A Combined Life Cycle Cost and Performance Approach for Selection of Optimal Flexible Pavement Strategies

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Pavements are complex structures subjected to diverse loading and environmental conditions. Pavement structural design should handle this complexity in a rational way. The evaluation procedure used must enable the selection of a pavement design option that provides adequate performance as well as adequate distribution of life cycle cost. The research described in this paper was based on the development of an evaluation model that incorporated future maintenance activities in the initial design concepts to achieve structural safety, riding comfort, and economical costs during the life cycle span of flexible pavement structures, which is the predominant type of pavement in Egypt. Due to the complexity of the problem and the amount of data to be analyzed, a computer program was developed to calculate the life cycle costs of different flexible pavement design alternatives. A second program was developed to transform the first program from a cost model to a decision support model. This program uses two decision support models to select the design option that achieves the best combination of cost, performance, and time for the considered maintenance policy. Other models are provided to help the decision maker analyze the information and make the optimal selection among all possible maintenance policies.

The road network in Egypt includes about 27 000 km of roads, of which approximately 13 000 km are paved. The Egyptian Roads and Bridges Authority (RBA) is currently improving the road maintenance and rehabilitation standards of the paved roads. Due to these efforts, pavement condition has improved; it is estimated that about 60 percent of the network is now in good condition (including most of the dual carriageways), 30 percent is in fair condition, and 10 percent is in poor condition (*1*).

These improvements are a result of the maintenance program recommended by the Development Research and Technological Planning Center (DRTPC) of Cairo University for the analysis period (1982 to 1991) (*2–5*). To facilitate the improvements, RBA established a project to review and evaluate existing manpower and training facilities so a systematic approach could be developed to meet future manpower and training demands (*6*). It is believed that a practical training management system can have a significant impact on improved standards of performance, increased productivity, and maximum cost effectiveness of highway maintenance.

Although improvements have been made, traffic volumes have doubled in the past 4 to 5 yr, which accelerates the rate of pavement performance loss. In addition, severe economic restraints have been imposed on the local highway network due to decreased revenues, high inflation, and an increase in the need for maintenance and rehabilitation on the existing network. Also, in spite of the new program, pavement-related activities (design, construction, maintenance, and rehabilitation) are still being conducted on the basis of subjective assessment of engineering experience.

RESEARCH OBJECTIVES

The primary objective of this research was to incorporate future maintenance activities in initial pavement design concepts to achieve structural safety, riding comfort, and economical costs during the life cycle span of flexible pavement structures. Accordingly, the second objective was to develop an evaluation model to help RBA evaluate and select the optimal combination of pavement structural design and maintenance policy to produce flexible pavement structure with adequate performance as well as adequate distribution of life cycle cost.

DESIGN AND DETERMINATION OF LIFE CYCLE COST

To achieve the research objectives, the following two tasks were completed:

1. An initial design/overlay procedure that included the development of a model to forecast serviceability/time (traffic repetitions) on any given pavement structure during the analysis period. This procedure involved serviceability predictions as well as prediction capabilities for overlaid sections. In the development of this task, the AASHTO pavement design-analysis concept (*7*) was used as the initial methodology because of its broad experience base and general acceptance in Egypt. Some modifications were made regarding pavement strength coefficients and subgrade effects on this strength as determined by the multilayered elastic theory concepts. In addition, the remaining life concept was used in association with the AASHTO design equation to allow serviceability/time to be forecast over the life of the overlaid pavement structure.
2. The establishment of costing models to estimate the pavement's cost and design life. This task included the establishment of the following models:

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- A construction cost model using current unit costs of the selected materials;
- An overlay cost model using current unit costs of the selected materials and adapted models that estimate leveling costs and traffic handling costs at the time of overlay;
- A salvage cost estimation;
- A routine maintenance cost responsive model, designed to assist in the maintenance management system (MMS) as a part of the overall pavement management system (PMS), that can be defined as "a technique or operational methodology for managing, directing, and controlling maintenance resources for optimal benefits" (*8*) by providing desired maintenance policies based on specific standards;
- A user cost model to predict the added user costs associated with overlay construction; and
- A user cost model based on locally available data to predict the running user costs from normal operation of specific two-lane roads, in addition to other sets of models for other types of roads.

LIFE CYCLE COST PROGRAM

The models described above were aggregated to develop the required life cycle cost (LCC) computer program. An original version developed for the Maryland State Highway Administration (*9*) was modified to reflect Egyptian conditions.

The LCC program contains two subsystems:

1. Structural design/overlay (based on AASHTO concepts), and
2. Highway cost (based on local and internationally adapted models developed for construction, routine maintenance, and user costs).

The program can consider an initial construction (and overlay) problem or an overlay (over an existing pavement structure) problem only.

Any combination of inflation and discount rates can be considered, and the equivalent single-axle load (ESAL) of any traffic record can be computed. Routine maintenance costs can be calculated for any number of responsive maintenance policies. Also, a single model for computing costs of routine maintenance can be used. User costs are calculated for different area and road types, and updating facilities are included for all models.

DECISION SUPPORT METHODOLOGY

As part of this research, the benefit of the LCC program was generalized from a cost model to a decision support model. A decision support model not only generates the needed information but helps the decision maker analyze the information and make the optimal selection. An evaluation procedure must be followed to determine the desirability of the different alternative strategies and to provide the information to the decision maker in a useful, comprehensive form. Furthermore, the evaluation procedure should be tailored to the agency's objectives and goals.

