USE OF CAR ROAD METERS IN A ROAD MASS INVENTORY

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One of the most important instruments in any pavement management system is the road mass inventory, which can be divided into 3 subsystems: structural, traffic, and safety characteristics. This paper explains the part played by car road meters in the collection of data on the structural characteristics of road surfaces and provides some idea of the planning and control of the collection of data across Quebec; it also indicates the limitations of the device and comments on the results.

One of the major difficulties encountered in roughness studies is the calibration of car road meters. The data compiled are gathered and put in graphic form by the computer (road diagram) and sent to the road engineers. These data are used simultaneously with those on deflection and those compiled through condition surveys to prepare a list of structural priorities. The roughness criteria will be assessed and corrected if the need arises. A table gives a global picture of the road network from the point of view of roughness and serves as a planning tool. A graph shows the theoretical relation between the roughness coefficient K_r and the riding comfort index (RCI). This paper clearly shows the use made of car road meters in a structural mass inventory of a vast road network.

The purposes of a road mass inventory are to obtain an overall picture of all classes of roads, from the viewpoints of structure, traffic, and safety; to keep track of the condition of the roads over a period of time; to establish the network's priorities with a view to short-term and long-term programming of maintenance and reconstruction; to rationalize a budget for bituminous overlay; to guide the road engineers in repairing and rebuilding roads in their regions; and to provide a tool for planning within the pavement management system.

Road mass inventories, then, are of immense importance to highway department engineers and should be made on as many Quebec roads as possible. Also, the most important data can be collected in areas such as pavements, bases and subbases, road geometry, and traffic. In order that they be more useful, these data must form an integral part of a management system; they will be stocked in a data bank for reference and study purposes and processed by computer.

IMPORTANCE OF ROAD MASS INVENTORY

The pavement management system emphasizes the role played by the road mass inventory. The proposed management system outline (Fig. 1) shows the main elements of such a system and stresses the use of the inventory in deciding on priorities. The data gathered during the inventory on the actual state of the highways allow verification of performance standards and establishment of criteria for good roads. Performance standards may possibly lead to correction of design standards. All the data from any road mass inventory are compiled in a road data bank, and the results of the research are used as guidelines in making decisions following the preparation of a list of urgent sections covering the entire numbered road network. The numbers that appear above each pattern refer to the patterns for the global system shown in Figure 2. Essentially, the management system shown here is that designed by Haas (1), with a

Figure 1. Pavement management system.

