Economic Analysis of Effectiveness of Pavement Preventive Maintenance

ABDULLAH I. AL-MANSOUR AND KUMARES C. SINHA

Pavement maintenance can be categorized into two main categories: corrective maintenance and preventive maintenance. The current practices of most highway authorities concentrate on the first category, with minor attention given to preventive maintenance. The main reason for this is the shortage of available funds, which directs some decision makers toward putting the limited funds on corrective measures to satisfy road users, leaving nothing or, at most, negligible portions for preventive maintenance. This situation will continue unless studies show the economic benefits of preventive maintenance. An evaluation of two pavement preventive maintenance techniques, namely, chip seal and sand seal coating, is described. The evaluation process consists of three basic steps. First a data base that included all relevant data on pavement sections was developed. Second a set of models describing pavement deterioration, maintenance costs, and user costs was developed. Finally a comprehensive life cycle analysis was conducted; this included the costs of all items associated with different types and timings of maintenance strategies.

When pavement condition deteriorates below a prescribed minimum level reconstruction or resurfacing activity must be performed. Basic routine maintenance, such as patching, crack sealing, and basic shoulder maintenance activities, tends to slow down the pavement deterioration process, and thus resurfacing or construction can be deferred. However as the pavement ages and its condition deteriorates the cost of basic routine maintenance and the associated user costs increase. Often periodic pavement maintenance such as seal coating is performed to hold the pavement condition above the minimum acceptable level.

Seal coat treatment is a broad term embracing several types of asphalt-aggregate applications placed on any kind of roadway surface. It includes chip seals, sand seals, slurry seals, and fog seals. The most common types, however, are chip and sand seals. Chip sealing involves coating the full width of the roadway section with hot bituminous materials; this is followed by application of a coarse aggregate cover. In sand sealing the cover aggregate is sand rather than coarse aggregate.

The objective of the study described here was to develop an algorithm for evaluating the cost-effectiveness of seal coating activities (chip and sand seals). The algorithm that was developed focuses on the identification of the optimal timing of application of seal coats. This was achieved by using life cycle cost analysis to evaluate the effectiveness of a variety of maintenance strategies by using chip and sand seals.

To accomplish this objective, a data base was developed (*1*). The data base included information on pavement characteristics, pavement routine maintenance and periodic maintenance history, traffic, and pavement performance. These data elements were extracted from the Indiana Department of Transportation (INDOT) data bases. The data were collected over the period from 1984 to 1987. The appropriate data were collected on the basis of contract sections. A contract section is that portion of a highway pavement that is contracted out to one contractor for a specific activity such as resurfacing. Pavement contract sections within 12 of the 37 INDOT subdistricts were included. A stratified sampling scheme was used to select the 12 subdistricts. Four of these subdistricts were located in the northern region of the state, and the other eight subdistricts were located in the southern region of the state.

A. I. Al-Mansour, Civil Engineering Department, College of Engineering, King Saud University, P.O. Box 800, Riyadh, Saudi Arabia. K. C. Sinha, Department of Civil Engineering, Purdue University, West Lafayette, Ind. 47907.

PROBLEM FORMULATION

As the pavement section gets old surface roughness increases. User costs as well as basic routine maintenance costs also increase. If at a given point in time a decision is made to seal coat the pavement section, a certain amount of capital is then invested. Seal coating reduces the basic routine maintenance requirements. Because of the resulting improvement in pavement condition, user costs are expected to decline. In addition the service life of the pavement is extended. The main issue here is whether the benefits accrued in terms of reduced basic routine maintenance costs, reduced user costs, and opportunity costs gained because of the deferment of resurfacing equate or exceed the cost of the investment in seal coating. If the savings from seal coating are greater than the investment, the next issues are when is the most economical time to perform seal coating and how many seal coating activities should be performed during the pavement life cycle before the gain from seal coating becomes less than its cost. Figure 1 illustrates this concept. If the seal coating timing is delayed for a certain period of time, say from $t(s1)$ to $t(s2)$, the pavement condition is expected to be worse at $t(s2)$ than at $t(s1)$. Hence the cost of seal coating at a later date would be higher. The benefits from seal coating acquired from reductions in basic routine maintenance and user costs could be less than those from seal coating at the previous time, but there are gains in the added service life. To determine the best seal coating strategy, the costs and benefits need to be discounted to a common base for comparison.

