Illustration of Pavement Management: From Data Inventory to Priority Analysis

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A typical case history of a pavement management implementation project is summarized. The project covered a major part of the highway system of the province of Prince Edward Island (PEI) and was undertaken in conjunction with the Federal-Provincial Atlantic Provinces Highway Strengthening Improvement Agreement. An extensive field inventory was performed on approximately 500 km of PEI's Trans Canada and major-arterial road networks. These field tests provided the basis for detailed analysis to determine the pavement-improvement needs for the portion of the road network considered over a 10-year programming period. A program of pavement-improvement priorities over the programming period was then determined through economic analysis and an optimization of projects, improvement strategies, and project timing. The effect of budget level was then analyzed by comparing the expected average network serviceability profiles over the programming period at the specified budget level with the case of zero capital budget for both the Trans Canada and major-arterial networks. PEI is one of the first areas in North America to successfully adopt such a comprehensive pavement management system. This indicates that the concepts of pavement management, which have been developed during the last decade, are now being put into practice.

In 1978, Prince Edward Island (PEI) entered into an agreement with Transport Canada to strengthen sections of the Trans Canada Highway. Transport Canada carried out its own cost/benefit analysis, by which the needs of the province were determined. The strengthening then began on a cost-shared basis.

After the problem had been given due consideration, it was decided that the province's future needs would best be served by implementing a comprehensive pavement management system. This exercise, it was thought, would not only generate an adequate objective data base for determining pavement-improvement needs but would also ensure that the province's large investment in the pavement portion of its road network would be protected and that the traveling public would be provided with an adequate level of service.

The pavement management concept was first conceived in the mid-1960s to organize and coordinate the activities involved in achieving the best value possible for the available public funds. Since then, both the public and the private sectors have made extensive efforts in the development of pavement management technology. The purpose has been to provide highway engineers with the tools needed to manage their pavement networks more effectively.

The PEI Department of Highways, like many other highway agencies in North America, has always been in competition with other departments for the limited tax dollars available for public projects. In most instances, these other competing departments have been able to document their cases more effectively and convincingly than the highway department has; the main reason is that the highway department has lacked a systematic and objective approach for determining pavement-improvement needs, establishing priorities for these needs, and clearly illustrating the consequences of failing to implement these priorities.

In the light of these considerations, PEI decided to implement a pavement management system on its highway network. Consequently, a contract was awarded for implementing such a system, initially on approximately 500 km of the province's Trans Canada Highway and major-arterial road system. The remainder of the arterial network will be covered in the next phase of the project.

Although PEI is one of the smallest provinces or states in North America, its highway network provides an excellent self-contained proving ground for pavement management implementation. Moreover, all the elements exist for their network as they do for a much larger network of a big state or province and there is no need to select only a small pilot portion of a much larger network to test the system.

The project started in the fall of 1978 and was completed in 1979. The purpose of this paper is to describe the results of the project, specifically the following:

1. Field inventory scheme used to collect data for establishing the current status of the road network in terms of its surface condition, ride quality, and structural capacity;
2. Procedure used to identify needs for pavement improvements;
3. Evaluation of the rehabilitation alternatives considered for those roads that require immediate action and/or will require rehabilitation within the next 10 years;
4. Priority-analysis technique used, which is based on objective field measurements, detailed economic analysis, and specified budget constraints; and
5. Budget-level analysis used to test the effects of different budget levels on the annual average condition of the network.

FIELD MEASUREMENTS

The program for acquiring field inventory information on the 500.9 km of road involved (a) section identification, (b) deflection measurements, (c) roughness measurements, (d) condition survey, and (e) core sampling.

Section Identification

In the first phase of the field work, 500.9 km of road were divided into sections. Highway department personnel provided the necessary input. Past experience, contract length, and the following factors were considered in the section-identification process: traffic volumes; pavement type, age, and thickness; and geometric characteristics (number of lanes, length, etc.). An attempt was made to identify homogeneous sections on the basis of traffic volume, pavement type and thickness, and geometric characteristics.

Extensive field studies and discussions with department personnel produced 25 sections on the Trans Canada Highway and 73 sections on other routes, which resulted in a total of 98 sections. A detailed list of the sections included in the project are given in a report prepared by Pavement Management Systems (1).

Deflection Measurements

In the spring of 1979, deflection measurements were taken in the outer wheelpath of each road section by using a Dynaflect unit. An average of six tests per kilometer was taken.