Selection Within One Maintenance Policy

Optimization techniques that ensure a least cost or maximum benefit/cost ratio for each agency should be considered while meeting minimum condition management constraints. As the PMS is used, the identification of future budget needs is likely to be a significant step toward allocating the current year's budget. A comparison between the agency's actual cash flow and the expected cash flow for each alternative will economically finalize the selection of the optimal alternative.

Figure 1 illustrates the performance curve for any given pavement. Costing and serviceability values are shown on the curve. As can be seen, some costs result from constructing the new pavement (or rehabilitating the old pavement) and some from keeping the pavement in good condition. Thus, utility (*U*) can be divided into two phases. The first phase

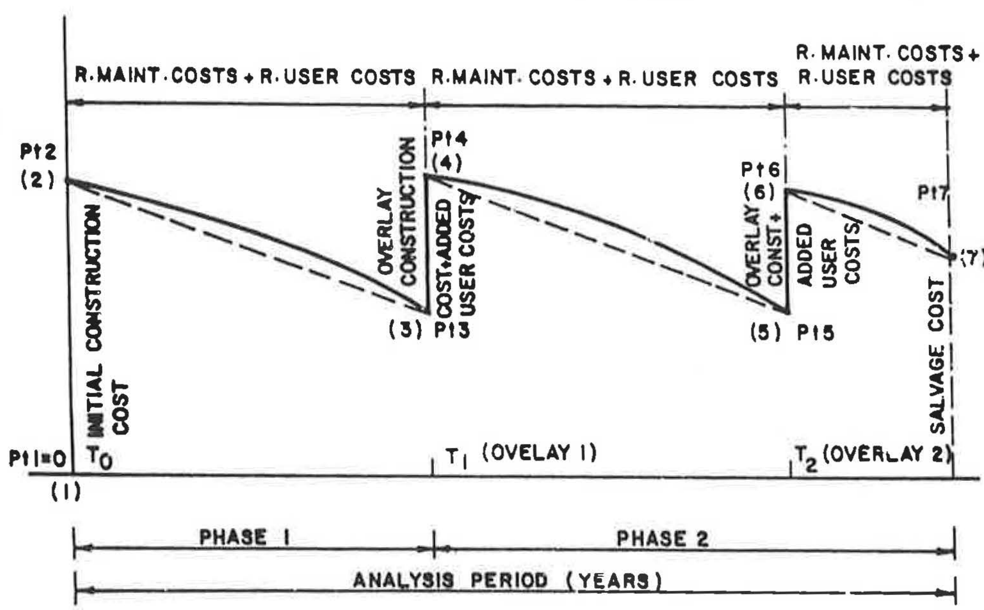

FIGURE 1 Performance curve and costing items (initial construction).

includes initial construction, routine maintenance, and running user costs. Through this phase, serviceability is decreased from P_{t2} to P_{t3}. Thus the utility of this phase can be presented by the sum of (initial construction costs + routine maintenance costs + running user costs) divided by the drop in the level of serviceability ($P_{t2} - P_{t3}$) for time T_1. In the next phase, several utilities may be incurred when each overlay is constructed at time T_2. At the end of the second phase, negative salvage cost is considered as a negative utility. On the basis of Figure 1, the following model can be obtained, assuming a linear drop in serviceabilities and a linear relationship between utility and time:

$$U_j = \left[\frac{C(I + M + R)/T_1}{P_{t(k)} - P_{t(k+1)}} + \sum_{i=1}^{n-1} \frac{C_i(O + M + R)/T_i}{P_{t(k)} - P_{t(k+1)}} + \frac{(C_n(O + M + R) - SC_j)/T_n}{P_{t(k)} - P_{t(k+1)}} \right]_j \quad (1)$$

where

U_j = utility of alternative j;
$C(I + M + R)$ = initial construction costs + routine maintenance costs + running user costs, calculated for alternative j during the intercepted time (T_1);
$P_{t(k)}$ and $P_{t(k+1)}$ = two successive serviceability levels measured at the beginning and end of the regarded intercepted time;
$C_i(O + M + R)$ = overlay construction costs + routine maintenance costs + running user costs, calculated for overlay i executed in alternative j during an intercepted time (T_i);
$C_n(O + M + R)$ = same as above but calculated for the last overlay (n) executed in alternative j during the intercepted time (T_n); and
SC_j = salvage cost value of the analysis period, which may be positive, zero, or negative.

On the basis of the LCC and cost/performance models, the considered number of alternatives was limited to two (or possibly one):

- One representing the least cost/time, and
- One (which may be the same) representing the highest cost/performance ratio.

If two alternatives are available, the decision maker will have to select one of these two options. This selection should be based on a technique known as time stream analysis, by which the second decision model is developed.

The AASHTO performance equation (*7*) illustrates that time is an important parameter affecting the performance of flexible pavements. On the basis of this concept, time stream analysis should be performed for each alternative to measure the effect of time on the performance of the considered pavement, in other words, to measure how the degree of desirability for the given strategies varies with time.

Because the number of performance curves may vary from one alternative to another, the average value of the performance/time ratio is considered for each alternative as follows:

$$PT_j = \sum_{i=1}^{n} PT_{i,j}/n \quad (2)$$

where

PT_j = average performance/time value for alternative j,
$PT_{i,j}$ = performance/time value for stage i of alternative j, and
n = total number of stages included in alternative j.

