RELATIONSHIPS BETWEEN FACTORS AFFECTING THE LEVEL OF SERVICE PROVIDED BY A PAVEMENT AND MAINTENANCE COSTS

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(The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agencies.)

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1888

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SUMMARY

This study attempted to establish and analyze relationships between forms of deterioration or distress that reduce the level of service provided by a highway pavement and the cost of correcting them. Using statistical computer analyses of 30 highway projects, the most significant relationships were identified. Very strong statistical relationships were identified between axle loadings (ESAL-18's) sustained and maintenance costs and between pavement age and maintenance costs. For a large majority of the projects, it was found that the unaccounted for variables (principally environmental) had no significant influence on the relationship between ESAL-18's and maintenance costs.

With additional refinement, the results of this study could be used to predict needed levels of funding for highway maintenance activities.

1890

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INTRODUCTION

Declining highway revenues over the past several years have led to increased attention to the levels of highway maintenance expenditures, particularly to the expenditures for maintaining the pavement structure. And concomitantly, increased attention has been given to determining the factors leading to the need for maintenance.

Highway engineers made great strides in assessing the factors leading to pavement deterioration in the early 1960s with the completion of the AASHO Road Test.(1) In that test, numerous pavements were tested to failure through repeated applications of various axle loadings. The test results were used to define an 18,000 lb. (18-kip) equivalent single axle load, often abbreviated as ESAL-18. ESAL-18 equivalency factors were then developed for various vehicle weights and axle configurations, depending upon the observed pavement damage related to those weights and configurations at the road test. Particularly noteworthy was the finding that passenger cars and light trucks contributed almost nothing to the structural damage undergone by the pavements. The results were further extended to develop design equations and charts in which projected ESAL-18 values, along with the characteristics of soils and paving materials and a regional factor related to unaccounted for variables, are major parameters.(2)

Following AASHTO's exhortations, the Virginia Department of Highways and Transportation, as have most major highway agencies, developed its own design guide patterned after the AASHTO approach, but with adjustment factors to accommodate variations in soils as they differ from those represented at the road test.(3) In this method, the pavement thickness index (a structural strength parameter) is a logarithmic function of cumulative ESAL-18's to be sustained over the life of a pavement. The major maintenance cost is for resurfacings to restore the structural capability consumed in service.

With the development of such design approaches and the inferences drawn from their use, one would assume that assigning responsibility for pavement maintenance costs among the different categories of highway users would be a simple matter of documenting costs and traffic. Such has not been the case, as was recently demonstrated in two cost responsibility studies.[4,5] The difficulty lies in the fact the AASHO Road Test was conducted over a short period of time (2 years) while in-service pavements are expected to perform adequately for 20 or more years. Thus, it is argued that pavement deterioration is, in fact, a function of both traffic and the environment, but that long-term environmental impacts were not evaluated by the AASHO Road Test. An extension of this argument is, correctly, that other design procedures, such as Virginia's, do not adequately address environmental considerations. Cost responsibility studies must, therefore, go beyond the parameters established in design procedures.

PURPOSE AND SCOPE

It was for the purpose of providing background for cost responsibility studies in Virginia that the present effort was undertaken. Both pavement maintenance costs and traffic data are readily available for primary and interstate highways in the state. Since some of this information recently had been summarized as part of a continuing research effort on the interstate system, those pavements were chosen for analysis in the present study.[6]

For a given pavement, ESAL-18's, pavement age, use of soil cement, thickness index, and soil resiliency factors were analyzed to assess their relation to pavement maintenance costs, and the strongest influences were identified.

It was initially hypothesized that accumulated ESAL-18's and accumulated maintenance costs would be the most significantly related. If this proved to be the case, then the establishment of a relationship between ESAL-18's and maintenance costs could permit the assignment of a dollar figure to ESAL-18 data.

METHODOLOGY

The approach selected was to identify statistically significant relationships between maintenance costs, traffic, and other design parameters. The expected results would be somewhat clouded by the absence of a formal pavement management system where maintenance expenditures would be triggered by thresholds of pavement distress. It was recognized that historical expenditures such as presently available stem from a variety of factors among which are pavement distress, availability of funds, and an ingrained idea that pavements should be resurfaced every 8 to 10 years. Nevertheless it was hoped that an examination of the variables would provide some insight for the attribution of maintenance costs among highway users.

Analytical Technique

The parameter relationships were evaluated using ordinary least squares regression analyses. Monitoring the coefficients of determination (R^2's), the t-statistics, and the estimated coefficients permitted the assessment of the significance and the potential of the various relationships for use in predicting cost figures. Using this statistical approach, various equation specifications were examined, among them simple linear relationships between maintenance costs and the other parameters, log-linear relationships, and log-log relationships.

