A Study of the Effects of Routine Pavement Maintenance

TIEN F. FWA AND KUMARES C. SINHA

Knowledge of the effects of routine maintenance on pavement performance is important to the management of highway pavements at both the network and the project level. In this paper is described a methodology for evaluating these effects on the basis of pavement performance data and aggregated pavement routine maintenance cost information. The proposed methodology was applied to assess the effects of routine pavement maintenance on 75 highway routes in Indiana. In addition, statistical analyses were performed to examine the influence of environmental and climatic conditions on the effects of routine maintenance on these routes.

In recent years the main emphasis of most state highway agencies has been shifted from building new facilities to maintaining and preserving the existing system. Pavement maintenance has now become a major area of expenditure in the budgets of many highway agencies. To make optimal use of the limited funds available, it is important for a highway agency to have knowledge of the effect that routine maintenance might have on the performance of a given pavement, or a network of pavements, under a known set of environmental conditions. Unfortunately, there is relatively little documentation and information on this in the literature.

In this paper is described a procedure for evaluating the effect of past routine pavement maintenance on pavement performance. This effect is expressed in terms of an index, known as the pavement routine maintenance effectiveness index, that provides a measure of the amount of improvement in pavement performance that is achievable with a unit increase in maintenance expenditure. The results of this analysis for each pavement may then be correlated with its characteristics and the associated environmental conditions to provide information that is useful in maintenance planning and programming.

The proposed procedure was used to evaluate the effects of routine pavement maintenance on 75 highway routes in Indiana. A description of this application is presented for purposes of illustration. In addition, statistical analyses were performed to examine the influence of environmental conditions on the effects of routine maintenance on rigid, flexible, and overlay pavements in Indiana.

CONCEPT

It is generally agreed that improved pavement performance can be achieved by having better routine pavement maintenance. This notion may be presented schematically as shown in Figure *1a*, where the pavement condition at a given time is expressed in terms of its present serviceability index (PSI). The same notion can be expressed in mathematical terms:

$$(\text{PSI loss})_{1,t} < (\text{PSI loss})_{2,t} \tag{1}$$

where

$$(\text{PSI loss})_{1,t} = (\text{PSI})_0 - (\text{PSI})_{1,t} \tag{2}$$

$$(\text{PSI loss})_{2,t} = (\text{PSI})_0 - (\text{PSI})_{2,t} \tag{3}$$

Alternatively, as suggested by Fwa and Sinha (*1*), the relationship in Equation 1 may be expressed in terms of PSI-ESAL losses as defined in Figure *1b*. Equation 1 may then be rewritten as follows:

$$(\text{PSI-ESAL loss})_{1,t} < (\text{PSI-ESAL loss})_{2,t} \tag{4}$$

where ESAL stands equivalent 18-kip single-axle loads.

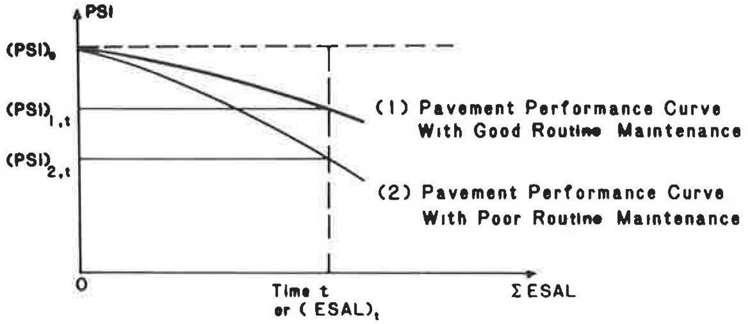
Although PSI loss represents the state of pavement at the time of analysis and makes no reference to its past history, PSI-ESAL loss is computed over the entire analysis period and therefore is also a function of the past conditions of the pavement. Because the effect of routine maintenance is a cumulative result of repetitive maintenance activities during the same analysis period for which PSI-ESAL loss is computed, it is reckoned that PSI-ESAL loss is a more suitable parameter for use in the analysis of routine maintenance effects.