The term $PT_{i,j}$ can be determined by measuring the inclination of the chord of performance curve (stage), i.e., chords 2–3, 4–5, or 6–7 in Figure 1. Thus,

$$PT_{i,j} = (P_{t(k)} - P_{t(k+1)})_{i,j}/T_{i,j} \quad (3)$$

where

$(P_{t(k)} - P_{t(k+1)})_{i,j}$ = drop in serviceabilities with ranks k and $k + 1$ for stage i of alternative j, and
$T_{i,j}$ = intercepted time between the above serviceabilities, i.e., the time of stage i of alternative j.

Consequently, the lower the value of PT_j, the better the performance/time ratio. This concept can be used to choose between the two alternatives that were selected according to the minimal cost/time ratio and maximum cost/performance ratio. The selection of the final alternative is based on a summary module in which the two strategies are ranked according to the number of times they have been chosen. Thus, the first rank is given to the strategy that has been chosen twice (a score of 2), while the second rank is given to the strategy that has been chosen once (a score of 1).

Final Selection Among Policies

The LCC program provides the user with a set of feasible strategies for one maintenance policy or for a group of suggested maintenance policies. This group can be executed consecutively for the same ordinary data or for various ordinary data.

Maintenance policies are applied according to the regulations of the agency's MMS. These systems are used by agency directors and field managers to plan, control, and evaluate road maintenance programs. The basic components of an MMS include performance standards, inventory of maintenance features, budgeting, scheduling, and a management information reporting process. Because many factors influence the performance of an agency's MMS, the level of certainty decreases when comparing several maintenance policies. Moreover, the level of uncertainty increases with the following parameters (*10*):

- The length of the planning horizon,
- The amount of resources committed for a given course of action, and
- The difficulty of reversing a decision once implementation begins.

When the decision making is done by the same user (agency), then these concepts of uncertainty can be reduced and limited. This limitation must be directed by factors that are beyond the agency's control. Therefore, the effective measure that should be considered is the financial measure.

In the life cycle cost analysis of pavement, the financial

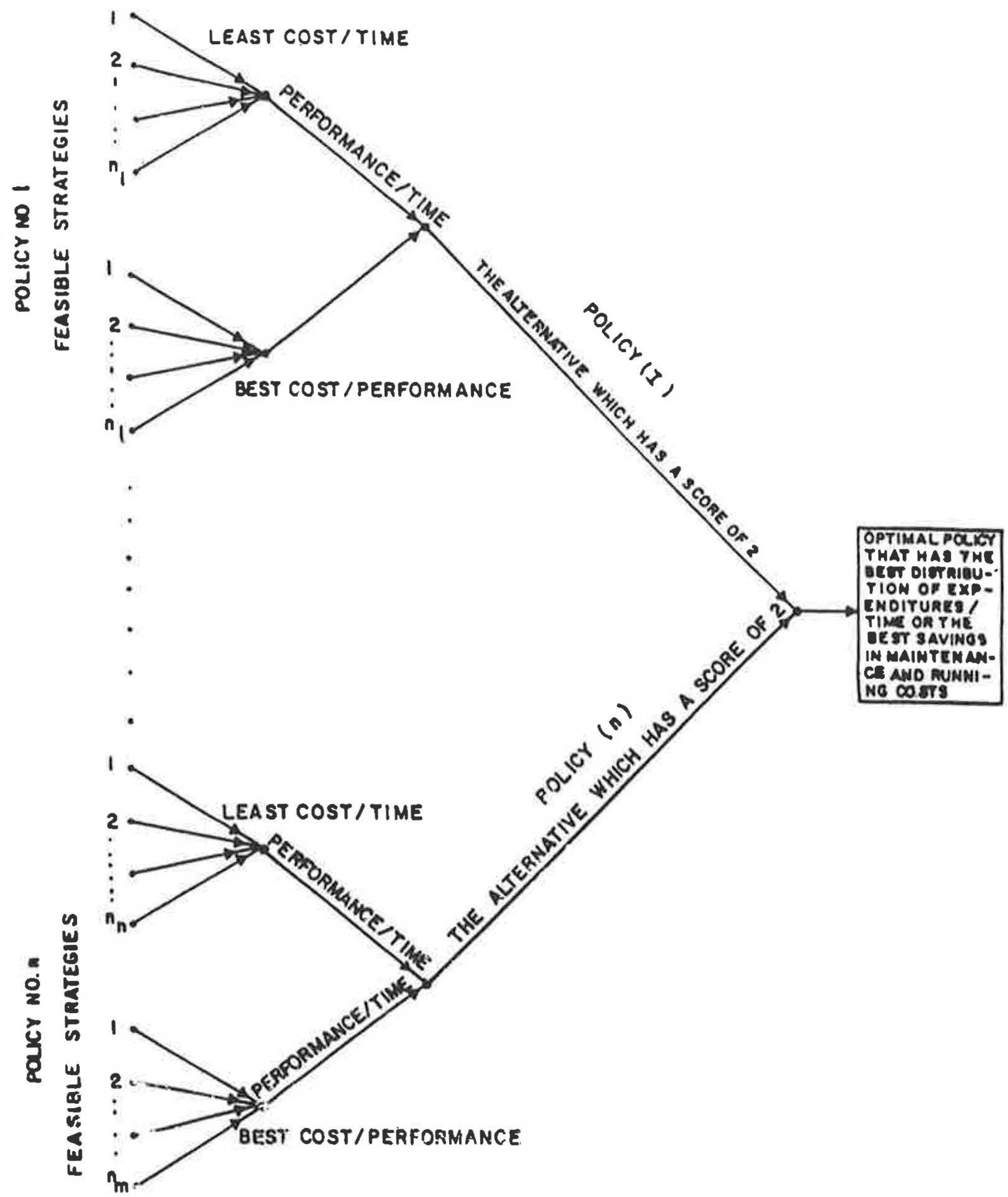

FIGURE 2 Decision optimization tree.

measure is affected by time. Figure 2 summarizes the steps in the decision optimization tree for a set of maintenance policies provided by the LCC program.

