Analysis of Pavement Routine Maintenance Activities in Indiana

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ABSTRACT

An analysis of pavement routine maintenance costs for the state highway system in Indiana is presented. The data base includes pavement maintenance records for 4 years, 1980-1983. The results include a trend analysis as well as a correlation analysis. First, the total cost trends as well as individual activity costs are examined. Then the resource consumption trends are analyzed in terms of labor and materials use. Finally, a statistical correlation analysis is presented in order to examine the relationship of maintenance expenditures in the earlier years and the level of maintenance expenditures in subsequent years. The analysis showed high correlation between maintenance expenditures in a given year and the expenditures of the previous 2 or 3 years. The results of this study should be of direct use in the planning and management of annual pavement maintenance programs.

Pavement maintenance activities constitute one of the major parts of highway routine maintenance. In Indiana the share of pavement maintenance in the total highway routine maintenance expenditures was about 18 percent for FY 1979. This share is now about 24 percent for FY 1983 (1,2).

A study is being conducted at Purdue University to develop prediction models for pavement routine maintenance needs. These models can be used for making decisions about pavement maintenance management and cost control. A summary of the first phase of this study is presented. The first phase includes a historical data analysis of pavement maintenance costs and resources used as well as an examination of possible relationships between expenditures from year to year.

The data used in this study included detailed records of highway routine maintenance activities from the Indiana Department of Highways (IDOH) for FY 1980-FY 1983. These records are the compiled form of actual field information on all maintenance activities, which are recorded on field crew day cards.

TRENDS IN PAVEMENT MAINTENANCE COSTS

Pavement maintenance costs were computed for each highway section in terms of dollars per lane-mile. To avoid changes in unit prices from year to year, all costs were converted to 1982-1983 dollars. Of the total 874 sections, 768 sections [62 in the Interstate system (IS) and 706 in other state highway system (OSHS)] were found to have received one or more maintenance activities during the last 4 years. The remaining sections did not receive any pavement maintenance during the last 4 years.

It was observed that, in general, the average total cost of pavement maintenance of the IS is less than that of the OSHS. The average total cost on the OSHS is 30-120 percent higher than that of the IS. For instance, 10 percent of the total IS lane-miles received maintenance at an average cost of $295 per lane-mile per year, whereas 10 percent of the total lane-miles of the OSHS received an average of $547 per lane-mile per year in the last 4 years. The reason the IS sections have lower maintenance costs per lane-mile can be traced to the fact that the IS receives more dollars per lane-mile of major maintenance activities such as resurfacing and rehabilitation, which reduces the need for more frequent routine maintenance activities.

The major activities contributing most to the total maintenance costs are patching (activities 201 and 202 in Table 1) and sealing (activities 206 and 207 in Table 1). About 85 percent of the total cost of IS pavement maintenance was spent on these four activities during 1980, and 87, 82, and 90 percent were spent during 1981, 1982, and 1983, respectively. For the OSHS, these figures were 66, 69, 66, and 66 percent for 1980, 1981, 1982, and 1983, respectively (3-6).

TABLE 1 Pavement Routine Maintenance Activities *(7)*

Activity	Code No.	Production Units
Shallow patching	201	Tons of mix
Deep patching	202	Tons of mix
Premix leveling	203	Tons of premix
Seal coating	205	Lane-miles
Sealing longitudinal cracks and joints	206	Linear miles
Sealing cracks	207	Lane-miles
Cutting relief joints	209	Linear feet
Joint and bump burning	214	Bumps removed
Other	219	Man-hours

The single activity with the highest portion of pavement routine maintenance cost is shallow patching (activity 201). The share of this activity in the total cost was 27, 28, 38, and 30 percent during 1980, 1981, 1982, and 1983, respectively, for the IS. The corresponding figures for the OSHS were 32, 31, 40, and 29 percent, respectively.

The implication of these results is that, in developing routine maintenance prediction models, separate consideration should be given IS and OSHS. In addition, the results clearly show that the accuracy of prediction models would depend largely on the accuracy of the prediction of patching and sealing activity needs.

TRENDS IN LABOR CONSUMPTION

To analyze the labor requirements of pavement maintenance activities, average labor consumption rates in terms of man-hours required to produce one unit of a particular activity were calculated for each of the highway systems separately for each of the 4 years (3,4,7).

A review of the average labor consumption rates

revealed that patching activities (201 and 202) on the IS required more labor than did those on the OSHS. On the other hand, the labor consumption rates of sealing activities (206 and 207) on the IS are less than those on the OSHS. This apparent discrepancy can be explained by the fact that both activities on the IS require more elaborate safety arrangements during maintenance operations causing a larger number of man-hours to be spent. However, the relative magnitude of cracks sealed per lane-mile in the OSHS is much higher than that in the IS and this is causing a higher net need for man-hours for sealing activities on the OSHS.