MATHEMATICAL FORMULATION OF LIFE CYCLE COST ALGORITHM

The total life cycle costs, as used in the present study, consist of resurfacing or reconstruction cost, basic roadway and shoulder routine maintenance costs, seal coating costs, and user costs. The resurfacing cost was considered to be a single payment made at

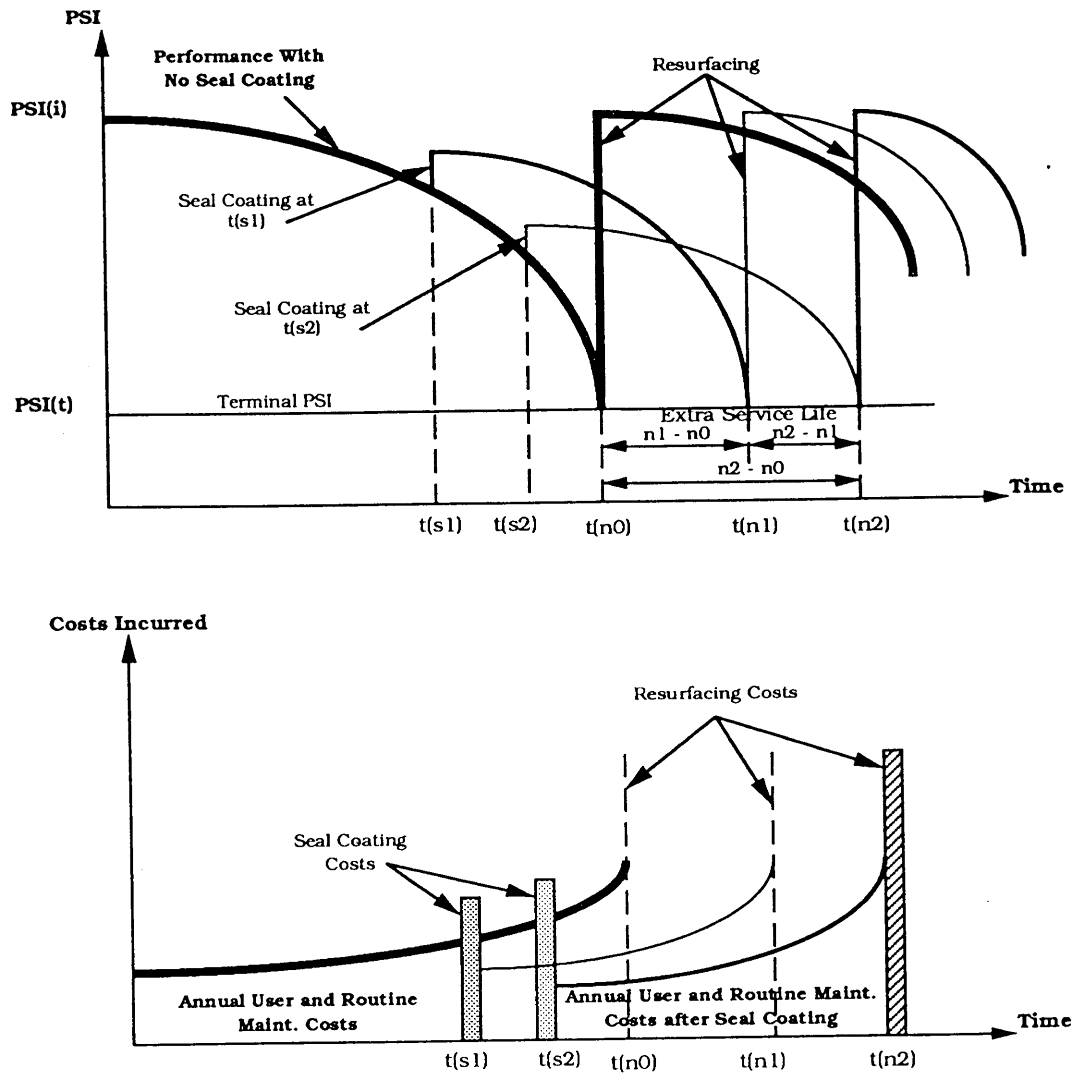

FIGURE 1 Timing effects of seal coating activity.

a future year depending on the given standard for terminal pavement condition. The basic roadway and shoulder routine maintenance costs were considered to be annual single payments at the end of each year. Seal coating costs were treated as single payments made in the years in which sealing was carried out. User costs were accounted as annual single payments at the end of each year on the basis of the pavement condition index in that year.