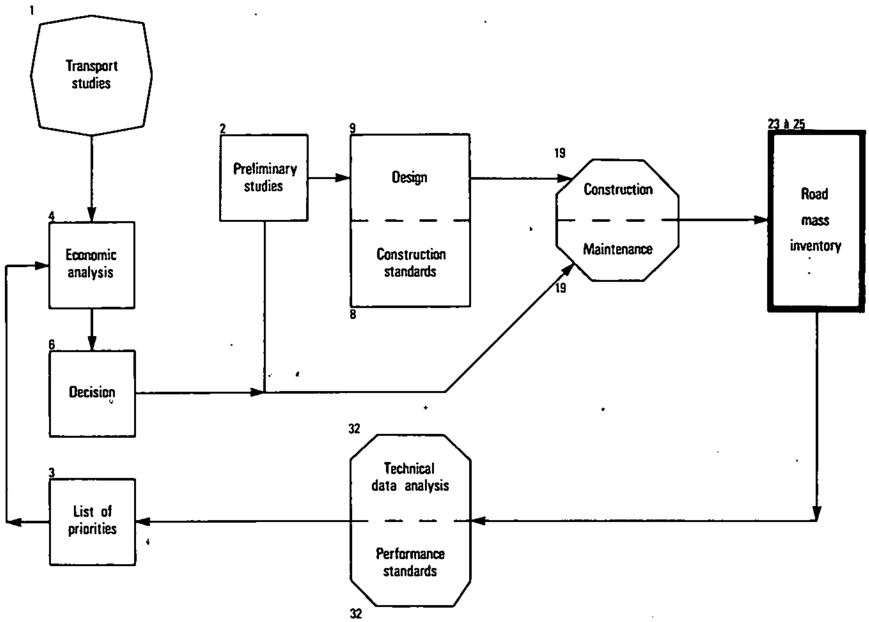
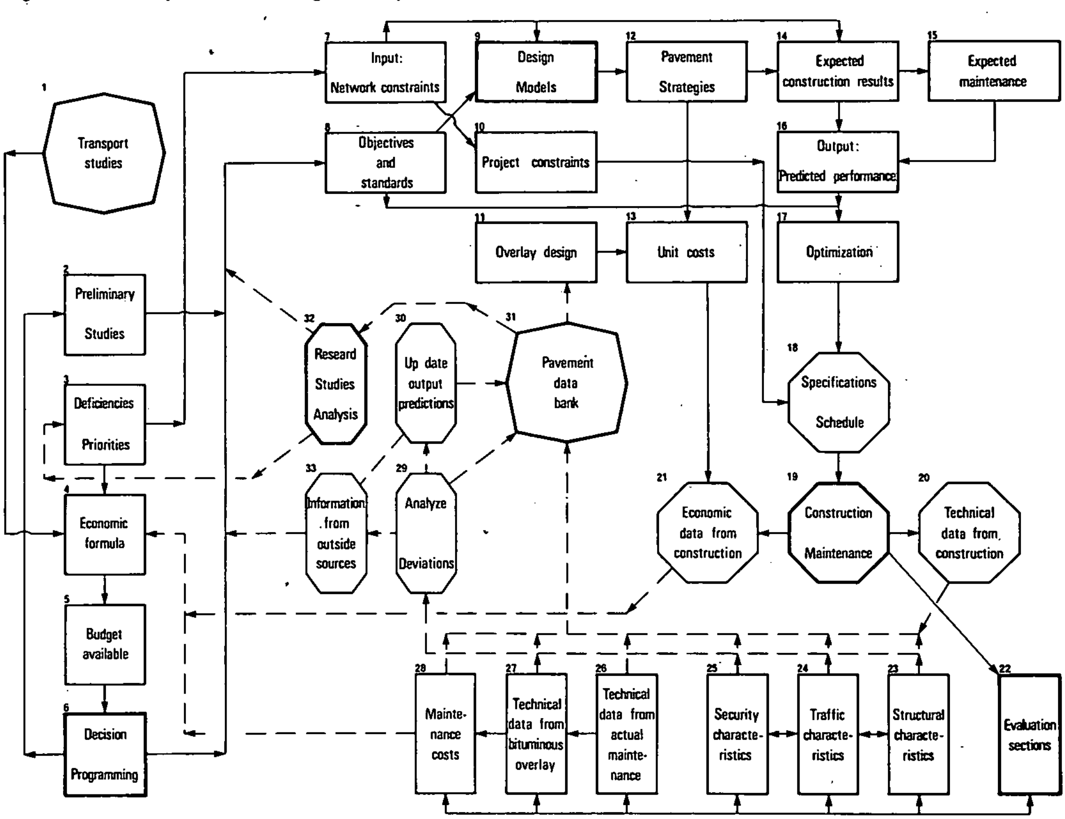


Figure 2. Global pavement management system.



few changes, especially in the part that deals with road mass inventory. Other pavement management systems have been put forth (2, 3).

It will be seen that the system outlined here (Fig. 2) only gives the titles of the principal activities within the pattern of the system. Each activity will eventually be developed accordingly and explained, but that is not the object of this paper. In order to clarify the system, we have divided it into 5 sections or activity groups: planning (1 to 6), design (7 to 17), construction (18 to 21), mass inventory (22 to 28), and research (29 to 33). Each group has its own pattern (model) for making the system easier to understand. The broadest patterns represent the key activities within the system. Attention is drawn to the size of the road mass inventory shown in patterns 22 and 28, which feed the data bank. Figure 3 shows the role played by the data bank, indicating total input (bottom) and total output (top). In this way a good idea can be had of all the data that will be processed and how the decision will be made once a list of deficiencies and priorities has been drawn up through research, with account being taken of the economic analysis and budgets allowed or available.

IMPORTANCE OF ROUGHNESS DATA IN A ROAD MASS INVENTORY

Having established the importance of inventories within a global pavement management system, our next step is to determine the means of compiling the necessary data in a road mass inventory. In order that the data may be better prepared, the results better analyzed, and a global list of priorities better drawn up for the road network, the inventory has been divided into 3 subsystems, structural, traffic, and safety characteristics, which are shown respectively in patterns 23, 24, and 25 (Fig. 2). Each subsystem will build up its own list of priorities, taking account of structural, traffic, and safety deficiencies. The global list of priorities will constitute an integration or mixture of 3 lists (structural, capacity, and security) given by the 3 subsystems within the road mass inventory. Once a list of priorities has been drawn up for the whole road network, programs will be decided on and drawn up based on economic analysis and budgetary constraints.