The relationship depicted in Figure 1 is qualitative. To obtain a quantitative assessment of the effect of routine maintenance, it is necessary to replace the qualitative description of level of routine maintenance by some appropriate quantitative parameter. For a given maintenance policy and technology, the mean annual pavement routine maintenance expenditure per lane-mile appears to be a logical choice. An implicit assumption involved in adopting this parameter is that higher maintenance expenditure is associated with higher levels of routine maintenance and vice versa. This parameter has been used by Sharaf (*2*) in a study dealing with routine maintenance cost prediction and by Fwa (*3*) in investigating load- and non-load-related effects on pavement performance.

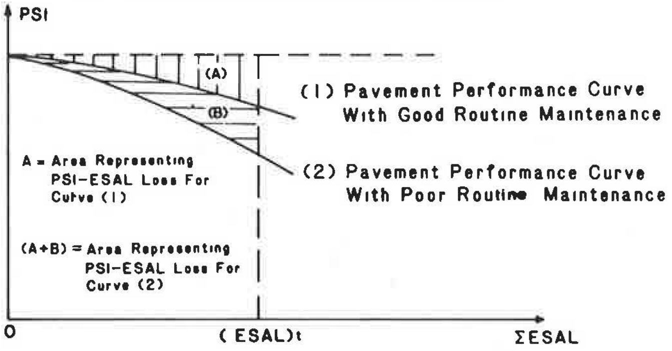
When the hypothesis of positive correlation between expenditure on routine pavement maintenance and level of routine maintenance is valid, a family of n possible pavement performance curves can be imagined for a given pavement. Expenditure on routine maintenance increases incrementally from Curve 1 to Curve n, as shown in Figure 2. The increment in maintenance expenditure from Curve i to Curve (i + 1) is given by δS_i. The corresponding difference in PSI-ESAL loss between the two curves is designated as δA_i.

Reduction in PSI-ESAL loss (δA_i) results when maintenance

T. F. Fwa, Department of Civil Engineering, National University of Singapore, Singapore. K. C. Sinha, School of Civil Engineering, Purdue University, West Lafayette, Ind. 47907.



(a) Pavement Deterioration Expressed In PSI Loss



(b) Pavement Deterioration Expressed In PSI-ESAL Loss

FIGURE 1 Relationship between pavement performance and routine maintenance.

expenditure is increased from S_i to $(S_i + \delta S_i)$ and represents the amount of improvement in pavement performance achieved. As the maintenance expenditure increment (δS_i) becomes infinitesimally small, the following index (defined as a routine pavement maintenance effectiveness index) provides a measure of improvement in pavement performance for a unit change in maintenance expenditure.

$$M_i = -\lim_{\delta S_i \to 0} (\delta A_i/\delta S_i) = -(dA/dS)_i \tag{5}$$

where

M_i = routine pavement maintenance effectiveness index evaluated at the routine maintenance level represented by S_i in Figure 2,
A = PSI-ESAL loss,
S = routine maintenance expenditure, and
δA_i and δS_i are as defined in Figure 2.

When S is expressed in mean annual maintenance expenditure per lane-mile, the unit of an effectiveness index (M) has a

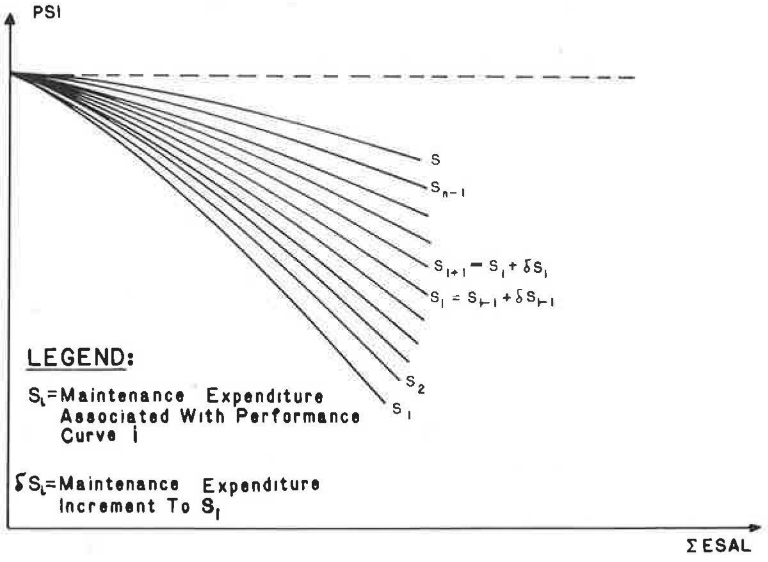


FIGURE 2 Family of possible performance curves for a given pavement.