Because future decisions on the timing of a particular type of maintenance activity are uncertain, it is a common practice in life cycle cost analysis to assume certain sequences and types of maintenance work. This corresponds to the well-known repeatability assumption in financial analysis. After the first pavement's life cycle, the same work sequence and type are assumed to be repeated in perpetuity.

Having established the basic assumptions of the proposed life cycle costing approach, the present worth of resurfacing cost is determined by applying the following formula:

$$\text{PWV1} = \text{RS} \cdot (\text{SPPWF}, i, n) \quad (1)$$

where

PWV1 = present worth of resurfacing [$/1.61 lane-km ($/lane-mi)],
RS = resurfacing cost [$/1.61 lane-km ($/lane-mi)],
SPPWF = single payment present worth factor = $[1/(1 + i)^n]$,
i = discount rate (in decimals), and
n = pavement life cycle (service life).

Similarly the present worth of the periodic maintenance cost (seal coating cost) is determined by using Equation 2:

$$\text{PWV2} = \text{SC} \cdot (\text{SPPWF}, i, t) \quad (2)$$

where

PWV2 = present worth of seal coating cost [$/1.61 lane-km ($/lane-mi)],
SC = seal coating cost [$/1.61 lane-km ($/lane-mi)], and
t = year at which seal coating is performed.

The present worth of annual basic routine maintenance costs is calculated by using Equation 3.

$$\mathrm{PWV3} = \sum_{j=1}^{n} \mathrm{AMC}_j \cdot (\mathrm{SPPWF}, i, j) \qquad (3)$$

where PWV3 is the present worth value of all annual basic routine maintenance costs during the pavement service life [$/1.61 lane-km ($/lane-mi)], and AMC_j is the annual basic routine maintenance cost at the jth year [$/1.61 lane-km ($/lane-mi)].

Similarly the present worth of user costs is determined by applying Equation 4.

$$\mathrm{PWV4} = \sum_{j=1}^{n} \mathrm{UC}_j \cdot (\mathrm{SPPWF}, i, j) \qquad (4)$$

where PWV4 is the present worth value of all annual user costs [$/1.61 lane-km ($/lane-mi)], and UC_j is the annual user cost at the jth year [$/1.61 lane-km ($/lane-mi)].

The total present worth value of all life cycle cost components under a maintenance strategy is calculated by using the following summation:

$$\mathrm{TPWV} = \mathrm{PWV1} + \mathrm{PWV2} + \mathrm{PWV3} + \mathrm{PWV4} \qquad (5)$$

This amount can then be viewed as an outlay to be made in perpetuity every n years. Then the total present worth value in perpetuity can be expressed as

$$\mathrm{TPWV}_p = \mathrm{TPWV}\{(1 + i)^n/[(1 + i)^n - 1]\} \qquad (6)$$

Finally the equivalent uniform annual cost in perpetuity for a maintenance strategy over the pavement service life is determined by applying Equation 7.

$$\mathrm{EUAC}_p \text{ (in perpetuity)} = \mathrm{TPWV}_p \cdot i \qquad (7)$$

DEFINITION OF MAINTENANCE STRATEGIES

The analysis in the present study focused on basic routine maintenance and preventive periodic maintenance activities. Basic routine maintenance included both roadway and shoulder activities. The roadway maintenance consisted of shallow patching, deep patching, sealing of longitudinal cracks, and crack sealing. The shoulder maintenance involved spot repair of unpaved shoulder, blading of unpaved shoulder, and clipping of unpaved shoulder. Periodic maintenance activities are those used as preventive measures to repair minor damage and to hold the pavement condition until higher-order treatments, such as resurfacing, become necessary. In the present study these included chip sealing and sand sealing.

Several pavement maintenance strategies were included in the life cycle cost analyses. Each strategy consisted of one or more maintenance activities. These strategies ranged from resurfacing at the end of a period of no maintenance to routine basic roadway and shoulder maintenance in conjunction with seal coating at different levels of pavement condition. Table 1 lists the various maintenance strategies considered in the life cycle cost analysis.