The list of structural priorities will be established by the structural characteristics subsystem. The main characteristics to be used as basic data in any structural analysis of roads are deflection, roughness, cracking, patching, and drainage. Through a multiple regression analysis it will be possible to establish the relative value of each variable considered important in preparing a list of structural priorities: deflection $(x + 2\sigma)$, roughness coefficient K_r, cracking index, patching index, and drainage index. Other data on the background of the road and its surface, traffic, and maintenance will be used in the analysis. Activity 23, structural characteristics, consists of gathering data on roughness, deflection, condition survey, and drainage. Roughness data constitute one of the principal components of the "structural characteristics" activity. Roughness becomes one of the guidelines used in drawing up a list of structural priorities. Once the importance of each of these variables has been established, it will be relatively easy to make a list of structural priorities, using an appropriate point system.

Until now, we have placed the characteristic of roughness within one of the 3 subsystems of the road mass inventory, which itself is part of the global network of pavement management systems. We hope soon to be able to demonstrate its importance in relation to the other variables analyzed within the structural characteristics subsystem.

CALCULATION OF ROUGHNESS

Roughness was assessed quantitatively; it was surveyed on the road network within the road mass inventory in the following manner. We used a car road meter, a device that measures roughness over many miles but within a relatively short time. Three of these meters were used to measure the roughness of 10,500 miles of Quebec roads in 2 years (1970 and 1971). We intend to complete the collection of data on the roughness of Quebec's entire numbered road system in 1972, a total distance of 12,500 miles. For mass inventory needs, the roads have been divided into large sections, sections, and subsections. Identification can be illustrated by the following example: 0155, road; 02, large section; 060, section; and 01, subsection.

Figure 3. System data bank.