It can be concluded that the timing of various costs is an important element in choosing a pavement maintenance policy. A policy in which the costs are evenly distributed and the benefits occur in an early life cycle stage may be preferable over one in which the initial costs constitute the bulk of the expenditures. Because of this, a time stream analysis component should be used to illustrate the differences in the timing of costs and benefits among the available policies. The uniformity of expenditures can then be defined to achieve an adequate balance between the budget and the life cycle expenditures of a road. By using the LCC program, the life cycle cost of a road can be determined for the expected future phases of the road's anticipated useful life span. If the initial budget can be invested at a certain interest rate, then a uniform rate of return can be expected. Consequently, future returns and expenditures will be uniformly distributed over the useful life of the road, and budget deficiencies can be limited.

When a new road is built or an existing road is improved, three different effects can be expected (*11*):

1. A redistribution of traffic flows between existing roads and the new road and the generation of new traffic flows,
2. A transformation of the production structure in the area crossed by the road, and
3. Social consequences linked to the increased access to public facilities enjoyed by the area's population.

In most developing countries, indirect road benefits are related primarily to the redistribution of traffic flows and only marginally to development resulting from the transformation of the area's production structure. In other words, indirect road benefits can be regarded as amounting to user savings and road maintenance savings (11). These two types of savings constitute a large part of total road benefits; in the evaluation of a road project, they can be safely assumed to account for their entirety.

In this paper, several maintenance policies are evaluated for one project (i.e., project level). Thus, the above two types of savings are a suitable tool in the final evaluation among the suggested policies. To establish this concept, the policy that contains the maximum sum of maintenance and running user costs should be determined first. Second, the maintenance and user costs for the remaining policies should be subtracted from the values of this policy. The relative saving/cost ratios can be determined as follows:

$$B_{i/j} = \frac{MC_i - MC_j}{MC_j} + \frac{RC_i - RC_j}{RC_j} \tag{4}$$

where

$B_{i/j}$ = savings (benefits) in maintenance and running user costs obtained when using policy i with respect to policy j, which represents the maximum sum of the two costs;
MC_i = total maintenance costs of policy i;
MC_j = total maintenance costs of policy j;
RC_i = total running costs of policy i; and
RC_j = total running costs of policy j.

The candidate policies can be ranked according to the values of benefits in a descending form. Consequently, two evaluation tools are available for each policy: the uniformity of expenditures and the savings in routine maintenance and running user costs. The optimal decision must consider the policies of the agency and the circumstances of the particular project. Therefore, weights should be assigned to the above measures so the maintenance policies can be rated and the optimal pavement strategy can be selected for the project. It should be noted that this procedure is not applicable when computing initial costs only, since in this case the least-cost policy would be the optimal one.

Decision Support Program

To transfer the LCC program from a cost model to a decision support model, a decision support program (DSP) was developed. The previous decision models are used in this program. Figure 3 shows the flow chart of the DSP.

As shown in the figure, the DSP can compute the data needed to make the final selection among the given maintenance policies. A number of items are determined and printed in the DSP report:

- The discrete costs and the percentages of cumulative costs for each policy,
- The equation of the least-squares line and the equation of the straight line for the percentages of cumulative costs,
- The existed median for the first line and the ideal median for the second line,
- The percentage error between the two medians, and
- The total routine maintenance costs and running user costs.

These factors can then be used to choose the optimal policy, as demonstrated by the following sample problem.

SAMPLE PROBLEM

An example was constructed to demonstrate the method. In this example, it was assumed that in 1987, a flexible-pavement four-lane (divided) rural highway was to be constructed to accommodate traffic for a 30-year period. Using the LCC and DSP programs, the 10 best alternatives were to be selected for five suggested maintenance policies based on the initial, overlay, routine, maintenance, added user, and running user costs. A discount rate of 24 percent and an inflation rate of 19 percent were used in the economic analysis. The prevailing rate of exchange during 1987 was 2.20 £E/$. The traffic expected over the 30-year analysis period is as follows:

Average daily traffic = 10,000 vpd (both directions)
Directional split = 50 percent
Percent trucks on road = 15 percent
Traffic growth rate per year = 10 percent
Traffic count base year = 1986
ESAL/100 trucks = 0.64

Based on 1986 rates, it was found that added user costs have increased by an average value of 10 percent. Running user costs have increased by an average value of 20 percent during 1987.

The design California Bearing Ratio (CBR) for the subgrade is 1.5, and the regional factor is 0.4. The suggested material/layer combinations for the initial construction are shown in Table 1. All feasible alternatives must have a minimum of three layers. Table 1 also shows the suggested combinations for overlay construction, in which all feasible alternatives must have at least one overlay.