Roughness Measurements

The automatic road-analyzer (ARAN) unit was used in the summer of 1979 to measure road surface roughness on one full lane length of each road section. This involved sampling at 50-m intervals at a travel speed of 50 km/h.

The ARAN unit (2,3), which has been used extensively across North America, has the capability of simultaneously obtaining data on surface roughness and condition, skid resistance, grade angle, and transverse profile (including rut depth and cross slope) at normal travel speeds on an automated basis. This unit is housed in a Ford van and measures roughness by use of an accelerometer. The data are recorded in digital form. The unit has an on-board intelligent computer terminal that has a keyboard plus an acoustic coupler transmission system. It also has hard-copy recording and on-board editing capabilities by using specially developed software. Extensive repeatability measurements at various speeds and roughness levels have been made on the unit in cooperation with the Ministry of Transportation and Communications of Ontario. These indicated a high degree of repeatability and the fact that the unit can be used over a wide speed range (i.e., can "float" in traffic).

Condition Survey

The surface condition of each road section was also rated by evaluating and recording various types of surface defects or distress on a specially developed keyboard in the ARAN unit. Each type of distress, the extent, and the severity were actually recorded in coded form on the keyboard.

Core Sampling

One core per kilometer or a minimum of one core per section was taken to determine the layer thicknesses of the existing pavements. Subgrade soil type and the condition of the materials in the existing pavement structure were also determined by inspection in the field.

ANALYSIS OF DATA

Structural-Adequacy Analysis

The deflection readings taken on each road section were first adjusted to a spring value by multiplying by a spring/fall ratio. The mean, standard deviation, and design deflection ($\bar{x}$ + 2s) for the adjusted deflection measurements were then calculated for each road section.

These adjusted deflection measurements were then used with the appropriate traffic data (supplied by the department) to determine the structural-adequacy rating (SAR) of each pavement section. The SAR for a pavement section reflects the degree of structural deficiency, if any, that exists in the pavement structure. (SAR values that range between 0 and 4.9 indicate structural inadequacy, whereas values between 5.0 and 10.0 indicate structural adequacy.) Pavement Management Systems has detailed descriptions of the method used to calculate the SAR (1,4). Table 1 presents 1979 SAR values for all road sections analyzed in the project.

Riding-Comfort-Index Analysis

The ARAN roughness data collected on each road section were first edited to check for errors that might have occurred in the field. High roughness readings due to extreme external effects (i.e., railway crossings, etc.) were eliminated from the data.

Speed corrections were made to convert readings at actual test speeds to roughness at 50 km/h. A mean roughness value was then calculated for each section. The mean ARAN roughness value for each section was converted to a riding-comfort-index (RCI) value by using a previously established correlation between ARAN roughness and subjective panel ratings. This relationship, which was developed specifically for PEI conditions, can be found in a Pavement Management Systems report (5). Table 1 presents 1979 RCI values for all road sections analyzed in the project. The RCI ranges between 0 and 10; a value of 0 indicates the worst imaginable riding comfort, whereas a value of 10 indicates a perfectly smooth pavement (6).

Condition-Index Analysis

The condition survey data collected on each road section were edited at the same time as were the ARAN roughness data. The codes assigned to the various types, amounts, and severities of distress surveyed were then translated into numerical values. These condition indices (CIs) varied between 0 and 10. A value of 10 indicates no observable amount of a particular type of distress, whereas a value of 0 indicates very severe and extensive amounts of a particular type of distress.

The index values assigned to the 10 different distress types were then weighted according to the importance of each type of distress and combined into one CI. (See Table 1 for the average CIs calculated for all pavement sections analyzed in the project.)

Overall-Serviceability Analysis

In this project, the overall serviceability of a pavement section was assumed to be a function of its structural adequacy and riding comfort. The overall serviceability index (SI) is expressed as follows:

$$SI = a(RCI) + b(SAR) \quad (1)$$

where the overall SI is measured on a scale of 0-10, on which 10 represents a perfectly smooth and strong pavement and 0 represents a totally unacceptable pavement, and a and b are weighting factors (a + b = 1.0).

The weighting factors generally depend on the agency's policy and objectives. Some agencies give more weight to the user by assigning a higher weighting factor (a) to the RCI. Similarly, the structural characteristics may be more important to other agencies. This can be reflected in the calculations of overall SI by using a higher weighting factor (b) for SAR.