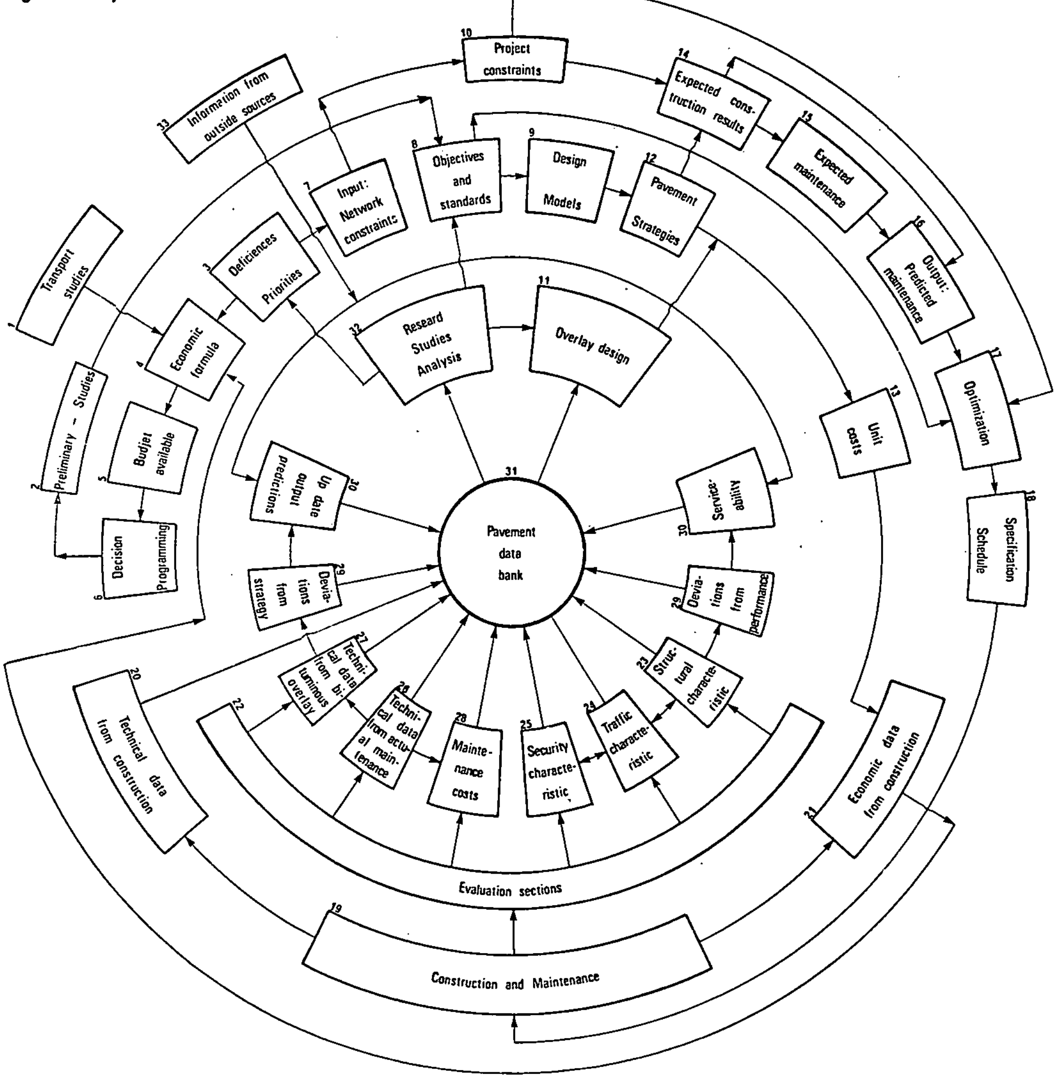


Figure 4. Correlation of index q and road meter Σ-counts.

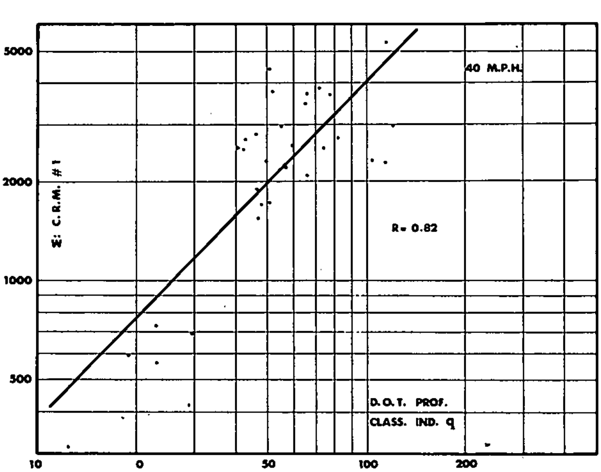
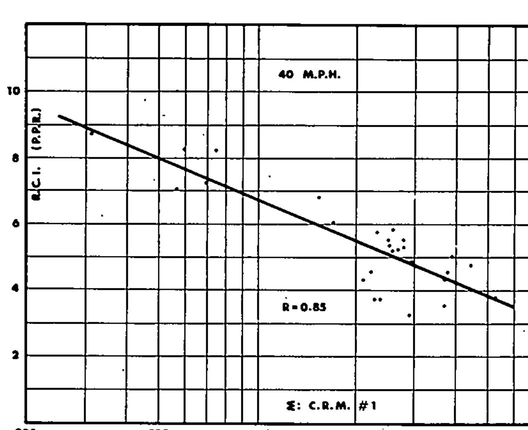


Figure 5. Correlation of RCI and road meter Σ-counts.



In order to ensure the shortest possible run and proper control of the results of the inventory, we divided the province of Quebec into 10 circuits in which deflection and roughness data were collected. Each car road meter (3 in 1970 and 2 in 1971) was given a number of circuits that were completed individually. Knowing the speed of each day's operation, we were able to control the surveys and check the car road meters any time during the week. Weekly reports were submitted by the teams involved.

SELECTION OF A STANDARD CAR ROAD METER

Calibration of the machines was one of our major problems. It was necessary to make sure that the value given by one meter for one section could be compared to another value given by a second machine for another section of the road, i. e., that the sections were comparable from the point of view of roughness. First, we calibrated all car road meters with the British profilometer used by the Department of Transport in Ottawa. The results of this calibration are discussed in a report prepared by Argue (4). Figure 4 shows the correlation obtained between the classifier index q and the summation of counts (Σ-counts) given by car road meter 1 for 1 mile. The coefficient of correlation R is 0.82. The average reading error on both sides of the calculated straight line is in the order of 33 percent. This correlation is not satisfactory. The correlation between Σ-counts of the other car road meters used and q is about the same.