unit given by PSI-ESAL loss per dollar per year per lane-mile. The expression in Equation 5 implies that, if A is plotted against S, the slopes of such a plot give the values of M at different levels of S. This offers a relatively convenient way to derive the values of M at desired levels of S. A negative sign is added to the expression in Equation 5 so that an M-value would be positive for the usual case in which a PSI-ESAL loss reduction would result from an increase in maintenance expenditure.

APPLICATION

A case study is presented in this paper as an example of the application of the concept described. The computations in this case study were based on data on the state highway system in Indiana. A total of 75 highway routes in Indiana were analyzed. These included 8 Interstate highways and 67 U.S. and state routes. These roads represent nearly 70 percent of the total state highway system mileage in Indiana.

The data requirements for pavement performance and routine maintenance analysis are discussed in this section. This discussion is followed by a description of the computational procedure involved in the analysis. The implications and significance of the results of this case study are also discussed.

Description of Data

Two main types of data were needed for the case study: data required for establishing the performance curve of a given highway route and routine pavement maintenance cost data.

Data on Pavement Performance

The PSI history of a given pavement section of a given highway route was determined from the annual Roadmeter roughness records maintained by the Indiana Department of Highways (IDOH). Three successive studies, covering a period of 8 years, were conducted by Purdue University and IDOH (*4–6*) in an effort to establish a comprehensive model of statistical correlation between Roadmeter roughness numbers and PSI for the state highway system of Indiana. The final results of this research effort are given in Equations 6 and 7.

For flexible and overlay pavements,

$$PSI = 8.72 - 1.9633 * \log (RN) \qquad (6)$$
$$R^2 = 0.71$$

For rigid pavement,

$$PSI = 11.73 - 2.83369 * \log (RN) \qquad (7)$$
$$R^2 = 0.68$$

where RN is roadmeter counts per mile and R^2 is the statistical coefficient of multiple determination.

The next requirement for establishing a performance curve is ESAL information. The data required for ESAL computation include traffic volume, traffic stream composition, vehicle axle configuration, and operating weights of vehicles. Traffic volume information was obtained from the annual traffic maps published by the IDOH. The remaining data were derived directly from the records of the 1984 Indiana Highway Cost Allocation Study (*7*). These records were the results of an extensive data collection effort made by the cost allocation study team. Fourteen vehicle classes were identified and subdivided into a total of 93 weight groups. Detailed information on axle weights and the traffic stream proportion of each weight group was available by highway functional class. These data enabled a sufficiently accurate computation of cumulative ESAL history to be made for the present case study.

Cost Data for Routine Pavement Maintenance

The IDOH maintains detailed records of routine highway maintenance activities. These records are compiled from information recorded on field crew-day cards. A field crew-day card is prepared each time a maintenance crew performs an activity. The information recorded on each field crew-day card includes type of routine maintenance activity, date, location, number of crew members, man-hours spent, types of equipment employed with corresponding usage in miles or hours, types and quantities of materials used, and work accomplishment measure such as lane-miles for seal coating and linear feet for cutting of relief joints. These data are recorded by activity and by fiscal year for each highway section. A highway section is defined as the portion of a highway that lies within the boundaries of a county.

The information from crew-day cards was summarized to aggregate yearly pavement maintenance costs that included the costs of the following routine pavement maintenance activities: shallow patching, deep patching, premix leveling, seal coating, sealing longitudinal cracks and joints, sealing cracks, cutting relief joints, joint and bump burning, and miscellaneous. A detailed description of the computational procedure for these aggregated pavement routine pavement maintenance costs is given elsewhere (*2*).

Analysis Procedure

The following steps were involved in the analysis of routine maintenance effects for each of the 75 highway routes considered in the case study:

1. Identify sections of the highway route that have the same pavement characteristics (material type, age, and thickness).
2. Compute routine pavement maintenance expenditure on each highway section for the analysis period.
3. Establish the performance curve for each highway section and calculate the corresponding PSI-ESAL loss for the analysis period.
4. Plot PSI-ESAL losses derived in Step 3 against the corresponding maintenance costs computed in Step 2, and calculate the routine pavement maintenance effectiveness index (M) as shown in Figure 3.