In PEI, different levels of weighting factors were used for different levels of RCI. The weighting factors used in the project for four levels of RCI and SAR are given below. These reflect the relative importance of RCI for very rough pavements and, conversely, the relative importance of SAR for smoother (but possibly weaker) pavements.

	Weighting Factor	
RCI Level	a (for RCI)	b (for SAR)
<4.0	1.0	0.0
4.1 - 6.0	0.6	0.4
6.1 - 8.0	0.4	0.6
>8.0	0.0	1.0

The SI of each road section was then calculated from Equation 1 and Table 2:

RCI = 5.3, SAR = 7.1: SI = 0.6 x 5.3 + 0.4 x 7.1 = 6.0
RCI = 3.5, SAR = 5.0: SI = 1.0 x 3.5 + 0.0 x 5.0 = 3.5.
RCI = 8.5, SAR = 6.2: SI = 0.0 x 8.5 + 1.0 x 6.2 = 6.2.

(See Table 1 for 1979 values of SI for all road sections analyzed in the project.)

Minimum Acceptable SI

Minimum acceptable SIs of 5.0 and 4.5 were used in the analysis for Trans Canada and major-arterial sections, respectively. Hence, a section on the Trans Canada Highway that had a present SI (PSI) of 5.0 or less was identified as requiring a major rehabilitation in 1979. Similarly, a Trans Canada section that had an acceptable SI in 1979 may have become a candidate project for rehabilitation if its predicted SI dropped to 5.0 or less within the 10-year programming period.

INPUT DATA TO PROGRAM

The types of input data obtained from the department were as follows: traffic information, alternative rehabilitation strategies, cost information, and budget information.

Traffic Information

The traffic data obtained for each section included average annual daily traffic (AADT), percentage of annual growth, and percentage of commercial traffic. The information was provided by the department's traffic personnel and was used directly in the project without any modifications. The most-recent traffic counts were employed in the AADT calculations. An AADT estimate was provided by the department for those sections that had no traffic counts.

Available Rehabilitation Strategies and Costs

The following five alternative rehabilitation strategies for each road section considered in the project were analyzed by the priority program: overlay type 1, overlay type 2, overlay type 3, reconstruction, and surface treatment. For PEI conditions, these were defined as follows:

1. Overlay type 1: Asphalt concrete overlay 39 mm thick placed on top of the existing pavement at a cost of $\$2.75/m^2$;

Table 1. Summary of results of sectional inventory analysis.