A calibration was made between the car road meters and the RCI. Figure 5 shows the correlation between the Σ-counts for car road meter 1 and the RCI established by a 3-man panel for the same sections analyzed by the British profilometer. The coefficient of correlation was 0.85, and the average reading error on both sides of the calculated straight line was about 10 percent. The correlation shows a slight improvement over that in the preceding figure. The correlation between Σ-counts of the other meters and the RCI established by the same 3-man panel is about the same. If another, or a larger, panel had been used, the correlation might have been quite different because the appraisal of the RCI varies with the panelists. A correlation between Σ-counts and RCI for the same meter varies according to the members of the panel or panels at the time.

Calibrations were later established among the Σ-counts of the different car road meters used for the calibration and also among the roughness coefficients of these instruments. The roughness coefficient is defined in Fortin's paper (5). Figure 6 shows the correlation between the Σ-counts for car road meters 1 and 2 respectively at an operating speed of 40 mph. The coefficient of correlation is 0.97, and the average reading error on both sides of the calculated straight line is about 11 percent. The correlation for the other meters is similar ($R > 0.95$). It is more satisfactory for an operating speed of 40 mph than for 30 mph.

Sections of roads change with time, as do the machines used; they deteriorate. Vehicles also change, and this makes the interpretation of roughness data among sections and years extremely difficult. Because the correlation between Σ-counts or between roughness coefficients of car road meters is satisfactory, we chose a road meter that would be used only to calibrate the other road meters used in our study of roughness. This was merely a partial solution because after some years the standard road meter itself will also change. It is essential that a time-stable mechanical device for calibrating road meters be developed.

The standard meter will be satisfactory for calibrating the road meters that we will use on Quebec roads during the next 2 years. Calibration was established between all the road meters used and the standard road meter in 1971, and this will be done again in 1972 and 1973. Correlation coefficients have been highly satisfactory (> 0.95). A line of correlation is thus established between each road meter and the standard apparatus for a speed of 40 mph. Another correlation is established for each machine between the speeds of 30 and 40 mph. For each section studied, then, we have the K_r or Σ-counts expressed in relation to the standard road meter, for an operating speed of 40 mph. In order to follow the development of the standard road meter over a period of time and to ensure its flexibility, we selected checking sections on concrete pavement that was likely to remain practically unchanged over the next few years and on which riding conditions remained very good (varied as little as possible). Figure 7 shows

Figure 6. Correlation of Σ-counts for road meters 1 and 2.

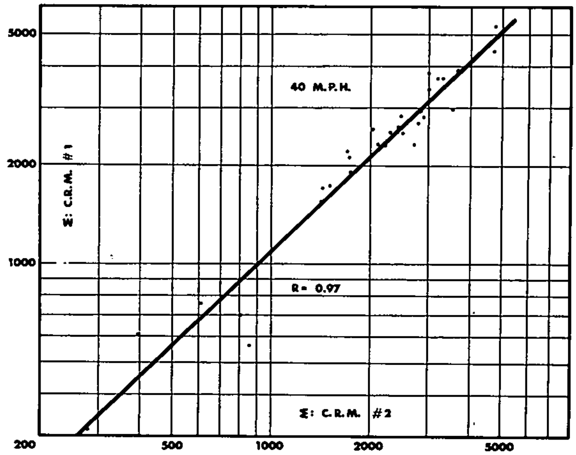


Figure 7. Road meter performance.

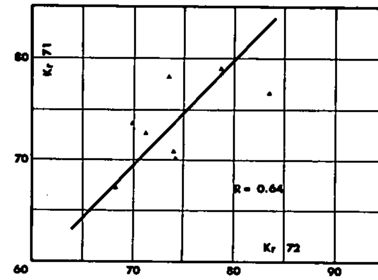


Figure 8. Theoretical relation between RCI and K_r.