TABLE 1 Maintenance Strategies Considered in Life Cycle Cost Algorithm

Maintenance Strategies	Activities Performed
Do Nothing	None
Basic Routine Maintenance (BRM)	Patching, Crack Sealing, Spot Repair of Unpaved Shoulders, Blading Unpaved Shoulders, Clipping Unpaved Shoulders
BRM and Chip Sealing	BRM Activities and Chip Sealing before Resurfacing
BRM and Sand Sealing	BRM Activities and Sand Sealing before Resurfacing

RELATIONSHIPS NEEDED FOR LIFE CYCLE COST ANALYSIS

Pavement maintenance life cycle costing requires the determination of the rate of pavement condition deterioration and the timing for resurfacing. The effectiveness of various maintenance activities must also be known. The scheduling of maintenance activities depends on the effectiveness of these activities. To determine the rate of pavement condition deterioration and the effectiveness of maintenance activities, a set of condition prediction models was developed. The timing for resurfacing was estimated by determining the age (number of years) after which the pavement condition reaches a terminal value. The costs of performing different maintenance activities were also needed for the economic analysis. This section presents a brief description of the different models needed for the life cycle cost analysis.

Pavement Condition Prediction Models

The available data base was used to develop a relationship between pavement serviceability index (PSI) and pavement age. Two groups of pavement contract sections were identified. The first group included all pavement contract sections that did not receive any maintenance during the study period (1984 to 1987). The second group included the pavement contract sections that received basic roadway and routine shoulder maintenance activities. To capture the effect of climate on pavement condition, the pavement contract sections within each group were classified according to the climatic region. The pavement contract sections within each climatic region were further subdivided on the basis of their annual average daily traffic (AADT) into two categories: pavement contract sections with high traffic levels (AADT > 2,000) and those with low traffic levels (AADT ≤ 2,000). The latest subdivision was applied to account for the effect of traffic level on pavement condition. However because of the limited numbers of pavement contract sections within each climatic region on which no maintenance was performed, the effect of traffic was excluded from this group.

The regression procedure of the Statistical Analysis System (SAS) computer package (*2*) was used to test a large number of models. The best model was found to be in the following form:

$$PSI = a + b \cdot Age \quad (8)$$

where

PSI = pavement serviceability index,
Age = pavement age (in years) since construction or last resurfacing, and
a, b = estimated regression parameters.

The statistical characteristics and estimated regression parameters are presented in Table 2.

A PSI value of 2.2 was used as the minimum value for acceptable pavement serviceability. On the basis of this terminal value the pavement service life of contract sections with no maintenance was found to be 16 years in the northern region and 19 years in the southern region. When basic roadway and shoulder maintenance activities were applied the pavement service life was extended to 20 years for the northern region with a high raffic level, 23 years for the northern region with a low traffic level, 22 years for the southern region with a high traffic level, and 24 years for the southern region with a low traffic level.

Gain in PSI Due to Seal Coating

In the available data base a total of 34 pavement contract sections received chip sealing and 20 pavement contract sections received sand sealing. Eleven sections were located in the northern region and the remaining 23 were located in the southern region of the state. All sections that received sand sealing were located in the northern region of the state. Both chip and sand sealing were found to result in an improvement in pavement condition.

To determine a functional relationship between the immediate gain in PSI and the PSI at the time of application of the seal coating, the regression procedure of the SAS package was used. The immediate gain in PSI represents the change in PSI estimated within 1 year of undertaking a seal coating activity. The following form of such a relationship was found to be statistically valid for both chip sealing and sand sealing activities.

$$\Delta PSI = a \cdot (PSI - b) \quad (9)$$

where

ΔPSI = gain in pavement serviceability owing to seal coating activities,
PSI = PSI at time of seal coating application, and
a, b = estimated regression parameters.

Table 3 summarizes the results of the statistical analysis and presents the estimated regression parameters for both chip and sand sealing activities.

Routine Pavement Maintenance Cost Models

Many factors could be postulated as affecting annual routine maintenance expenditures, for example, the pavement's condition, the pavement's age, traffic loads, the maintenance procedures performed, and the availability of funds. In the present study the annual amounts of basic routine maintenance on roadways and shoulders were related to pavement condition at the two traffic

