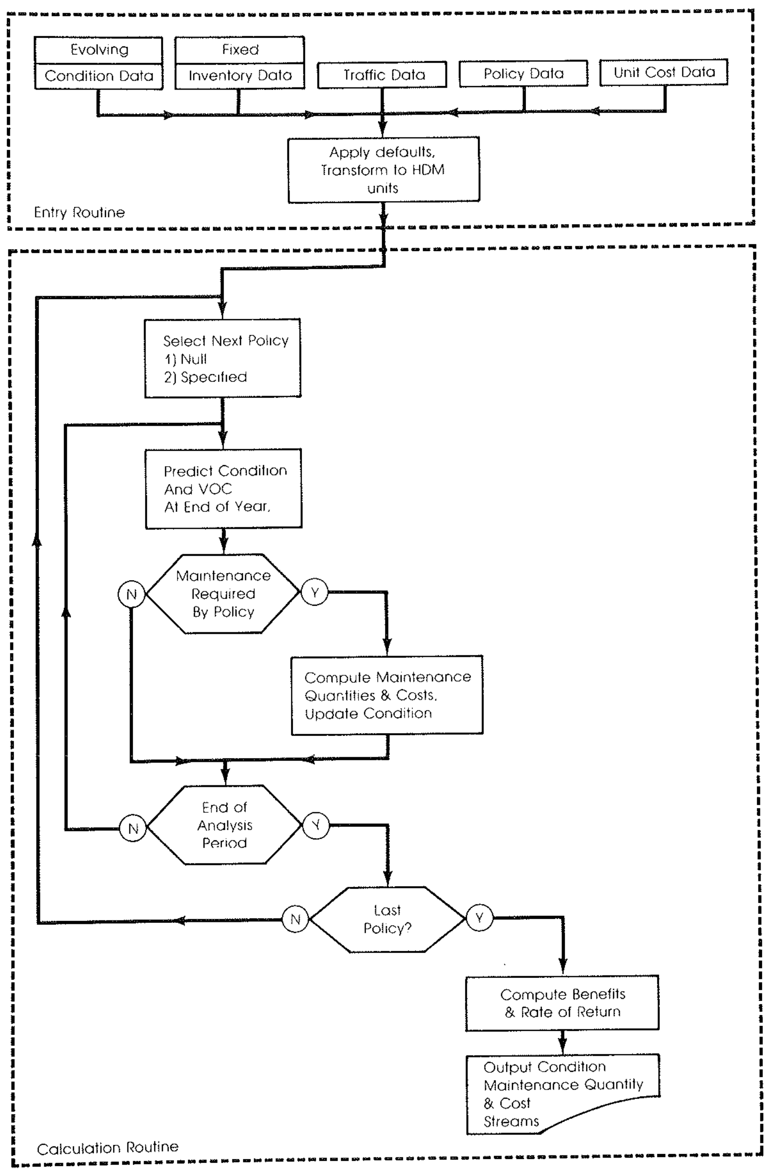

FIGURE 3 Flow chart of computer model used to prepare maintenance program with economic indicators.

consist of vehicle operating costs and maintenance costs, are summed for all sections in the road link. The total costs are then compared for the null and with maintenance policies. Then the costs are discounted to develop an economic rate of return for the investment in periodic maintenance on the road link.

It should be noted that this analysis is performed for each homogeneous section of a road link. In practice the type of maintenance applied can vary in roughly 100-m lengths. This level of analysis is therefore needed to produce as accurate an estimate as possible of the quantities of maintenance works.

CONTRACT DOCUMENTS

For lots that consisted of road sections that do not need to be strengthened, the results of the RMU analysis are sufficient to be directly incorporated in the bills of quantities in contract documents. However, although the average costs of improving severely deformed sections are used to permit the RMU to develop a program of works and its economic justification, the level of analysis is insufficient to define an engineering solution for construction. A conventional engineering study should be performed for such sections, including deflection testing and test pits to identify the cause of the problem, and to permit the improvement in pavement structure to be properly designed.

RESULTS OF THE ANALYSIS

The Government of Niger has as a stated policy to preserve the national heritage. The analysis performed by the RMU has been an important factor in extending this general policy to the maintenance of the road infrastructure. In spite of a financial crisis, a satisfactory level of funding has been allocated in the investment budget to periodically maintain the road network. The general policy of the government and the trend among foreign donors to lend money for road maintenance have both been strengthened by the RMU analysis. Budgetary allocations for this purpose are now supported by several donors.

FUTURE DEVELOPMENT

The maintenance program that is currently being executed was based on the decision grid of maintenance policies related to pavement condition. The next step in the program was to refine the decision grid. The vehicle for this is a national transport study that is now in progress in Niger. One important element of this study is the installation of the full HDM program in Niger. This is now possible because the HDM has been restructured to run on microcomputers with the capabilities of the IBM AT. The network data in the RMU data bank will be used to examine the sensitivity of the thresholds that trigger each maintenance task. A wide range of different policies will be tested and applied to links and sections that are representative of the whole road network in Niger. The economic results will then be calculated. A series of iterations will enable national maintenance policies to be refined. These policies can then be applied to the link analysis to develop annual maintenance programs.

CONCLUSION

As was stated earlier, Niger is a country with very limited human and financial resources. It is therefore important that the best possible use be made of all investments, including highway maintenance. The Niger Road Maintenance Unit can ensure that funds are spent on those projects that give the highest returns by using the methods and techniques described in this study.

The views and interpretations expressed in this paper are those of the authors and should not be attributed to the World Bank, to its affiliated organizations, to the Government of Niger, or to any individual acting in their behalf.