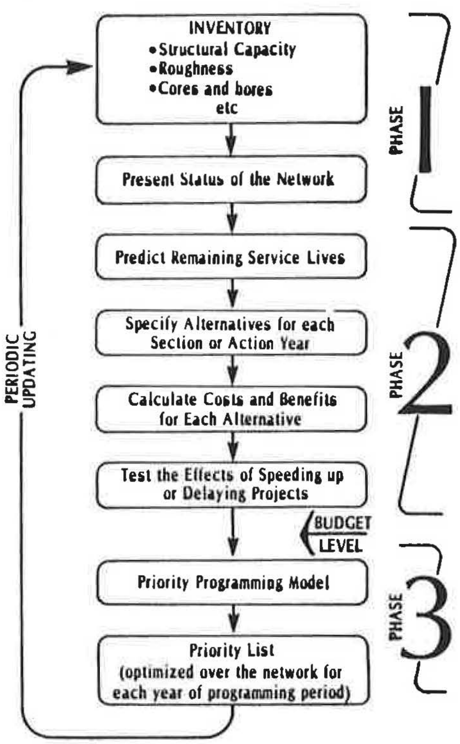
Section	CI	RCI	SAR	SI	Section	CI	RCI	SAR	SI
0001	2.8	2.6	0.5	2.6	0050	8.0	7.4	7.5	7.5
0002	3.8	3.0	0.8	3.0	0051	8.4	7.5	8.0	7.8
0003	4.8	2.8	0.5	2.8	0052	8.2	8.2	5.8	5.8
0004	3.3	4.9	2.3	3.9	0053	8.5	7.7	4.3	5.7
0005	3.0	3.7	1.0	3.7	0054	4.3	5.1	4.3	4.8
0006	4.2	5.1	0.0	3.1	0055	10.0	5.0	2.0	3.8
0007	4.2	5.4	1.3	3.8	0056	6.3	6.0	6.3	6.1
0008	4.2	4.7	0.5	3.0	0057	4.1	5.0	5.0	5.0
0009	3.7	6.8	0.8	3.2	0058	8.2	5.5	6.3	5.8
0010	7.2	6.5	3.5	4.7	0059	10.0	7.8	6.3	6.9
0011	7.9	6.8	0.0	2.7	0060	10.0	7.7	7.0	7.3
0012	6.6	6.7	0.0	2.7	0061	10.0	7.8	6.3	6.9
0013	5.7	4.2	0.0	2.5	0062	9.9	8.4	5.3	5.3
0014	4.1	4.1	1.5	3.1	0063	2.8	2.9	5.0	2.9
0015	6.4	4.9	1.8	3.7	0064	10.0	8.6	5.0	5.0
0016	4.4	4.1	0.0	2.5	0065	10.0	7.7	1.5	4.0
0017	4.0	5.4	1.0	3.6	0066	10.0	8.1	7.8	7.8
0018	2.1	2.9	3.3	2.9	0067	10.0	8.1	4.8	4.8
0019	5.9	3.0	3.0	3.0	0068	10.0	5.4	5.5	5.4
0020	9.7	7.9	4.3	5.7	0069	10.0	5.3	4.8	5.1
0021	4.2	4.6	1.8	3.5	0071	6.2	6.5	4.3	5.2
0022	7.6	1.8	0.8	1.8	0072	3.1	3.4	1.8	3.4
0023	3.6	3.7	4.0	3.7	0073	3.5	5.4	4.8	5.2
0024	9.6	7.3	5.0	5.9	0074	6.1	5.6	0.8	3.7
0025	3.6	3.5	3.5	3.5	0075	3.7	4.6	4.3	4.5
0026	2.7	3.8	2.0	3.8	0076	4.1	5.3	0.3	3.3
0027	5.7	4.3	0.5	2.8	0077	5.7	3.9	0.0	3.9
0028	4.8	4.0	0.8	4.0	0078	5.5	6.3	4.3	5.1
0029	7.3	4.4	4.8	4.6	0079	4.8	5.9	1.0	3.9
0030	7.2	4.9	5.0	4.9	0080	5.3	6.8	4.8	5.6
0031	5.4	6.0	5.0	5.6	0081	4.3	5.6	0.5	3.6
0032	6.0	6.9	4.5	5.5	0082	7.6	6.0	0.3	3.7
0033	5.0	7.3	3.5	5.0	0083	4.9	4.5	2.8	3.8
0034	6.3	7.4	2.3	4.3	0084	7.3	4.1	0.5	2.7
0035	6.0	7.4	1.3	3.7	0085	9.8	7.7	1.0	3.7
0036	4.0	6.2	0.8	3.0	0086	6.8	4.9	0.5	3.1
0037	6.3	7.5	0.8	3.5	0087	6.2	5.6	1.0	3.8
0038	10.0	7.3	2.0	4.1	0088	7.6	5.0	0.5	3.2
0039	10.0	7.4	1.5	3.9	0089	4.2	3.2	0.8	3.2
0040	10.0	7.9	5.0	6.2	0090	4.5	3.6	0.5	3.6
0041	10.0	8.1	6.5	6.5	0091	3.9	4.1	0.5	2.7
0042	7.6	5.9	1.5	4.1	0092	4.2	3.8	1.3	3.8
0043	9.6	7.0	4.5	5.5	0093	2.6	3.2	1.3	3.2
0044	8.8	7.4	2.5	4.5	0094	1.7	2.5	1.5	2.5
0045	3.6	5.9	2.3	4.5	0095	2.0	2.2	1.0	2.2
0046	4.5	5.7	5.0	5.4	0701	5.2	3.0	1.0	3.0
0047	7.0	6.3	3.8	4.8	0702	4.5	1.9	3.5	1.9
0048	6.6	4.7	1.3	3.3	0703	7.1	2.4	8.0	2.4
0049	7.2	4.1	1.5	3.1	0704	5.7	3.1	8.5	3.1

Note: CI = condition index; RCI = riding-comfort index; SAR = structural-adequacy rating; SI = serviceability index.

Table 2. Pavement rehabilitation improvement priorities by section over 10-year programming period (Trans Canada sections).