TABLE 2 Estimated Regression Parameters of Pavement Condition Prediction Models

$PSI = a + b*Age$

Climate Region	Maintenance Category	Overall Model Statistics				Estimated Parameters	
		No. of Observ	R^2	Adj R^2	P > F	a	b
North	No. Maint.	13	0.4797	0.3149	0.0084	3.8816	-0.1051
	Basic Routine Main						
	* High Traffic (AADT > 2000)	33	0.4127	0.3943	0.0008	3.9732	-0.0885
	* Low Traffic (AADT < =2000)	43	0.5403	0.5294	0.0001	4.1523	-0.0817
South	No. Maint.	45	0.5407	0.5301	0.0001	4.0135	-0.0978
	Basic Routine Main						
	* High Traffic (AADT > 2000)	48	0.5822	0.5733	0.0001	4.2315	-0.0915
	* Low Traffic (AADT < =2000)	102	0.4081	0.4023	0.0001	4.0736	-0.0773

TABLE 3 Estimated Regression Parameters of Gain in PSI Models

Gain in PSI = a*(PSI - b)						
Seal Coating Activity	Overall Model Statistics				Estimated Parameters	
	No. of Observ.	R^2	Adj R^2	P > F	a	b
Chip Seal	34	0.5453	0.5302	0.0001	0.3325	1.433
Sand Seal	20	0.5588	0.5147	0.0053	0.3728	1.9139

levels. Other factors were assumed to be either constant or confounded with the factors considered.

The pavement contract sections in the data base whose roadways and shoulders received basic routine maintenance were grouped on the basis of their AADTs into sections with high levels of traffic (AADT > 2,000) and sections with low levels of traffic (AADT ≤ 2,000). The average value of the AADT was used as the cutoff point between low and high traffic levels.

The maintenance expenditures versus pavement condition models were developed separately for roadway and shoulder maintenance activities. The functional form of the expenditures versus pavement condition models is given in Equation 10.

$$\text{Log AMC} = a + b \cdot (\text{PSI}) \qquad (10)$$

where

AMC = annual roadway or shoulder maintenance expenditure [$/1.61 lane-km ($/lane-mi)],
PSI = PSI at time of maintenance, and
a, b = estimated regression parameters.

The statistical characteristics of these models are given in Table 4.

Sand and Chip Sealing Cost Models

The expenditures for performing chip and sand sealing activities per 1.61 lane km (lane mi) were related to the pavement condition at the time that these activities were performed. It was found that the costs of these activities were higher when performed on sections with poor pavement condition than on those with good pavement condition. This finding was as expected since more materials and human-hours are required to perform seal coating activities on pavements in poor condition than on pavements in good condition. The functional form of the models is given as follows:

$$\text{Log SC} = a + b \cdot (\text{PSI}) \qquad (11)$$

where

SC = cost of performing chip sealing or sand sealing [$/1.61 lane-km ($/lane-mi)],
PSI = pavement serviceability index at time of sealing, and
a, b = estimated regression parameters.

The statistical parameters for these models are given in Table 5.

Development of User Cost Models

The life cycle cost algorithm that was developed provides an option for the inclusion of user costs as a function of pavement condition. Basically the user cost models determine the operating costs owing to a decrease in PSI. The consumption rate tables, developed by Zaniewski et al. (*3*) in the FHWA study, are the basis for these models. In the present study the operating costs were given by vehicle type, vehicle speed, pavement condition, and road geometrics. In the present study the cost numbers were updated to 1987 dollars by using FHWA cost indexes for maintenance and operations. The costs were updated for various levels of PSI, different types of vehicles, zero grade, and a speed of 89

TABLE 4 Estimated Regression Parameters of Annual Basic Routine Maintenance Cost Models

Log AMC = a + b*PSI							
Type of Maint.	Traffic Level	Overall Model Statistics				Estimated Parameters	
		No. of Observ	R^2	Adj R^2	P > F	a	b
Roadway Maint.	High Traffic (AADT > 2000)	55	0.5193	0.5141	0.0001	4.0283	-0.4621
	Low Traffic (AADT < =2000)	67	0.5887	0.5824	0.0001	3.7781	-0.4252
Shoulder Maint.	High Traffic (AADT > 2000)	14	0.4099	0.3645	0.0010	3.3221	-0.3547
	Low Traffic (AADT < =2000)	27	0.5693	0.5328	0.0001	3.5323	-0.4573

TABLE 5 Estimated Parameters of Seal Coating Maintenance Cost Models

Log SC = a + b*PSI						
Type of Seal Coating	Overall Model Statistics				Estimated Parameters	
	No. of Observ.	R^2	Adj R^2	P > F	a	b
Chip Seal	34	0.3079	0.2723	0.0018	3.6101	-0.1034
Sand Seal	20	0.4814	0.4597	0.0001	3.3427	-0.0782

km/hr (55 mph). User costs included only vehicle operating costs. Costs arising from accidents and travel time were not included in the analysis.