The suggested maintenance policies (1001, 1002, 1003, 1004, and 1005) are shown in Table 2. The ranges of terminal serviceability, the minimum times required for the overlays, and the minimum times required between any two successive overlays are provided for each maintenance policy.

The DSP output shows that alternative 1 is optimal for policies 1001, 1003, and 1004, while alternative 9 is best for policy 1002. Policy 1005 was excluded because no feasible strategies could be obtained for it. The alternatives selected achieve the least life cycle cost, the best cost/performance relationship, and the best performance/time relationship for their related maintenance policies. The values of discrete costs, percentages of cumulative costs, existing cost/time relationship, existing median, ideal cost/time relationship, ideal median, percentage error, total routine maintenance costs, and total running user costs are also given for each optimal policy.

Figures 4a and 4b show the discrete time streams and the cumulative time streams, respectively, for the five maintenance policies based on the results of the output.

By comparing the percentage of error for the median of each relationship with the median of its related linear relationship, the five policies can be ranked in the following ascending order:

1. Policy 1003,
2. Policy 1004,
3. Policy 1001,
4. Policy 1002, and
5. Policy 1005 (excluded).

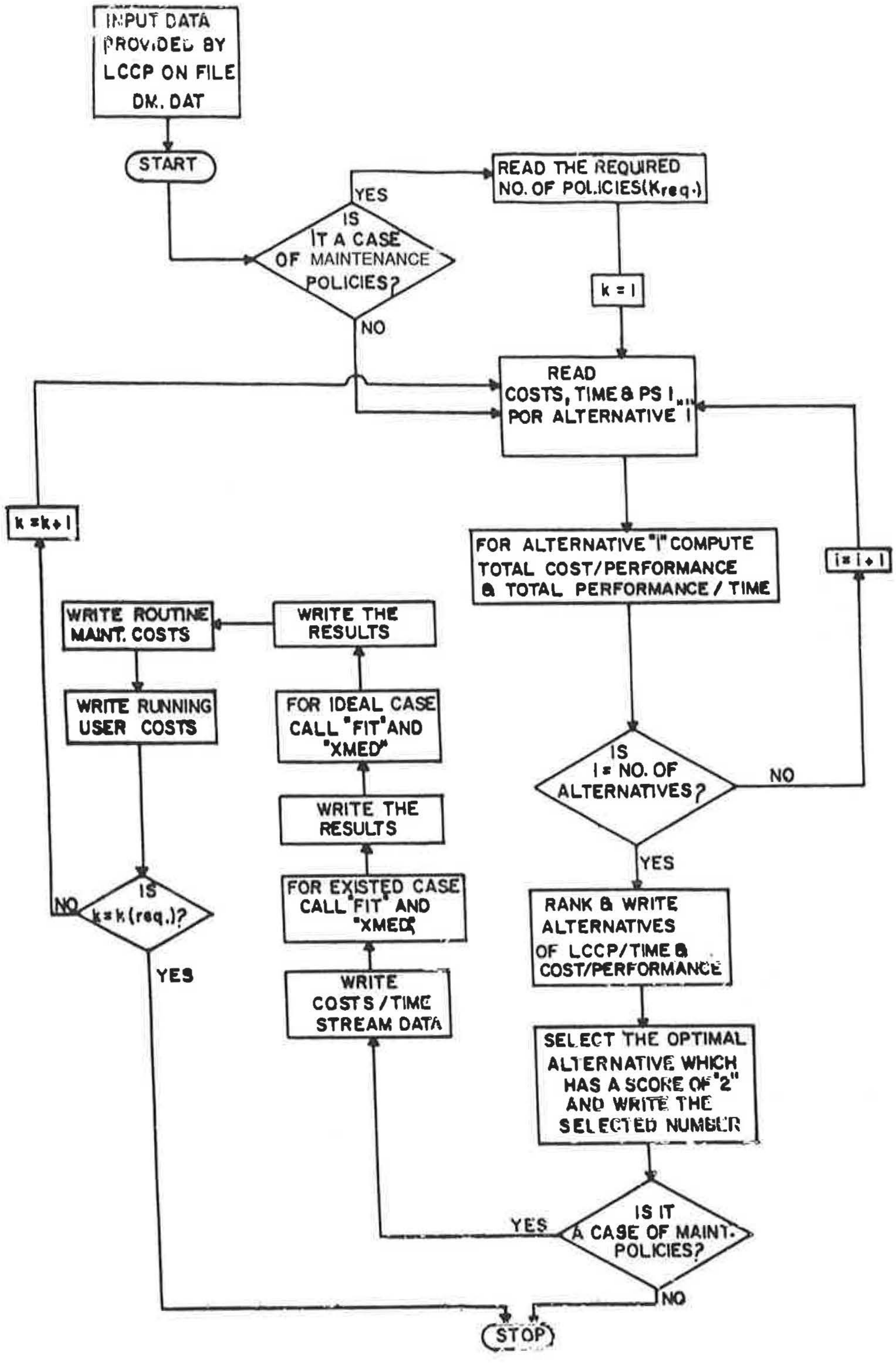

FIGURE 3 Flow chart of DSP.