Year	Section Number	Type of Rehabilitation	Percentage of Rehabilitation
1979	55	A4	97
	63	A4	-
	701	A4	-
	702	A4	-
	703	A4	-
	704	A4	-
1980	54	A4	54
	55	A4	3
	57	A4	-
	64	A4	20
	65	A4	-
1981	54	A4	46
	56	A3	-
	61	A3	-
1982	58	A4	-
	62	A4	92
	64	A4	80
	67	A4	-
1983	52	A4	57
	62	A4	8
	71	A4	-
1984	60	A3	-
	66	A3	-
	68	A4	83
1985	52	A4	13
	53	A4	-
	68	A4	17
	69	A4	-
1986	52	A4	30
	59	A4	-
1987	-	-	-
1988	-	-	-

Figure 1. General structure of system.



2. Overlay type 2: Asphalt concrete overlay 89 mm thick placed on top of the existing pavement at a cost of $\$6.40/m^2$;

3. Overlay type 3: Asphalt concrete overlay 140 mm thick placed on top of the existing pavement at a cost of $\$10.03/m^2$;

4. Reconstruction: Completely new pavement (including paved shoulders on Routes 1, 1A, 2, 3, and 4) that has a structural design of 152-mm asphalt concrete surface and 254- to 305-mm base (existing in situ surface material is used as base after pulverization); costs of reconstruction were \$18.81, \$16.72, and $\$16.30/m^2$ for Trans Canada sections, major-arterial sections, and shoulders, respectively; and

5. Surface treatment: Double 9.5-mm chip seal that cost $\$2.00/m^2$.

Budget Information

An expected rehabilitation budget of \$3 600 000 was suggested by the department for the 119.4 km of Trans Canada sections considered in the project. Similarly, \$860 600 was assumed to be allocated to the sections on the major-arterial road network in the province. Although these figures were suggested specifically for 1980, they were assumed to remain constant (i.e., inflation was not included in budgets and costs) over the 10-year programming period.

NETWORK MANAGEMENT SYSTEM

The network management system described by Karan and Haas (7-9) is basically composed of three main phases (see Figure 1).

It starts with inventory work on the identified sections. Deflection measurements for determining SAR values, used to identify ride quality, and coring and boring constitute the major elements of this inventory.

The present status of the network is then determined from these inventory data. The PSI of each section in the network is calculated and will be described subsequently.

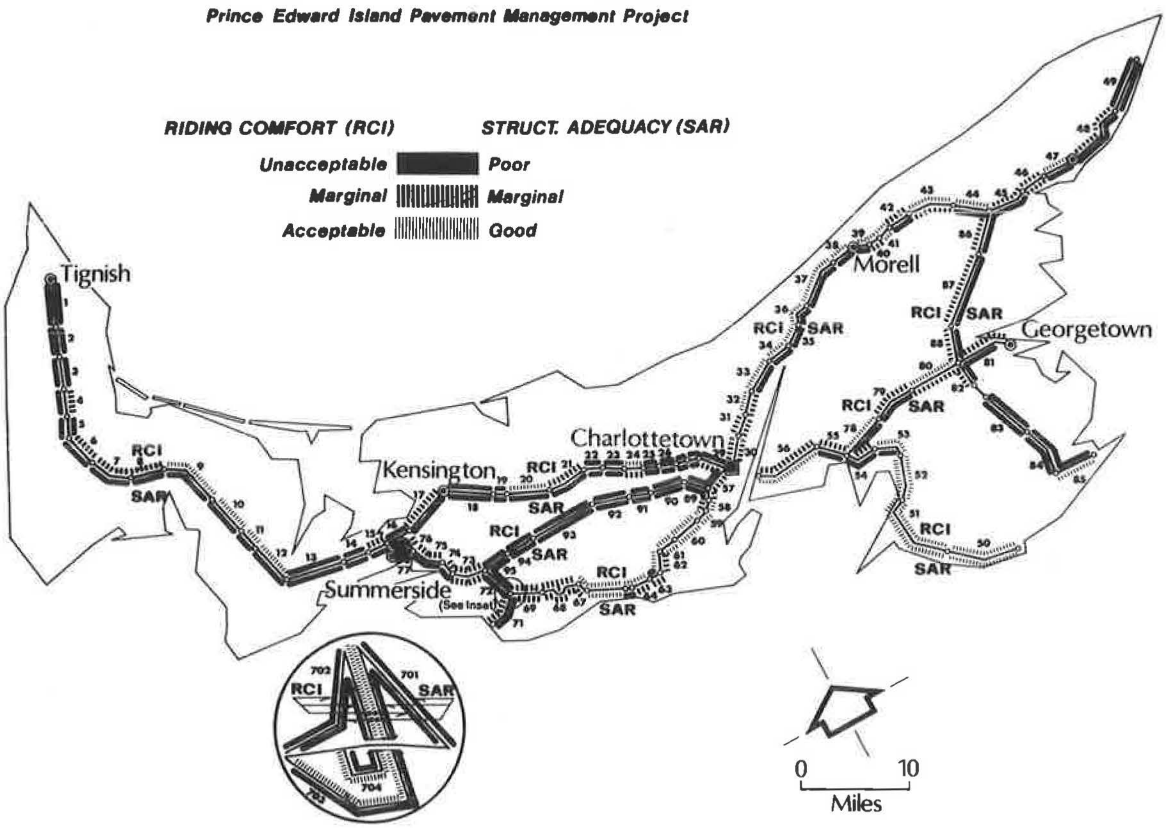
The remaining service life of each section is predicted by a performance-prediction submodel. This model, which is based on engineering experience, starts with the PSI of the section. Then, by using a technique known as Markov modeling, SI levels in future years are predicted. The remaining service life is then defined as the time required for a section to drop from its PSI to the minimum acceptable SI.