Because of the relatively small number of data points available in each of the 75 cases analyzed and because there was a

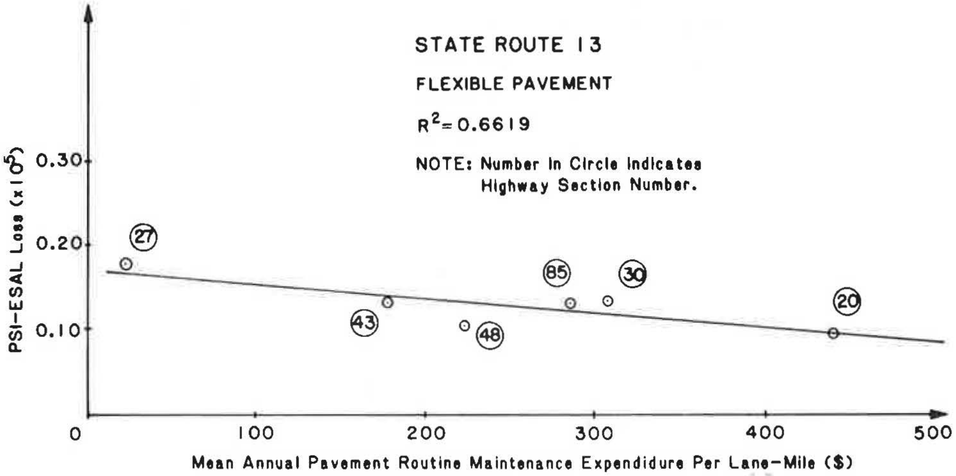


FIGURE 3 Example of PSI-ESAL loss versus maintenance expenditure.

lack of information on the true relationship between the parameters PSI-ESAL loss and routine pavement maintenance cost, the method of least squares was used to fit a straight line to the data points in each case.

Results of Analysis

The computed values of the routine pavement maintenance effectiveness index (M) for the 59 flexible, 10 overlay, and 6 rigid pavement cases are given in Tables 1 and 2. For flexible and overlay pavements, the M-values were evaluated at a cumulative ESAL level of 1.5×10^5. For rigid pavements, they were estimated at a cumulative ESAL-value of 1.5×10^7. These cumulative ESAL levels were selected by making reference to the median and mean values of the cumulative ESAL-values for the three pavement types. The six rigid pavements, because they are Interstate highways, carried greater traffic and were much older than most of the flexible and overlay pavement routes. This explains the large difference between the cumulative ESAL-values. A summary of the statistical characteristics of the distribution of the effectiveness indices (M) of Indiana highways is given in Table 3.

It is obvious from the definition of M and the results that a comparison of M-values is meaningful only if these values are evaluated at the same cumulative ESAL level and for the same pavement type. When these requirements are met, a higher M-value indicates a more effective routine maintenance program that produces more improvement in pavement performance for each maintenance dollar spent.

Regional Effects on Effectiveness of Maintenance

The effects of environmental and climatic factors on the effectiveness of routine maintenance work is an area on which relatively little research has been done. The routine pavement maintenance effectiveness index proposed in this study provides a convenient way of measuring such effects.

The results given in Tables 1 and 2 are also classified into N (northern) and S (southern) environmental-climatic regions. These two environmental-climatic regions of Indiana, as shown in Figure 4, have been commonly used in pavement-related studies conducted in Indiana (*2*, *3*, *7*).

The characteristics of these two regions are given in Table 4. Also given in this table are the ranges of values of various climatic and environmental variables for each of the two regions. In general, the northern region has a longer period of depressed temperature, as reflected by its higher freeze index, and heavier snowfall. On the other hand, the southern region receives more precipitation and is exposed to more changes of air temperature across the freezing point. It is interesting to study the impacts that the characteristics of these two regions have on routine maintenance.