TABLE 1 MATERIAL/LAYER COMBINATIONS FOR INITIAL AND OVERLAY CONSTRUCTIONS (SAMPLE PROBLEM)

	Material			Layer						
Construction Type	ID No.	Name	Construction Cost (£E/m³)	No.	Name	Coefficient (a)	Coefficient (b)	Allowable Thickness (mm) Minimum	Maximum	Increment
Initial	10	Asphalt concrete	100.0	1	Surface course	0.45	0.00	40.0	50.0	10.0
	22	Premix	80.0	2	Binder course	0.40	0.00	100.0	100.0	10.0[a]
	30	Crushed stone	20.0	3	Base course	0.14	0.00	200.0	300.0	50.0
	50	Crushed stone (bigger size)	20.0	4	Subbase course	0.11	0.00	300.0	400.0	50.0
Overlay	10	Asphalt concrete	100.0	1	Surface overlay	0.45	0.00	40.0	40.0	10.0[a]
	22	Premix	80.0	2	Base overlay	0.40	0.00	50.0	100.0	25.0

[a]To be assumed greater than 0.0.

TABLE 2 SUGGESTED RESPONSIVE MAINTENANCE POLICIES (SAMPLE PROBLEM)

Description	Policy No. 1	2	3	4	5
Code number	1001	1002	1003	1004	1005
Base type[a]	GR	GR	GR	GR	GR
Patching of unpatched cracks (%)	50.0	65.0	75.0	85.0	90.0
Maximum patched area (m²)	100.00	80.0	60.0	50.0	30.0
Patching unit cost[b] (£E/m²)	3.50	3.50	3.50	3.50	3.50
Type of surface dressing[c]	PR	AC	AC	PR	PR
Percentage of cracking and patching in the road (%)	8.0	10.0	20.0	30.0	40.0
Minimum years/one dressing	2.0	3.0	4.0	5.0	6.0
Maximum years/one dressing	5.0	6.5	7.0	8.0	9.0
Maximum analysis period/one dressing (yr)	20.0	25.0	25.0	30.0	30.0
Number of layers/one dressing	2	1	2	1	1
Unit cost/dressing (£E/m²/layer)	1.25	1.50	1.50	1.25	1.25
Unit lump sum cost of other routine maintenance activities (£E/km/yr)[d]	0.0	0.0	0.0	0.0	0.0
Minimum time for first overlay (yr)	5.0	10.0	15.0	15.0	20.0
Minimum time between overlays (yr)	10.0	10.0	7.5	5.0	5.0
Pt (min.)	2.5	2.5	2.4	1.8	2.5
Pt (max.)	3.0	3.0	3.0	2.4	3.0
Pt (increment)	0.50	0.50	0.60	0.6	0.5

[a]GR = granular base.
[b]Unit cost is divided: 50% skin patching and 50% deep patching.
[c]PR = premix; AC = asphalt concrete.
[d]This cost is considered to be negligible.

On the other hand, on the basis of the largest amount of savings obtained by applying Equation 4, the policies can be ranked in the following descending order:

1. Policy 1002,
2. Policy 1001,
3. Policy 1004,
4. Policy 1003, and
5. Policy 1005 (excluded)

Thus, policy 1003 gives the best uniformity of expenditures, while policy 1002 gives the best savings (benefits) in routine maintenance and running user costs.

If, for example, the agency is interested more in the concept of uniformity of expenditures than in the concept of savings, then the second concept would have a weight of 0.4 if the first had a weight of 0.6. In addition, the following ratings can be assumed for the policies according to their ranks as included in the first concept:

1. Policy 1003 = 100,
2. Policy 1004 = 75,
3. Policy 1001 = 50, and
4. Policy 1002 = 25.

The following ratings can be assumed for the policies according to their ranks as included in the second concept:

1. Policy 1002 = 100,
2. Policy 1001 = 75,
3. Policy 1004 = 50, and
4. Policy 1003 = 25.

Consequently, the following function can be used to provide a single aggregate desirability measure for the preferred policies (*9*):