The sections that reach their minimum acceptable SI within the programming period of 10 years become candidate projects and are selected for further analyses. The five alternative rehabilitation strategies described previously are generated for each candidate project, and an economic analysis is conducted.

One of the most attractive features of the system is its capability for testing the effects of project timing. This means that a project does not have to be rehabilitated in the year in which it first reaches its minimum acceptable SI. It can be delayed (by using extensive routine maintenance) and may not be rehabilitated at all (in the programming period), depending on the economics involved and the budget available. Such factors as increased maintenance costs associated with the delay need to be taken into account in this case.

Similarly, a project can be rehabilitated before it reaches its minimum acceptable SI if adequate funds are available. The program allows the user to specify the number of acceleration years desired in the analysis (projects were allowed to accelerate a maximum of five years in this analysis). Each road section analyzed in the program is then accelerated by the specified number of years, and detailed analyses are conducted starting from that year if the serviceability level for that year is not greater than a previously set limit. An upper SI

Figure 2. Riding comfort and structural adequacy of Trans Canada and major-arterial sections.



level of 6.5 was used in this project.

Economic analyses are conducted for each implementation year and for each combination of project and rehabilitation strategy. The output of this phase is a list of sections (projects), alternatives and their direct costs to the agency, and user benefits (i.e., savings in vehicle operating costs due to improved pavement conditions) for each possible implementation year in the programming period of 10 years.

In the third phase, this information is used in a mathematical-optimization (linear-programming) model that establishes pavement-improvement priorities on the basis of benefit maximization and budget constraints. This model also recommends an optimum rehabilitation strategy for each project (section) considered in the analysis.

The final output of the system, therefore, is an optimum rehabilitation strategy and implementation year for each project. It is based on the maximization of user benefits and at the same time ensures that the agency will stay within its budget in each year throughout the programming period.

PRINCIPAL FINDINGS

Present Status of Network

In general, the Trans Canada sections analyzed in the project were found to be in a better condition than the major-arterial sections were. The average SAR and RCI levels calculated for these sections were significantly higher than the averages calculated for major arterials. The average SAR on Trans Canada was 5.2 as opposed to one of 2.1 on arterials. Similarly, the average RCI on Trans Canada was 5.9, whereas major arterials had an average RCI of 5.3.

The 1979 CI, RCI, SAR, and SI levels for both Trans Canada and major-arterial sections were presented in Table 1. The 1979 RCI and SAR levels are also presented in a coded form in Figure 2. This figure indicates that the Trans Canada sections are generally stronger (for the traffic volume that they carry) than are the major-arterial sections. They also provide a better ride for the user than do the major-arterial sections. As a result, the overall SIs of the Trans Canada sections are higher than they are for the major-arterial sections.

Of the 25 Trans Canada sections analyzed in the project, 11 were found to have PSIs of less than 5.0. Thus, they were candidates for immediate rehabilitation, since these levels are unacceptable.

Similarly, 57 of the 73 major-arterial sections had unacceptable SI levels (below 4.5). These were also candidates for rehabilitation in 1979.