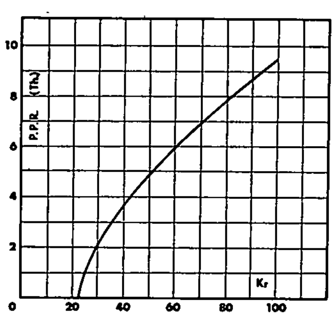
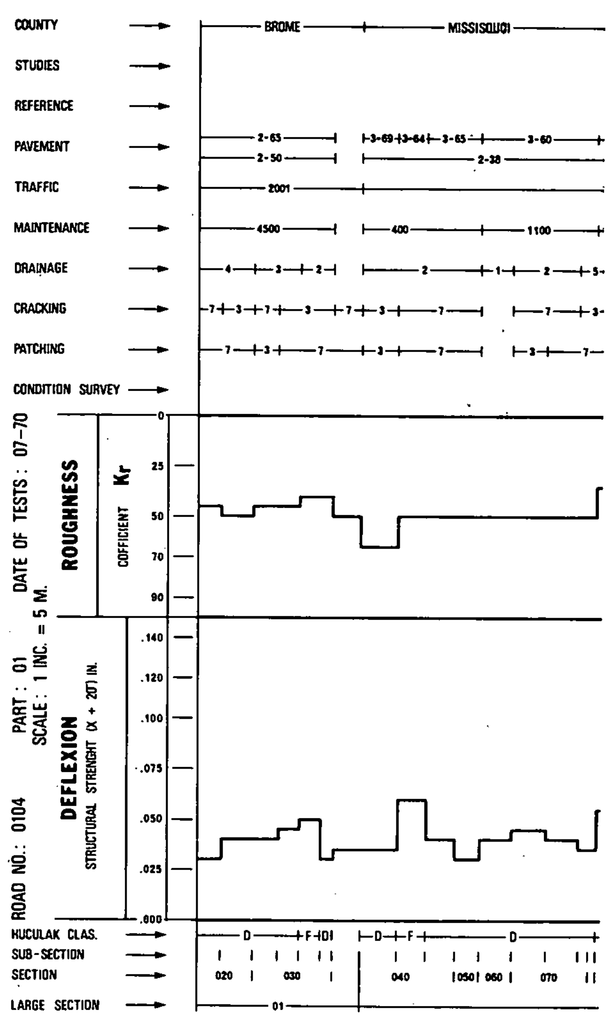


Figure 9. Road diagram.



the standard road meter's performance since 1971. Although these sections are few, there is a marked trend toward a 45-deg line, which shows that road meter readings in 1972 were substantially the same as for 1971. With more points, the line of correlation would be more precise.

K_r-COEFFICIENT IN TERMS OF RCI

In order to demonstrate the similarity between the RCI concept and the value of K_r, a theoretical relation has been established according to the following criteria (Fig. 8):

1. On ideal pavement, RCI = 10;
2. If only one meter is used, K_r = 100;
3. Pavement would be ideal if no reading was recorded;
4. When K_r = 100, it cannot be said that RCI = 10;
5. RCI can always be fixed at 9.5 when K_r = 100;
6. If all the meters record the same reading, K_r = 22, and the road is in very bad condition with an RCI of 0.0; and
7. If each meter (2 through 8) gives half the reading of the preceding one, K_r = 51, and the surface is passable with an RCI of 5.0.

In this way the curve shown in Figure 8 has been drawn, which represents a theoretical relation between K_r and RCI.

ROAD DIAGRAM

Figure 9 is an example of a road diagram that condenses the principal data for the pavement. In addition to the diagram, an overall table will be given for the road network, and a summary of data will be provided for each road in each county in Quebec. These tables will be sent to the planning staff and the road engineers. The road diagram and the tables will be prepared on request once a year and will help the engineers in planning their road maintenance work for the coming year.

SUMMARY

With the help of multiple regression, indications will be used for each of the following indexes: deflection, roughness, drainage, patching, and cracking. The combined indications for each road section that is inventoried will be used in drawing up a list of structural priorities for the entire road network, with criteria given and verified for each variable. Mathematical equations will be used to define the indexes of deflection and roughness in relation to the others. This process will be computer-operated and will also be of help to us in refining our criteria for performance and design.

The initial process should be completed within the next few years, taking account of the following points: improvement of measuring devices, time-stable calibration system, establishment of roughness data survey within a continuing road mass inventory, refinement of data processing, roughness criteria as a guide to road maintenance and as a means for checking pavement condition, a flexible system for adding and assessing other possible data, and constant circulation of information from the data bank with information feedback from the road engineers.

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