$$U_i = \sum_{j=1}^{m} e_{i,j}\, w_j,\ i = 1\ (1)\ m \qquad (5)$$

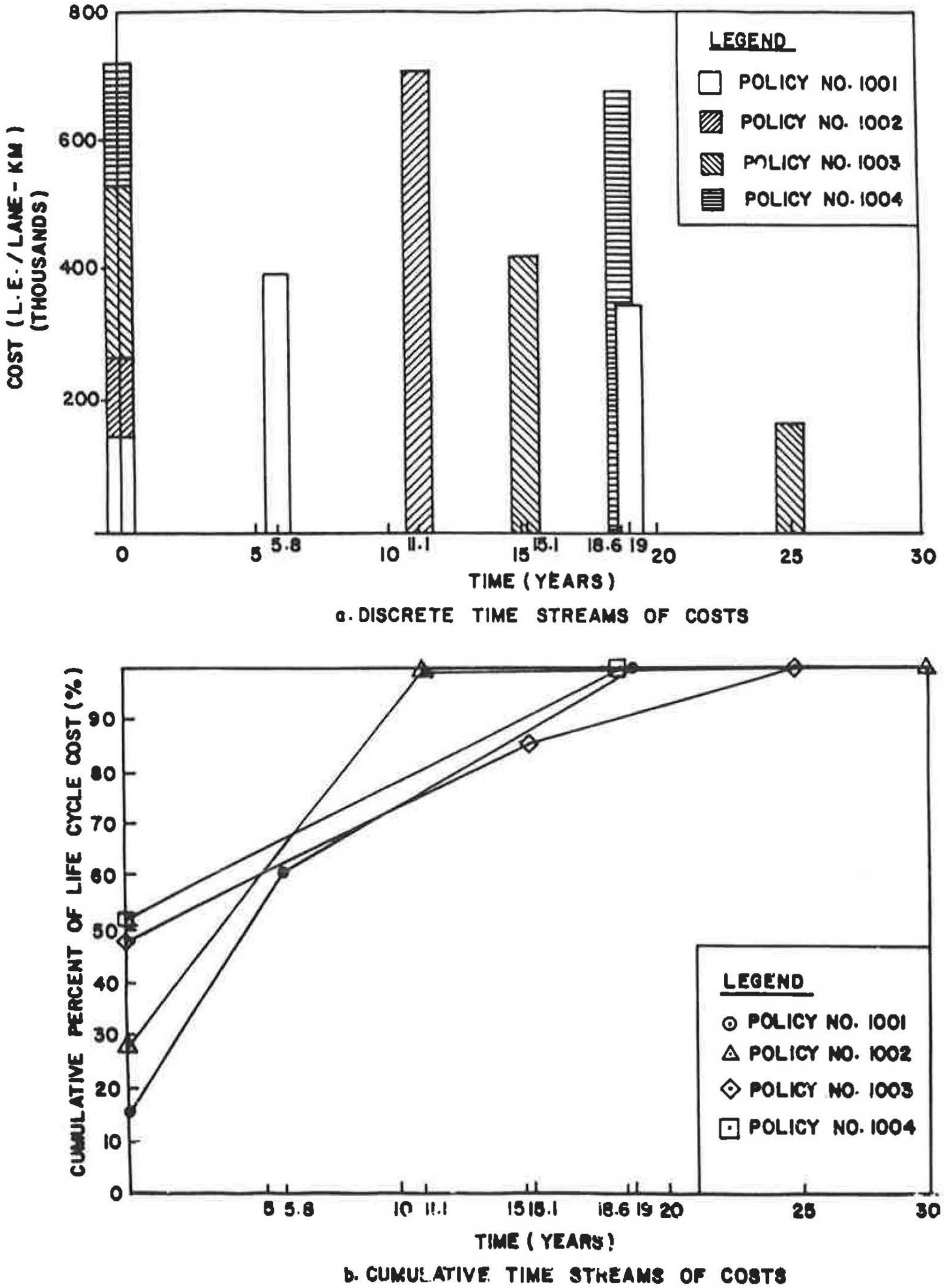

FIGURE 4 Distribution of current life cycle costs (sample problem).

TABLE 3 DECISION-MAKING REPORTS AND FINANCIAL DATA (SAMPLE PROBLEM) POLICY 1003

Ranking	
LCC	Cost/Performance
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	10
10	9

NOTE: Alternative 1 is optimal for Policy 1003.

TABLE 4 FINANCIAL DATA OF POLICY 1003

Time (yr)	Costs (£E/Lane-km) Discrete	Cumulative	Percent
.0	539977.7	539977.7	47.71
15.1	423133.0	963110.8	85.09
25.0	168755.5	1131866.0	100.00
30.0	−5525.7	1126340.0	100.00

NOTE: The existing relation is Cost (%) = 51.41 1.82 * time, R^2 = .9458; existing median = 17.52 years. The ideal relation is Cost (%) = 47.94 1.74 * time, R^2 = 1.0000; ideal median = 17.56 years. Percentage error = −.21634%; Total routine maintenance costs = 1986.2; Total running user costs = 956686.2.

where

U_i = summary score of strategy (or policy) i,
$e_{i,j}$ = rating of strategy (or policy) i with respect to measure j, and
w_j = weight of measure j.

Thus,

$$U_{1003} = 100 * 0.6 + 25 * 0.4 = 70$$

and

$$U_{1002} = 25 * 0.6 + 100 * 0.4 = 55$$

According to this calculation, policy 1003 is optimal. Tables 3 and 4 show the decision made by the DSP in selecting the optimal alternative for policy 1003 and display the financial data for this policy. On the basis of Tables 5 to 7 and the material listed here, the useful pavement life of 30 yr will be composed of two successive phases (18.6 yr and 11.4 yr):

Responsive Maintenance Policy 1003: Policy Description

Note: involved base is granular.

1. Patching 75.00 percent of unpatched cracks, but not more than 60.00 m²/km/yr; and at a present unit cost of 3.500 £E/m².
2. Asphaltic concrete surface dressing is applied when cracking and patching exceed 20.00 percent of the roadway, but not less than 4.00 yr/dressing, and not more than 7.00 yr/dressing, but not after analysis year 25. Required number of layers per one surface dressing = 2, at a present unit cost of 1.500 £E/m²/layer.
3. Other routine maintenance activities are also applied. They include drainage, vegetation, shoulders, and other miscellaneous activities. These activities are scheduled once per year and are estimated at a present (lump sum) cost of .000 £E/km/yr.
4. Overlay should be done when the value of PSI is between 2.40 and 3.00. Minimum allowable number of layers per overlay = 1. These layers are as prescribed above.

Figure 4b indicates that 51.40 percent of the current life cycle cost will be assigned for the first phase and 48.52 percent for the second phase. A surplus amount of 0.08 percent of the current life cycle cost will be inflated for 30 yr and deducted from the next life cycle cost. Thus, excluding the added and running user costs, the budget needed for construction and maintenance activities for the next 30 yr can be developed. The adequate rate of return can then be determined and the financial strategy investigated. The performance of the optimal strategy is illustrated in Figure 5.