The 11 Trans Canada and 57 major-arterial sections that had unacceptable PSI levels were identified as candidate projects for 1979. The other sections became candidate projects in the year in which they were expected to reach their minimum acceptable levels. In the following, the candidate projects for each year in the programming period of 10 years are described.

Determination of Need for Rehabilitation

The road sections that had PSI values that were greater than their minimum acceptable levels were analyzed in the program by using the Markov model to predict their future performance curves. A road section was identified as requiring a rehabilitation in the year in which it reached its minimum acceptable level (i.e., when the predicted performance curve crossed the minimum acceptable level).

The pavement-rehabilitation needs for Trans Canada sections are as follows: 1979, sections 54, 55, 57, 63, 64, 65, 67, and 701-704; 1981, sections 52, 53, 58, 62, 68, 69, and 71; 1983, sections 56, 59, and 61; and 1986, sections 60 and 66. The total is 23. This means that only two sections (50 and 51) had reasonably high SI levels and thus were not expected to reach their minimum acceptable levels within the 10-year programming period. They are not listed above and were excluded from the analyses.

All 73 major-arterial sections considered in the project were found to require rehabilitation within the programming period. Of this total, 57 sections were identified as requiring rehabilitation in 1979. The remaining 16 sections that appeared to have acceptable SI levels were expected to reach their minimum acceptable SI levels within the first five years of the programming period.

Pavement Improvement Priorities

The sections listed above would have been the priority list for Trans Canada sections if unlimited funds were available. Under budgetary constraints, however, some projects could not be built in the year in which they required major rehabilitation. They may have been delayed in time or not scheduled for rehabilitation at all, depending on the funds available.

Table 2 gives the recommended pavement-improvement priorities from application of the optimization model for the Trans Canada sections. Inspection of Table 2 indicates that only 6 of the 11 projects identified as candidate projects in 1979 could actually be built in that year. Hence, they were delayed and scheduled for subsequent years, depending on their economics. Section 57, for example, was delayed until 1980 and section 67 was delayed until 1982.

Also given in Table 2 is the type of rehabilitation applicable to each section scheduled for rehabilitation within the 10-year programming period. A 140-mm overlay (A3), for example, was recommended for section 56 in 1981. Similarly, reconstruction (A4) was recommended for section 63 in 1979.

The incremental solutions given in Table 2, which result from the budget constraints, may appear to be unrealistic. Of section 52, 57 percent, for example, was scheduled for reconstruction in 1983. This could be handled by reconstructing one-half of the section in 1983 and the other half in 1984, which could allow payment to be made from both the 1983 and the 1984 budgets. Another possibility is full reconstruction in 1983 with partial payment made in 1983 and the balance payable on January 2, 1984, or on the first day of the 1984 fiscal year. This could then be accounted for as a carry-over cost on the 1984 budget, a common practice in some areas of the country.

However, these approaches may be impractical in a contractual sense. Probably the best plan would be to award contracts on the other section (i.e., 71) first, compare the total bid price with the cost estimate, and then decide whether sufficient funds are still available to award a contract on section 52 or to delay it until 1984. If there were sufficient funds, another alternative would be to award a contract on one of the smaller jobs for 1984 (i.e., advance it to 1983).

This type of situation will always exist, since it is impossible to estimate costs and/or bid prices precisely. Also, there is always some error attached to estimating the future performance of any pavement and hence the action year in which rehabilitation is expected to be required. For these reasons, annual updating of both the actual costs and the network inventory and the priority analysis in turn is desirable. In other words, the priority list generated in any analysis is not necessarily the final solution, no matter how objectively it is based. Not only must it stand the test of reasonableness, per se, but the engineer, administrator, or politician must exercise the final responsibility for selecting the program of work and exercise the necessary judgment in making modifications where required (such as that discussed in the preceding paragraph).

The program scheduled all the 23 sections identified as candidate projects in the previous section. The periodic updating referred to in Figure 1 may, however, result in changes in the priority list of Table 2.