Statistical regression analyses were performed for flexible, overlay, and rigid pavements to test the significance of regional effect in each case. The relevant regression model is

$$\begin{aligned} M_i &= c_0 + c_1 Z_i + c_2 X2_i + c_3 X3_i \\ &\quad + c_4 X4_i + c_5 X5_i + e_i \\ i &= 1, 2, \ldots, n \end{aligned} \tag{8}$$

where

M = pavement routine maintenance effectiveness index in PSI-ESAL loss/dollar/year/lane-mile;
Z = 0 for southern region and 1 for northern region;
X2 = pavement age in years;
X3 = pavement thickness in inches for rigid pavement and structural number for flexible pavement;
X4 = mean annual ESAL;
X5 = total cumulative ESAL;
e = random error term;
c_k = regression parameters, k = 1, 2, . . . , 6; and
n = total number of data points.

Only variables that do not represent any environmental or climatic conditions are included in the model. The environmental and climatic variables (Table 4) that describe the conditions in each of the two regions were qualitatively represented by the indicator variable Z.

Because the goal was to determine whether the effects of

TABLE 1 ROUTINE PAVEMENT MAINTENANCE EFFECTIVENESS INDICES FOR FLEXIBLE AND OVERLAY PAVEMENTS IN INDIANA

No.	Highway Route	Index M	Region	No.	Highway Route	Index M	Region
1	SR 1(n)	5.50	N	36	SR 39(n)	11.31	N
2	SR 1(s)	1.89	S	37	SR 39(s)	4.02	S
3	SR 2	26.22	N	38	US 40	7.18	S
4	SR 3(n)	20.18	N	39	US 41	3.20	S
5	SR 3(s)	12.49	S	40	SR 42	1.50	S
6	SR 4	23.71	N	41	SR 43(n)	10.41	N
7	SR 5	26.93	N	42	SR 43(s)	3.00	S
8	US 6	11.90	N	43	SR 44	10.61	S
9	SR 8	32.72	N	44	SR 46	10.22	S
10	SR 9(n)	11.11	N	45	SR 47	14.29	S
11	SR 9(s)	14.38	S	46	SR 48	16.48	S
12	SR 10	20.38	N	47	US 50	5.21	S
13	SR 13	16.41	N	48	US 52(n)	5.89	N
14	SR 14	2.80	N	49	US 52(s)	10.80	S
15	SR 16	24.32	N	50	SR 55	7.60	N
16	SR 17	29.78	N	51	SR 56	3.09	S
17	SR 18	6.70	N	52	SR 57	13.22	S
18	SR 19	13.32	N	53	SR 58	14.88	S
19	US 20	14.81	N	54	SR 60	15.68	S
20	SR 23	16.01	N	55	SR 62	4.50	S
21	US 24	8.79	N	56	SR 63	12.72	S
22	SR 25	22.78	N	57	SR 64	11.01	S
23	SR 26	22.91	N	58	I 64	11.48	S
24	SR 28	12.39	S	59	I 65(s)	6.50	S
25	SR 29	10.59	N	60	SR 67	11.47	S
26	US 30	17.61	N	61	SR 75	8.50	S
27	US 31(n)	20.23	N	62	SR 135	10.61	S
28	US 31(s)	4.19	S	63	US 150	5.40	S
29	SR 32	5.10	S	64	US 231(n)	8.51	N
30	SR 33	19.57	N	65	US 231(s)	6.62	S
31	US 35	12.79	N	66	SR 234	10.68	S
32	US 36	10.38	S	67	SR 236	6.60	S
33	SR 37(n)	8.31	N	68	US 421(n)	10.09	N
34	SR 37(s)	2.82	S	69	US 421(s)	7.70	S
35	SR 38	16.29	N				

Note : 1. M is pavement routine maintenance effectiveness in PSI-ESAL loss/dollar/year/lane-mile.
2. All M values are avaluated at cumulative Esal value of 150,000 .
3. Cases number 26, 27, 28, 39, 41, 42, 47, 54, 57, and 59 are overlay pavement routes.
4. N = northern environmental-climatic region
S = southern environmental-climatic region

TABLE 2 ROUTINE PAVEMENT MAINTENANCE EFFECTIVENESS INDICES FOR RIGID PAVEMENTS IN INDIANA

Case Number	Highway Route	Effectiveness Index M (x 10^4)	Region
1	I-94	1.65	N
2	I-65	1.43	N
3	I-69	0.53	N
4	I-70	0.96	S
5	I-74	0.70	S
6	I-64	0.97	S