Data

The data base consisted of information collected from 133 flexible pavement projects located throughout Virginia's interstate highway system (refer to Appendix A). The maintenance cost information was collected and supplied by the Maintenance Division of the Virginia Department of Highways and Transportation. The following data were available for each project: location, length in miles, initial construction cost in dollars per 24-foot lane mile, average annual maintenance cost in dollars per 24-foot lane mile, various design data (use of soil cement, thickness index, and soil resiliency), age in months, age in months at the time of each overlay, and estimated cumulative and average annual 18-kip data in millions of ESAL-18's.(7)

Some initial adjustments to the data base were made. Minor changes were necessary in order to make the data reported by roadway maintenance section correspond to project construction sections.

ANALYSIS AND RESULTS

The analysis can be broken down into three iterative phases: FLEX, FLEX II, and FLEX III. The first two phases afforded quite poor results. The authors identified two factors which contributed to the poor results. First, in FLEX the cost data used were annual expenditures in current dollars. These data needed to be normalized for inflation in order for statistically valid results to be obtained. This was done for FLEX II, where all costs were normalized to 1980 dollars based on the Engineering News Record's highway cost indices.[8]

Secondly, the analyses were made on a cross section basis instead of on a time-series basis. In other words, the comparisons were made across a variety of projects located throughout the state. The better approach would have been to look at annual variations within individual projects and thereby eliminate discrepancies between projects.

This problem was corrected in the final phase of the analysis. FLEX included all 133 projects in cross section and FLEX II dealt with a cross section of 30 randomly selected projects. Finally, FLEX III analyzed, on an individual project time-series basis the 13 best of the 30 projects for which data were most nearly complete. (For a listing of additional FLEX III data please see Appendix B.)

Although the results from the first two phases did not prove to be satisfactory, some benefits were gained. The aforementioned problem areas were identified and insight was acquired into the mechanics of the various parameter relationships. Also, the results of simple correlation matrices indicated that age and ESAL-18 data were too highly correlated to permit a clear assessment of either's influence on the dependent variable, and therefore, that they must be analyzed in separate equations. Finally, it was demonstrated that the design parameters analyzed—thickness index, use of soil cement, and soil resiliency—did not have any significant effects on maintenance costs. This result was anticipated since proper design should account for such variables.

The remainder of this section will consist of a discussion of FLEX III, the phase which yielded the most interesting results.

FLEX III

In this final phase of the study, the analyses included the correlations and adjustments made in an effort to correct and account for the weaknesses and problems encountered in the earlier phases. All of these results were products of time-series analyses and the results were satisfactory both in terms of R^2's and significance levels.

Table 1. FLEX III Input Variables

Variable	Description	Dependent or Independent
I, II, etc.	Project I, II, etc., annual maintenance expenditures in dollars per 24-foot lane mile	Dependent
IC, IIC, etc.	Project I, II, etc., accumulating annual maintenance expenditures in dollars per 24-foot lane mile	Dependent
IK, IIK, etc.	Project I, II, etc., accumulating annual ESAL-18's in millions	Independent
IA, IIA, etc.	Project I, II, etc., accumulating pavement age in years	Independent
L1C, L2C, etc.	*ln (IC), ln (IIC), etc.	Dependent
L1K, L2K, etc.	ln (IK), ln (IIK), etc.	Independent

NOTE: In FLEX II the randomly selected projects were arbitrarily numbered 1 through 30. In FLEX III the project numbers correspond to the numbers of the "best" projects from FLEX II; namely I, II, XI, XII, XIV, XV, XVI, XVII, XVIII, XX, XXI, XXII, XXIII.

*ln = natural logarithm

From the rather detailed statistical output calculated by the computer program (see Appendix C), the coefficient of determination, (R^2), and the t-statistic were monitored to indicate the predictive potential and the significance, respectively, of a given combination of parameters. R^2, which is optimally 1.00, indicates the percentage change in the dependent variable that can be explained by a variation in the independent variable. For example, if running Project X's costs against its ESAL-18's yielded an R^2 of 0.95, then 95% of the variation in costs can be accounted for by the variation in ESAL-18.

The t-statistic indicates whether or not two parameters are significantly related in a statistical sense. In these analyses, there are 12 degrees of freedom, and for this study a t-statistic of 2.681 or greater indicates that the relationship is not due to chance.

The results of the least squares regression analyses performed on the FLEX III projects are shown in Table 2. This table shows that all of the results obtained in this phase were quite satisfactory, and it should be pointed out that classifying some results as better or some combination of parameters as best would be quite difficult to do with any degree of validity.