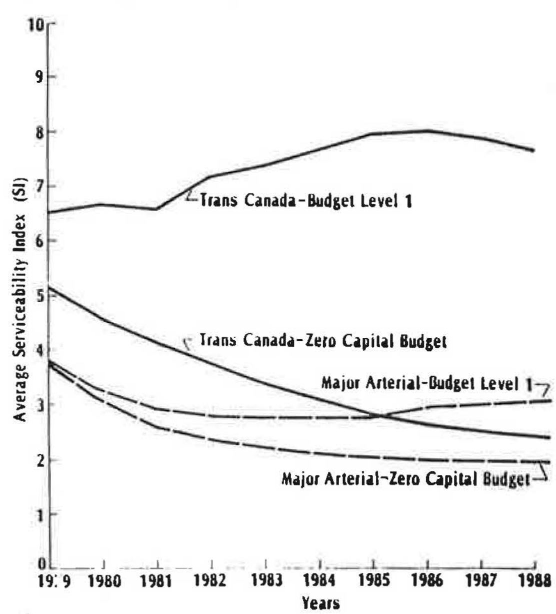
A similar priority list was developed for pavement improvements on the arterial sections. Fifty-nine of the major-arterial sections were not included on that priority list. This was because the budget available within the 10-year programming period was not enough to build all the major-arterial candidate projects analyzed. However, the same considerations regarding annual updating and exercising of judgment to make modifications where necessary, as previously discussed for the Trans Canada Highway sections, apply to these major-arterial sections. Of the 57 sections identified as requiring rehabilitation in 1979, only 6 were actually scheduled. The remainder of the projects were delayed or not scheduled at all, depending on their economics.

Budget-Level Analysis

The average SI levels for the Trans Canada and major-arterial networks in each year that would result from the implementation of the recommended priority lists are shown in Figure 3. The current mean serviceability level of the Trans Canada sections (about 5.2) was higher than that of the major-arterial sections (about 3.8), as mentioned earlier. The difference, however, increases significantly over the years as more and more Trans Canada sections are rehabilitated.

The implementation of the Trans Canada priority

Figure 3. Budget-level analysis for Trans Canada and major-arterial sections.



list in 1979, for example, would have increased the 1979 mean serviceability level to 6.5, whereas major-arterial sections would not have shown a significant increase in their 1979 mean serviceability level. The budget level used for Trans Canada sections (i.e., budget level 1 in Figure 3) resulted in a significant improvement in the mean serviceability levels over the 10-year programming period. The budget level used in the analysis for major-arterial sections (i.e., budget level 1) does not appear to have been sufficient to maintain the current status of the sections. Although there was an improvement compared with the case of zero capital budget (nothing is done except routine maintenance), the allocation of more funds to the major-arterial network appears to be justifiable.

Although the case of zero capital budget is an extreme one, it provides a good illustration of how a currently good road network could be allowed to deteriorate to an unacceptable level if funds for rehabilitation were cut off, which has in fact happened in some areas of the United States. An additional impact of such an action would be significantly higher user and maintenance costs and the likelihood of losing much of the existing investment (i.e., complete reconstruction would eventually be required).

SUMMARY AND IMPLICATIONS FOR THE FUTURE

The pavement management implementation project described in this paper was undertaken to provide PEI with

1. An objective data base for determining pavement improvement needs, and
2. An objective means for determining the most economical combination of projects, improvement strategies, and times of implementation for the portion of the road network considered.

The project involved a field inventory on some 500 km of PEI's Trans Canada and major-arterial networks, analyses of the inventory data to establish the improvement needs within a 10-year programming period, an economic analysis to determine the optimum list of pavement-improvement priorities, and an assessment of the effectiveness of the expected budget with regard to the average network serviceability.

The results of the project described in this paper have some major implications. The general one is the guidance provided for future management of the province's network of paved roads.

However, the results also indicate that if funds for rehabilitation of Trans Canada sections are decreased, the average serviceability level of these sections could decrease very substantially (Figure 3). Also, the arterial sections will further deteriorate below their current low level for the level of funding expected.

The investment the province has in its system of paved roads, the growing importance of this system, the increasing cost of maintaining it at a desirable service level, and its benefit to the province cannot be overemphasized. In our cost- and energy-conscious society, pavement management systems will continue to increase in importance to highway administrations at all levels of government. PEI is one of the first provinces to adopt such a complete system. Based on the success of this implementation project, the province is considering the expansion of this system to its entire network of paved roads.

The province has also recognized the importance in updating its inventory annually, since costs are constantly changing, some error in performance predictions is always likely, and the performance-prediction models can be readily defined as more field data become available. To this end, the province is attempting to expand its inventory equipment and field-testing capabilities so that by 1981 this annual inventory updating can be accomplished in-house.

The project and its resulting implications illustrate how the concepts of pavement management developed over the past decade have come of age and are now being used to provide an objective and systematic means for planning and justifying pavement-network expenditures.

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