Note : 1. M is in PSI-ESAL loss/dollar/year/lane-mile
2. All M values are evaluated at cumulative ESAl value of 15,000,000 .
3. N = northern environmental-climatic region
S = southern environmental-climatic region

TABLE 3 CHARACTERISTICS OF ROUTINE PAVEMENT MAINTENANCE EFFECTIVENESS INDICES FOR INDIANA HIGHWAYS

	Rigid Pavement	Flexible Pavement	Overlay Pavement
No. of cases analyzed	6	59	10
Reference cumulative ESAL level	1.5×10^7	1.5×10^5	1.5×10^5
Range of M			
Minimum	0.53×10^4	1.50	3.00
Maximum	1.65×10^4	32.70	20.23
Mean	1.04×10^4	12.38	9.70
Standard deviation	0.43×10^4	7.13	6.31

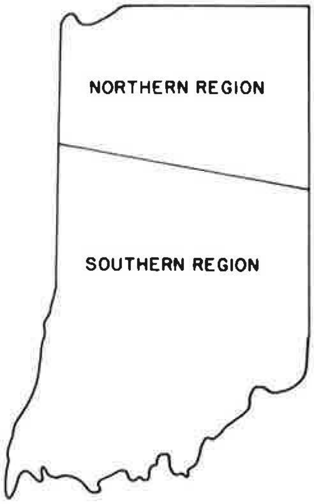


FIGURE 4 Northern and southern regions of Indiana.

routine maintenance on pavement performance were different in the two regions, no attempt was made to obtain the best regression model out of Equation 8. In drawing inferences about c_1, the appropriate statistical test was

$$H_0: \quad c_1 = 0$$

$$H_1: \quad c_1 \neq 0$$

Analysis of Regional Effect on Flexible Pavement

The results of the statistical analysis based on Equation 8 for the routine maintenance effectiveness index values of flexible pavements in Indiana are given in Table 5. The regional effect was found to be significant at both the 0.05 and the 0.01 level of significance, which means that the effects of routine maintenance on flexible pavements were significantly different statistically in the two regions of Indiana. The correlation matrix in Table 5 shows that there was little correlation between the indicator variable Z and the other independent variables included in the regression model.

These results led to the conclusion that the routine maintenance effectiveness index of flexible pavement was higher in the northern region than in the southern region. Physically, this means that the amount of pavement damage repaired (i.e., the amount of PSI-ESAL loss recovered) per dollar of maintenance work was greater in the northern region. In other words, it may be said that each dollar spent for maintenance per lane-mile in the northern region was more effective in improving pavement performance than it was in the southern region.

Analysis of Regional Effect on Overlay Pavements

Because of the relatively small number of overlay pavement cases included in the case study, a reduced version of the general model in Equation 8 was used for the analysis presented in this section. Because the several reduced models selected all led to the same conclusion about the regional effect on maintenance effectiveness, only one of them is presented here for the purpose of discussion. The model with the best coefficient of multiple determination (R^2) was

$$M_i = c_0 + c_1 Z_i + c_2 X2_i + e_i \qquad (9)$$
$$i = 1, 2, \ldots, 10$$

TABLE 4 CHARACTERISTICS OF NORTHERN AND SOUTHERN REGIONS OF INDIANA

Climatic/Environmental Factors	Northern Region		Southern Region	
	Minimum	Maximum	Minimum	Maximum
Freezing Index (°F-Day)	100	350	0	170
Mean Annual Snowfall (in.)	22	60	11	24
Mean Annual Rainfall (in.)	34	38	37	46
Mean Daily Temperature (°F)	50	52	52	57
Thornthwaite Moisture Index	30	41	35	55
Freeze-Thaw Cycle Index(*)	105	111	105	160
Soil Support Value	4.0	6.8	4.0	6.8

(*) Freeze-thaw cycle index refers to the mean number of air temperature changes across the freezing point, 32°F.