TRENDS IN MATERIALS USE

The rates of materials consumption in various activities were analyzed by examining the average rates of consumption of different material types by highway system for each of the 4 years.

A definite trend was observed in the use of bituminous mixtures in patching activities (activities 201 and 202). A significant increase took place in the use of salvage and cold bituminous mixtures to replace the conventional hot bituminous mixtures. For example, in 1980 for shallow patching activity (201), salvage bituminous mixtures were used rarely; they were not used at all on the IS and were used in only 1 percent of the OSHS jobs. However, in 1983, salvage and cold bituminous mixtures were used in 89 percent of the shallow patching jobs on the IS and in 100 percent of the OSHS jobs. At the same time, a gradual decrease took place in the use of conventional bituminous mixtures and bituminous materials. For example, bituminous mixtures were used in 100 percent of the shallow patching jobs on the IS during 1980 compared to 90 percent in 1983. The corresponding figures for OSHS jobs were 100 percent in 1980 and 82 percent in 1983.

The use of bituminous materials was also reduced during this period. In 1980, 77 percent of the shallow patching jobs on the IS used bituminous materials and in 1983 only 51 percent did. The corresponding figures on the OSHS were 65 percent in 1980 and 46 percent in 1983.

The same type of trend was observed in the materials use for deep patching activity (202). Furthermore, it was observed that the rates of consumption of both bituminous materials and conventional hot bituminous mixtures for patching were also reduced during the later years. For example, consider activity 201 (shallow patching). In 1980 the rate of consumption of hot bituminous mixtures for IS jobs was 1.0 ton per production unit, and in 1983 this rate dropped by about 40 percent to 0.61 ton per production unit. Similarly, for the OSHS jobs, the consumption rate was decreased from 0.95 ton in 1980 to 0.61 ton in 1983.

On the other hand, sealing activities (205, 206, and 207) showed different trends. While an increasing rate of bituminous materials consumption can be noticed for activity 205 (seal coating), a decreasing rate of consumption for the same material is observed for activities 206 and 207 (crack sealing). The reason for that increase in bituminous materials use in seal coating activity (recorded for OSHS jobs only) is due to the fact that this activity could be considered the only major maintenance activity applied on most of the OSHS (in the last few years, most of resurfacing and rehabilitation work was directed toward the IS). Thus the increase in the use of bituminous materials was to compensate for OSHS repair needs.

Finally, the other consumption rates and frequencies indicated a stable trend with only slight variations from year to year.

CORRELATION ANALYSIS OF PAVEMENT MAINTENANCE COSTS

Statistical correlation was performed between the pavement maintenance expenditures of a given year against the maintenance expenditures of a past year or number of years. Because the available data concerned 4 years, 1980-1983, three cases of correlation were applied: Case 1, correlation between each 2 successive years, that is 1980 with 1981, 1981 with 1982, and 1982 with 1983; Case 2, correlation between the average of 2 years' expenditures with the third year, that is the average of 1980 and 1981 with 1982, and the average of 1981 and 1982 with 1983; and Case 3, correlation between the average of 3 years' expenditures with the fourth year, that is the average of 1980, 1981, and 1982 with 1983. The results of the three cases are given in Table 2. As may be seen from Table 2, there is a general trend for higher correlation values between total costs for the IS than between those for OSHS. For example, in Case 2 (average of 2 years with the third year), the average correlation coefficient is 0.77 for the IS and 0.705 for OSHS, and in Case 3 these values are 0.82 and 0.72, respectively. The results also showed that the correlation coefficient is improved with the increase of number of past years considered. For instance, 0.65 was the correlation coefficient in Case 1 for both IS and OSHS, whereas the correlation coefficients in Case 2 were 0.77 and 0.705 for the two systems, respectively, and in Case 3 they were 0.82 and 0.72, respectively.

TABLE 2 Correlation Analysis of Total Costs

Pearson Correlation Coefficient					
Case 1[a]		Case 2[b]		Case 3[c]	
Interstate	Other State Highways	Interstate	Other State Highways	Interstate	Other State Highways
0.58	0.64	0.72	0.70	0.82	0.72
0.65	0.67	0.81	0.71		
0.73	0.65				
Average					
0.65	0.65	0.77	0.705	0.82	0.72

[a] Each 2 successive years, 1980 with 1981, 1981 with 1982, and 1982 with 1983.
[b] Average of 2 years with the third year, 1980-1981 with 1982, and 1981-1982 with 1983.
[c] Average of 3 years with the fourth year, 1980-1982 with 1983.