CONCLUSIONS

The major conclusions drawn from the research can be summarized as follows:

- When studying flexible pavements for a specific time, the lowest life cycle cost is not the only factor that can be used to evaluate alternatives at a project level. The lowest cost/performance utility ratio should also be considered.
- The final choice of a maintenance policy should be based on the alternative that has one of the above two ratios in addition to the least value of performance/time, in other words, the best performance for the analysis period.
- If several maintenance policies are being evaluated, the optimal selection is the policy that has more uniformity of expenditures (i.e., an adequate investment rate) through the

TABLE 5 INITIAL PAVEMENT STRUCTURE (OPTIMUM ALTERNATIVE FOR SAMPLE PROBLEM)

Layer Number	ID No.	Material Type	Thickness (mm)	Layer Coefficient
1	10	AC surface course	40	.45
2	22	Premix binder course	100	.40
3	30	Crushed stone base	300	.14
4	50	Crushed stone subbase	300	.11

NOTE: Optimum alternative 1. Structural number = 4.64.

TABLE 6 OVERLAYS (OPTIMUM ALTERNATIVE FOR SAMPLE PROBLEM)

Overlay Number	Layer Number	ID No.	Material Type	Thickness (mm)	Layer Coefficient	Time of Overlay	Serviceability Before	Serviceability After	Structural Number Before	Structural Number After
1	1	10	AC surface overlay	40	.45	15.1	2.40	4.08	3.64	5.92
	2	22	Premix base overlay	100	.40					
			Wedge/leveling	27						
2	1	10	AC surface overlay	40	.45	25.0	3.00	4.16	5.48	7.76
	2	22	Premix base overlay	100	.40					
			Wedge/leveling	19						

NOTE: Serviceability at 30.00 years is 3.68.

TABLE 7 PRESENT WORTH COSTS (OPTIMUM ALTERNATIVE FOR SAMPLE PROBLEM)

	Initial Construction	Overlay Construction: Wedge/ Leveling	Overlay Construction: Overlay	Overlay Construction: Traffic Handling	Routine Maintenance	Added User	Running User	Salvage
Initial construction	72461.2				1451.7		466064.9	
Overlay 1		24344.1	11329.3	1567.7	534.5	2850.1	382507.3	
Overlay 2		10980.5	6988.7	847.7	.0	41824.6	108114.0	
TOTAL	72461.2	35324.6	18318.0	2415.4	1986.2	44674.7	956686.2	−5525.7

NOTE: Total Cost = 1126340.0. All costs in £E/lane-km.

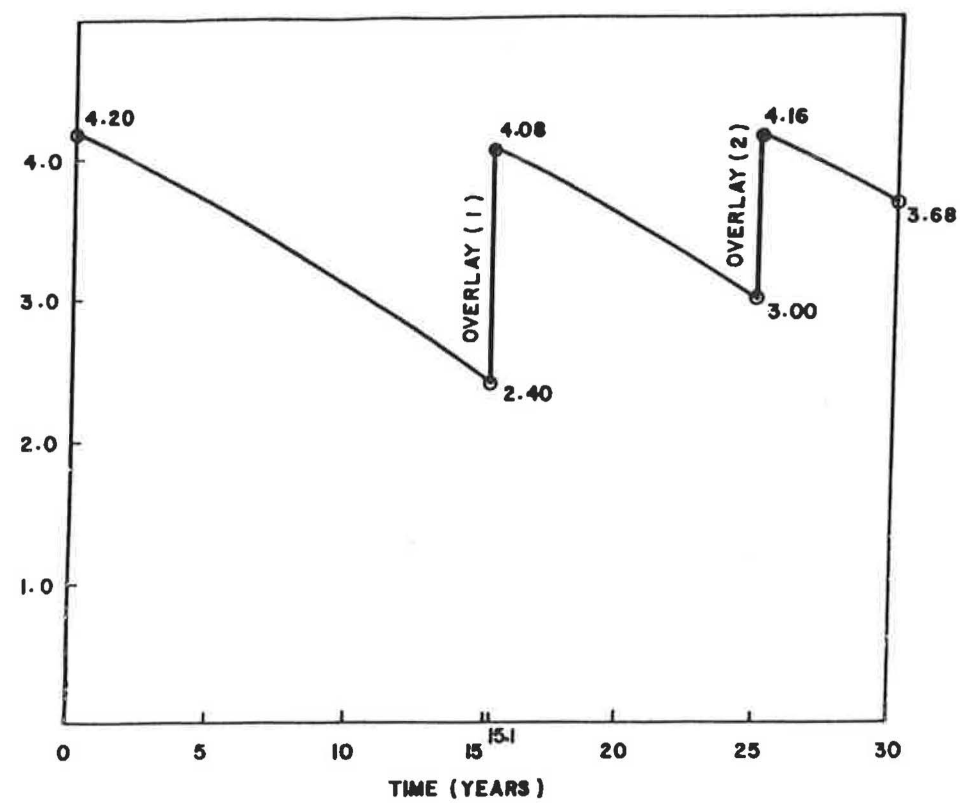

FIGURE 5 Performance of the optimal strategy (sample problem).

analysis period, based on the financial data provided by the program.

- This decision should be supported by estimating the benefits, as represented by the savings in routine maintenance costs and running user costs.
- The agency's policies and the circumstances of the project must also be considered in selecting the optimal routine maintenance policy for the PMS. Weights should be specified by the agency for use in the final choice among policies.

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