The equation specifications examined for each project were accumulating maintenance costs versus accumulating age (Cost vs. Age), accumulating maintenance costs versus accumulating ESAL's (Cost vs. Kips), accumulating maintenance costs versus ln of accumulating ESAL's (Cost vs. L Kips), and ln of accumulating maintenance costs versus ln of accumulating ESAL's (L Cost vs. L Kips). The logarithmic relationships were examined due to known similar relationships among design variables. The coefficients of determination all indicated statistically significant relationships between the variables. The indices ranged from 0.4371 to 0.9746 with only 13% of the values being below 0.7000 and 27% above 0.9000. These figures indicate that practically all of the variation in maintenance costs can be explained by the independent variables.

Determining the statistical significance of the various relationships by analyzing the t-statistics was a bit more involved, because the t-statistics were computed for two independent variables per project equation specification. Cost was the dependent and a form of age or kips and a constant were the independent variables. These constants (C) served as buffers against the effects of omitted variables (e.g. climatic conditions, deviation from standard procedures, equipment differences, mix variance, and topography differences).

The t-statistics given in Table 2 show that every equation specification for each project yielded a significant relationship between the dependent and independent variables. The t-statistics for age and kips were significant 100% of the time, whereas those for the constant were significant only 71% of the time. These results indicated that age or kips were more significantly related to maintenance costs than were the unaccounted for factors.

Table 2. FLEX III Results

	Cost vs. Age			Cost vs. Kips			Cost vs. L Kips			L Cost vs. L Kips		
	T-Statistic			T-Statistic			T-Statistic			T-Statistic		
Project	Age	C	R^2	Kips	C	R^2	L Kips	C	R^2	L Kips	C	R^2
I	4.62	1.79	0.6405	5.46	1.65	0.7131	3.05	4.81	0.4371	8.28	37.10	0.8510
II	9.14	3.98	.8744	8.37	2.22	.8538	6.09	9.83	.7553	8.70	26.27	.8631
XI	10.17	5.69	.8960	11.36	2.39	.9149	7.52	7.19	.8250	4.49	17.06	.6273
XII	10.17	6.06	.8960	11.98	2.12	.9229	7.47	5.05	.8232	4.55	14.81	.6331
XIV	9.62	4.76	.8851	16.96	2.14	.9599	7.67	6.01	.8305	18.69	200.14	.9668
XV	12.95	7.68	.9332	19.12	5.25	.9682	9.49	0.10	.8825	13.11	64.67	.9348
XVI	8.91	3.55	.8686	7.92	0.33	.8396	7.37	5.16	.8191	11.45	27.22	.9161
XVII	8.91	3.49	.8687	7.63	0.24	.8291	7.34	5.86	.8180	11.00	54.54	.9097
XVIII	11.69	1.71	.9192	7.73	2.04	.8329	14.54	15.89	.9463	6.22	37.93	.7633
XX	5.30	2.73	.7007	7.93	2.37	.8399	3.80	2.23	.5458	19.78	75.54	.9702
XXI	9.94	4.19	.8918	19.97	3.71	.9708	6.39	5.28	.7731	21.44	112.81	.9746
XXII	8.75	3.54	.8645	7.37	0.20	.8191	9.95	6.83	.8920	4.73	10.90	.6508
XXIII	6.89	2.09	0.7982	5.73	0.59	0.7326	8.69	5.59	0.8628	4.94	10.68	0.6709

1807

A closer examination of the results for individual equation specifications more clearly defined the controlling factor in the relationship. For Cost vs. Kips, 11 out of 13 projects (85%) were not significantly influenced by the unaccounted for variables, which included environmental factors, design considerations, and age. The next highest percentage of projects where the constant was insignificant was for Cost vs. Age, with 3 out of 14, or just 21%. These figures indicate that kips are the controlling variable in the maintenance cost relationships examined simply because the unaccounted for variables had no significant effects on the results 85% of the time.

Such a finding clearly suggests that it may be possible to ignore factors other than ESAL-18's in estimating maintenance costs on moderately to heavily travelled pavements such as those examined in this study. At the same time, Project I offers some evidence that it is difficult to assign causative factors to lightly travelled roads.

Finally, in an attempt to evaluate the practical applications of either pavement age or ESAL's in the prediction of annual maintenance costs, the authors selected known age or kip figures and the estimated coefficients as calculated by the computer program to estimate maintenance costs for a project in a given year. The actual cost figures were then compared with the estimates. The results of these comparisons can be seen in Table 3, and sample calculations may be found in Appendix D. When assessing the estimates it should be kept in mind that these values were determined using figures taken from the mean of the sample, and although the estimates were not extremely accurate, they did give good general figures with which to work. Another big problem with cost projections like these is probably the Department's spending patterns, which vary throughout the year and from year to year. For example, in Project XVI the actual expenditure was $163; however, the very next year the expenditures jumped to $833. Likewise, in Project XVII the expenditures jumped from $40,362 up to $206,162 in just one year. So, annual estimates of such varying actual figures are bound to be rough estimates.