In the life cycle cost algorithm for the present study a running speed of 89 km/hr (55 mph) and 0 percent road grade were assumed. The performance history of a particular type of pavement during its entire service life was estimated by calculating a PSI value for each year. The linear relationships developed earlier were used to determine pavement deterioration from an initial PSI to a terminal PSI value. If seal coating activities were performed at a given time the PSI value was adjusted for these activities. PSI values for future years were then recalculated by using the same linear models on the basis of the PSI after seal coating.

To convert the user cost values from dollars per 1609 km to dollars per 1.61 lane-km (dollars per 1,000 mi to dollars per 1 lane-mi), the reported AADT was multiplied by 0.5, since most of the state roads are two lanes. The final formula to change user cost unit to cost per 1.61 lane-km (lane-mi) is given by the following equation.

$$\begin{aligned} UC(I) = [(&UC_{pc}(I) \cdot ADT \cdot PPC \\ &+ UC_{st}(I) \cdot ADT \cdot PST \\ &+ UC_{tt}(I) \cdot ADT \cdot PTT)/1{,}000] \cdot 365 \end{aligned} \qquad (12)$$

where

$UC(I)$ = user cost for year I [$/1.61 lane km ($/lane mi)],
UC_{pc} = operating cost for passenger cars,
ADT = AADT · 0.5,
PPC = percentage of passenger cars,
UC_{st} = operating cost for single-unit trucks,
PST = percentage of single-unit trucks,
UC_{tt} = operating cost for semitrailer trucks,
PTT = percentage of semitrailer trucks.

CODING OF LIFE CYCLE COST PROGRAM

An interactive computer program was developed by using the proposed methodology for the pavement maintenance life cycle cost analysis. The computer program incorporated the pavement condition and maintenance cost models developed in the study and was written in FORTRAN language. The program inputs include maintenance strategy, terminal value of pavement serviceability, traffic characteristics, climatic region, years at which chip or sand sealing should be considered, resurfacing cost, and discount rate. The output of the program includes a list of pavement age and corresponding pavement serviceability, annual routine roadway maintenance, annual routine shoulder maintenance, and annual user cost. The program also prints out the costs of chip sealing and sand sealing if these activities are used. The program output also produces the equivalent uniform annual agency cost in perpetuity, equivalent uniform annual user cost in perpetuity, and equivalent uniform annual total cost of the selected maintenance strategy in perpetuity.

APPLICATION OF LIFE CYCLE COST ANALYSIS

The life cycle cost analysis program was used to determine the most cost-effective pavement maintenance strategy and to find the appropriate timing of chip and sand sealing activities. A terminal serviceability value of 2.2 was used. When pavement condition reaches the terminal value, the pavement was assumed to be at the end of its service life and a resurfacing was needed. The resurfacing cost was estimated to be $50,000 per 1.61 lane-km (lane-mi). This value was selected on the basis of the information provided by the INDOT (*4*) for the following resurfacing criteria:

1. 20-cm (8-in.) bituminous base for heavy traffic,
2. 3.8-cm (1.5-in.) bituminous binder for heavy traffic, and
3. 2.5-cm (1-in.) bituminous surface for heavy traffic.

The trigger point at which the seal coat was to be applied was varied; the following three PSI trigger point values were tested and analyzed: 3.25, 3.00, and 2.75. The objective of choosing these values was to study the optimal timing for seal coating activities.

For the purpose of calculating user costs, four levels of AADT (3,000, 2,500, 1,500, and 1,000) with a speed of 89 km/hr (55 mph) on a flat roadway were considered. The traffic volume was assumed to comprise 85 percent passenger cars, 5 percent single-unit trucks, and 10 percent semitrailer trucks. For all maintenance strategies resurfacing cost, seal coating costs, annual maintenance costs, and annual user costs were given in 1987 dollars. The discount rate was assumed to be 6 percent. A discussion of the comparison of agency costs, user costs, and the total costs of different maintenance scenarios are presented in the following sections.