TABLE 5 REGRESSION ANALYSIS FOR FLEXIBLE PAVEMENTS BASED ON MODEL IN EQUATION 8

Coefficient	Estimated Value	*t*-Statistic
c_0	54.933	3.898
c_1	6.531	4.143[a]
c_2	−1.868	−3.212
c_3	−5.387	−2.303
c_4	−266.608	−1.175
c_5	27.497	1.190

[a] Significant at levels 0.05 and 0.01.

Note: The correlation matrix is as follows:

	M	Z	X2	X3	X4	X5
M		0.428	−0.407	0.015	−0.041	−0.066
Z	0.428		−0.045	0.253	−0.083	−0.080
X2	−0.407	−0.045		−0.334	−0.001	0.083
X3	0.015	0.253	−0.334		0.118	0.092
X4	−0.041	−0.083	−0.001	0.118		0.995
X5	−0.066	−0.080	0.083	0.092	0.995	

where all terms are as defined for Equation 8.

The results given in Table 6 led to the conclusion that regional effect was significant at a level of significance equal to 0.05. That is, a unit of routine maintenance work performed in the northern region was more effective in improving overlay pavement performance than was a similar unit of work performed in the southern region.

TABLE 6 REGRESSION ANALYSIS FOR OVERLAY PAVEMENTS BASED ON MODEL IN EQUATION 9

Coefficient	Estimated Value	*t*-Statistic
c_0	9.851	1.890
c_1	9.504	2.693[a]
c_2	−0.329	−0.593

[a] Significant at level 0.05.

Note: The correlation matrix for all variables in Equation 8 is as follows:

	M	Z	X2	X3	X4	X5
M		0.696	−0.018	−0.078	−0.102	−0.022
Z	0.696		0.195	0.079	−0.138	−0.043
X2	−0.018	0.195		−0.583	−0.442	−0.388
X3	−0.078	0.079	−0.538		0.582	0.611
X4	−0.102	−0.138	−0.442	0.585		0.988
X5	−0.022	−0.043	−0.388	0.611	0.988	

Analysis of Regional Effect on Rigid Pavements

Because there were only six rigid pavement cases available for study, a reduced version of the general model in Equation 8 was again employed. Because all six pavements had the same slab thickness (10 in.) and because variables X4 and X5 were highly correlated, variables X3 and X5 were first eliminated from the model. All possible reduced models with different combinations of the remaining variables, Z, X2, and X4, gave similar conclusions to the statistical test for regional effect. Because X2 had the lowest correlation with Z, the following model is selected for illustration:

$$M_i = c_0 + c_1 Z + c_2 X2_i + e_i \qquad (10)$$
$$i = 1, 2, \ldots, 6$$

where all terms are as defined in Equation 8.

The results of the statistical analysis for the model in Equation 10 are given in Table 7. It was found that regional effect was significant only at a level of significance of 0.431. It may therefore be concluded that there was no difference statistically between the effectiveness of routine maintenance in the two regions.

TABLE 7 REGRESSION ANALYSIS FOR RIGID PAVEMENTS BASED ON MODEL IN EQUATION 10

Coefficient	Estimated Value	*t*-Statistic
c_0	25942.82	2.982
c_1	2439.30	0.907[a]
c_2	−1034.76	−2.021

[a] Significant at level 0.431; not significant at level 0.05.

Note: The correlation matrix for all variables in Equation 8 is as follows:

	M	Z	X2	X4	X5
M		0.420	−0.745	0.801	0.670
Z	0.420		−0.153	0.558	0.547
X2	−0.745	−0.153		−0.368	−0.191
X4	0.801	0.558	−0.368		0.980
X5	0.670	0.547	−0.191	0.980	

Findings of the Case Study

Statistical analyses of the results of the case study indicated that there was a significant regional variation in the effects of routine maintenance on flexible pavements in Indiana. It was concluded, at the 99 percent confidence level, that a unit of routine maintenance work was more effective in improving pavement performance in the northern region. The same conclusion was obtained for overlay pavements but with a slightly lower confidence level of 95 percent. For rigid pavements, no significant regional variation in the effects of routine maintenance was found.

It should be noted that the qualitative variable (Z) in Equations 8–10 was used for testing the regional variation of routine maintenance effects. Each region covers a big area and a large number of highway routes. The regional variable (Z) represents the net combined effect of all environmental and climatic factors in a region. Further research is being undertaken to investigate the influence of individual environmental and climatic factors on the effects of routine maintenance by indentifying the specific conditions of each highway route.