A second set of analyses was carried out to investigate the correlation between individual activity costs to determine if a relationship exists between expenditures of a past year or years and those of a following year. As in the previous analysis, the three correlation cases were applied for each individual activity. The results of the three cases are given in Table 3. The most important result is that patching and sealing activities (activities 201, 202, 206, and 207) showed the highest correlation values particularly when the expenditures of the past 2 or 3 years are considered (Case 2 or 3). It is believed that this is a good indication, because these activity costs represent more than 85 percent of total costs for the IS and more than 65 percent for the OSHS, which means that a good estimation of these activity costs using previous expenditure records can lead to a good overall estimation of total maintenance expenditures. Also, for these activities as well as most of the other activities, the IS correlation values were higher than those of the OSHS.

TABLE 3 Correlation Analysis of Individual Activity Costs

Activity No.[a]	Pearson Correlation Coefficient					
	Case 1[b]		Case 2[c]		Case 3[d]	
	Interstate	Other State Highways	Interstate	Other State Highways	Interstate	Other State Highways
201	0.73	0.69	0.82	0.71	0.82	0.72
202	0.63	0.24	0.76	0.27	0.76	0.33
203	0.16	0.06	0.21	0.04	0.23	0.02
205	NA	0.04	NA	0.06	NA	0.08
206	0.33	0.38	0.39	0.44	0.51	0.55
207	0.19	0.23	0.32	0.32	0.20	0.43
209	0.21	0.20	0.27	0.19	0.02	0.22
214	0.17	0.17	0.32	0.32	0.24	0.40
219	0.37	0.08	0.45	0.09	0.37	0.17

Note: NA = not applicable.

[a] Refer to Table 1 for activity names.
[b] Each 2 successive years, 1980 with 1981, 1981 with 1982, and 1982 with 1983.
[c] Average of 2 years with the third year, 1980-1981 with 1982, and 1981-1982 with 1983.
[d] Average of 3 years with the fourth year, 1980-1982 with 1983.

To summarize, the two correlation studies showed that the past expenditures could be of significant importance when used in maintenance prediction models for both total costs and individual activity costs. It should be noted here that the results give a general indication of the possible use of past records to predict future maintenance needs; however, no specific relationships could be derived from this analysis. The precise nature of these relationships merits further investigation.

CONCLUSIONS

On the basis of the findings of this study, the following conclusions can be drawn:

1. The accuracy of pavement maintenance cost estimation depends largely on the accuracy of predicting the cost of patching (shallow and deep) and sealing activities. These two activities constitute more than 85 percent of the total IS pavement maintenance costs and more than 65 percent of the total OSHS pavement maintenance costs.
2. The single activity that contributes most to total pavement maintenance costs is shallow patching activity, for which about 30-40 percent of the total pavement maintenance expenditures are made.
3. There is a significant difference in the use of labor and materials for the same pavement maintenance activities applied to IS and to OSHS. This is because maintenance practices are different for these two systems. In addition, the maintenance needs of these two systems are different. Consequently, the prediction of pavement maintenance costs should be undertaken separately for these two systems.
4. High correlation values were found in analyzing the year-to-year pavement maintenance expenditures, indicating the necessity of including past expenditures as a variable in maintenance cost prediction models. The average of the expenditures during 2 or 3 years showed better correlation values than were obtained when only 1 year was used to predict the following year's expenditure.
5. The results from disaggregate analysis of pavement maitenance costs can reveal much useful information that can be used in developing systematic maintenance management programs and in controlling maintenance costs.

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REFERENCES

1. Maintenance Workload and Performance Budget. Annual Report MM-103. Division of Maintenance, Indiana Department of Highways, Indianapolis, 1980-1983.
2. Accomplishment and Performance Analysis. Annual Report MM-113. Division of Maintenance, Indiana Department of Highways, Indianapolis, 1980-1983.
3. E.A. Sharaf, K.C. Sinha, C. Whitmire, and E.J. Yoder. Field Investigation of Resource Requirements for State Highway Routine Maintenance Activities. In Transportation Research Record 943, TRB, National Research Council, Washington, D.C., 1983, pp. 24-27.
4. E.A. Sharaf, K.C. Sinha, and E.J. Yoder. Energy Conservation and Cost Saving Related to Highway Routine Maintenance: Data Collection and Analysis of Fuel Consumption. Draft Interim Report FHWA/IN/JHRP-82/23. Purdue University, West Lafayette, Ind., Dec. 1982.
5. Annual Budget Report. Division of Accounting, Indiana Department of Highways, Indianapolis, 1979-1982.
6. Materials Usage Summary. Annual Report 116D. Division of Maintenance, Indiana Department of Highways, Indianapolis, 1980-1983.
7. Field Operations Handbook. Division of Maintenance, Indiana Department of Highways, Indianapolis, 1981-1982.

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