Comparison of Agency Costs

The analysis illustrates a consistently declining agency cost as the maintenance scenario changes from no maintenance to basic routine maintenance and as the number of seal coating activities increases during a pavement's lifetime. Agency costs were found to increase as the seal coating decision was postponed. This increase was more noticeable for pavement contract sections with high traffic levels than for sections with low traffic levels. This finding suggests that the optimal timing for performing seal coating activities is when the pavement condition reaches a PSI value of 3.25. On the basis of pavement performance data analysis in the study, this condition would occur when a pavement is about 8 years old in the northern region of the state and about 11 years old in the southern region. The reason for the difference in pavement ages at which seal coating activities become necessary may be related to the effect of the relatively harsher winter weather in the northern zone.

To compare agency cost savings as a result of performing chip and sand sealing, the results of applying these activities three consecutive times at a PSI trigger value of 3.25 were considered. The results indicated that performance of chip sealing instead of sand sealing would result in an average annual saving of 42 percent of agency cost for pavement contract sections with high traffic levels and an average annual saving of 56 percent of agency cost for pavement contract sections with low traffic levels. On the other hand sand sealing activities resulted in an average annual savings of 35 percent for pavement contract sections with high traffic levels and 54 percent for pavement contract sections with low traffic levels.

Comparison of User Costs

The analysis suggests that from the user viewpoint and for AADT of less than 2,000, the optimal maintenance strategy may be to perform basic routine maintenance and one chip sealing or sand sealing activity at a PSI trigger value of 3.00. For pavement sections with higher traffic levels, however, performance of basic routine maintenance and two or three seal coating activities within a pavement's service life is justifiable. To achieve the maximum user cost savings at either high or low traffic levels, the seal coating activities should not be postponed beyond a PSI value of 3.00. The analysis further indicated that if the seal coating activities are not performed at or before the pavement condition reaches a PSI value of 3.00, the best strategy from the user's point of view is to continue with the annual basic routine maintenance to the end of the pavement's service life. In comparing chip and sand sealing the analysis did not detect any major difference in the user cost values between the two activities on any of the traffic levels considered.

Comparison of Total Costs

The comparison between different maintenance strategies was based on the total uniform annual costs in perpetuity, that is, the summation of the total uniform annual agency costs and annual uniform user costs in perpetuity. The annual savings in dollars per 1.61 lane-km (1 lane-mi) per year in perpetuity under different maintenance strategies were calculated for the two climatic regions. The calculation indicated that if seal coating was performed at or before the pavement condition reaches a PSI value of 3.00, the maintenance strategy with the most savings was the application of three consecutive chip seals with basic routine maintenance. This result is true for both traffic levels and both climatic regions. However if seal coating activities are deferred beyond a PSI value of 3.00, the application of basic routine maintenance and one chip seal produced the most savings for both traffic levels and both climatic regions. The calculation also indicated that if seal coating is performed at a PSI trigger value of 2.75, the savings obtained from applying basic routine maintenance and three consecutive sand sealing activities were about equal to the savings resulting from performing basic routine maintenance and two consecutive chip sealing activities. Another observation is that for all maintenance strategies in the southern region the savings achieved at high traffic levels were much greater than those achieved at low traffic levels. However for the northern region a higher level of savings was achieved at high traffic levels if the seal coating was performed at or before the pavement condition reached a PSI value of 3.00. If seal coating was postponed beyond a PSI value of 3.00, pavement contract sections with low traffic levels seemed to produce higher savings than sections with high traffic levels.

SUMMARY AND CONCLUSION

To evaluate the cost-effectiveness of seal coating treatments a life cycle cost algorithm was developed. The components of the life cycle cost included annual routine maintenance costs, seal coating costs, future costs of resurfacing, and user costs. An interactive computer program was then developed on the basis of the life cycle cost algorithm encompassing the developed pavement performance and maintenance cost models.

The application of the life cycle cost program indicated that the optimal timing for performing seal coating, from the agency cost viewpoint, is when the pavement condition reaches a PSI value of 3.25. To achieve the most user cost savings for both high and low traffic levels, the seal coating activities should not be postponed beyond a PSI value of 3.00. As far as the total cost (agency plus user costs) is concerned, the most savings are obtained for both traffic levels and the two climatic regions when basic annual routine maintenance and three consecutive chip sealing activities during the pavement's service life were performed at a PSI trigger value of 3.00. However if seal coating is deferred beyond a PSI value of 3.00, the application of one chip sealing activity during the pavement's service life produced the treatment with the most cost savings.

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