CONCLUSIONS

Knowledge of the effects of routine maintenance on pavement performance is important to the management of highway pavement at both the network and the project level. A methodology for evaluating these effects, based on pavement performance data and aggregated routine pavement maintenance cost information, has been described.

An application of the concept has been illustrated with a case study in which 75 highway routes in Indiana were analyzed. The proposed methodology was employed to compute for each highway route a routine pavement maintenance effectiveness index that is a measure of the effect of routine maintenance work on pavement performance. The magnitude of the index provides a means of assessing the effectiveness of a given maintenance policy or program. Statistical analyses were performed to examine the regional variation in effects of routine maintenance in Indiana. Research is under way to derive further information about the effects of routine maintenance by taking into consideration the influence of individual environmental and climatic factors and the effectiveness of specific routine maintenance activities.

REFERENCES

1. T. F. Fwa and K. C. Sinha. A Rational Approach for Allocation of Highway Pavement Maintenance and Rehabilitation Costs. *Proc., North American Pavement Management Conference,* Vol. 1, Toronto, Ontario, Canada, March 18–21, 1985.
2. E. A. Sharaf. *Analysis of Highway Routine Maintenance Costs.* Ph.D. dissertation. School of Civil Engineering, Purdue University, West Lafayette, Ind., Aug. 1984.
3. T. F. Fwa. *An Aggregate Damage Approach for Highway Pavement Performance Analysis.* Ph.D. dissertation. School of Civil Engineering, Purdue University, West Lafayette, Ind., May 1985.
4. S. Mohan. *Development of a System for the Evaluation of Pavements in Indiana.* Interim Report FHWA/ISHC/JHRP–78/21. Joint Highway Research Project, Purdue University, West Lafayette, Ind., Oct. 1978.
5. E. S. W. Metwali. *Framework for a Pavement Evaluation System.* Report FHWA/IN/JHRP–81/7. Joint Highway Research Project, Purdue University, West Lafayette, Ind., May 1981.
6. K. Trezos and S. Gulen. *Correlation of Roadmeter Roughness Number with PSI.* Division of Research and Training, Indiana Department of Highways, Indianapolis, July 1983.
7. K. C. Sinha, T. F. Fwa, E. A. Sharaf, A. B. Tee, and H. L. Michael. *Indiana Highway Cost Allocation Study.* Final Report FHWA/IN/JHRP–84/20. Joint Highway Research Project, Purdue University, West Lafayette, Ind., Oct. 1984.

Publication of this paper sponsored by Committee on Pavement Maintenance.

Estimation of Service Life and Cost of Routine Maintenance Activities

KIERAN J. FEIGHAN, ESSAM A. SHARAF, THOMAS D. WHITE, AND KUMARES C. SINHA

Results of research on service life and cost of various routine maintenance activities in Indiana are presented. This research is a part of a larger project to develop an optimization program for the routine maintenance management system. The information on service life and cost is necessary to identify cost-effective solutions and to monitor whether or not changes in work practices or materials significantly influence the effectiveness of the activity. The routine maintenance activities considered were in the general areas of pavement, shoulder, and drainage. The unit cost information per production unit was obtained from an analysis of crew-day card reports. The service life data were developed through personal interviews with subdistrict foremen. The estimates of service life were related to pavement condition as well as to accomplishment per day. The resulting information provides a reasonable set of input data for the optimization of maintenance decisions.

Interest in pavement maintenance management has grown steadily during the last 10 years or so. This interest has been largely motivated by a desire to obtain a greater degree of control and standardization of approach in order to ultimately achieve a better return per dollar invested in the construction and maintenance of pavements. However, most of the research that has been undertaken to date has been in the area of major maintenance. Consequently, there is limited published information on techniques and data concerning routine maintenance activities and management. The awareness of routine maintenance as a major consumer of limited highway funds is the

---

K. J. Feighan, T. D. White, and K. C. Sinha, School of Civil Engineering, Purdue University, West Lafayette, Ind. 47907. E. A. Sharaf, Department of Civil Engineering, Cairo University, Cairo, Egypt.