The authors believe that this estimation technique shows promise as a tool for projecting highway maintenance costs, providing the rising trend in inflation continues at approximately the same rate. However, more work is needed, specifically in the number of projects analyzed. A greater number of projects must be included to give the estimates more statistical strength.

Overall, the results obtained in this study were excellent and provided a great deal of insight into the mechanics of highway maintenance costs as a function of other highway maintenance parameters.

Table 3. FLEX III Estimates in Dollars

		Cost vs. Age		Cost vs. Kips		Cost vs. L Kips		L Cost vs. L Kips	
Project	Actual Costs	Est. Cost	% Diff.	Est. Cost	% Diff.	Est. Cost	% Diff.	Est. Cost	% Diff.
I	51,865	40,044	- 23	44,221	- 15	30,306	- 42	39,878	- 23
II	246,753	236,206	- 4	236,492	- 4	214,910	- 13	423,526	+ 72
XI	159,766	140,030	- 12	123,185	- 22	173,661	+ 9	37,531	- 77
XII	62,141	66,399	+ 7	54,943	- 12	83,907	+ 35	12,043	- 81
XIV	28,400	35,632	+ 26	31,646	+ 11	43,908	+ 55	31,194	+ 10
XV	11,629	18,347	+ 58	26,477	+128	24,448	+110	23,287	+100
XVI	163	1,263	+675	1,044	+541	1,670	+925	318	+ 95
XVII	40,362	312,484	+674	264,906	+556	410,413	+917	76,780	+ 90
XVIII	51,901	42,763	- 18	38,451	- 26	47,771	- 8	18,586	- 64
XX	2,270	5,856	+158	2,776	+ 22	7,838	+245	2,207	- 3
XXI	4,597	14,895	+224	10,233	+123	18,725	+307	6,950	+ 51
XXII	149,910	142,204	- 5	142,922	- 5	156,220	+ 4	7,042	- 95
XXIII	27,664	40,407	+ 46	37,758	+ 36	38,454	+ 39	2,346	- 91

SUMMARY OF FINDING AND CONCLUSIONS

1. Very strong statistical correlations were established between cost and kips and between cost and age when analyzed on a project-by-project (time-series) basis.

2. In 35% of the projects analyzed, the omitted variables had no significant influences on maintenance costs. For the equation specification Cost vs. Kips, the influence of the omitted variables was not significant 85% of the time.

3. No statistically significant relationships were established on a cross section basis for the entire data set— probably due to the inherent differences between projects.

4. Basic pavement design was verified by the finding that design parameters such as the use of soil cement, thickness indices, and soil resiliency factors had no influence on maintenance cost relationships.

5. A good technique for predicting needed pavement maintenance funding levels could be derived from the relationships established in using projected kip data to predict cumulative maintenance costs.

6. The methodology implemented in this study could easily be used with future, similar analyses, providing improvements are made on the quality of the data base. The data base problems are clearly illustrated in this study by the use of only 13 out of 133 projects for in-depth analyses. Such data constraints force the evaluation of results to be made on a project-by-project basis rather than on a cross section basis.

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4. U. S. Department of Transportation, "Final Report on the Federal Highway Cost Allocation Study," May 1982.

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6. McGhee, K. H., "A Review of Pavement Performance on Virginia's Interstate System," VHTRC 77-R24, 1976.

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1902

APPENDIX A

FLEXIBLE PAVEMENT DATA

Legend

<u>Columns 1 - 5</u> Self-explanatory.

<u>Column 6</u> Construction cost in dollars per 24 ft. wide lane mile. Based on <u>Engineering News Record</u> construction cost index using contract unit prices converted to a 1980 base.

<u>Column 7</u> Average annual maintenance costs per 24 ft. wide lane mile. From information provided by the Accounting Division.

<u>Column 8</u> Layer thickness of pavement components. Values given are in inches for:

- AC — asphalt concrete
- AB — aggregate base
- SM — select material
- CTS — cement treated stone
- CSM — cement treated select material
- SC — soil cement subgrade

<u>Column 9</u> Thickness index determined from thickness and type of pavement components according to current design procedures.

<u>Column 10</u> Age in months of the pavement as of July 1, 1980, and at the time of each overlay.

<u>Column 11</u> EAL-18, 18,000 lb. equivalent axle loading:

- Design — daily capacity as determined from the thickness index and current design procedures.
- Average — daily usage as estimated from information provided by the Traffic and Safety Division.
- Cumulative — total usage as estimated from information provided by the Traffic and Safety Division. The values given are in millions.

FLEXIBLE PAVEMENT SUMMARY

Route	Project	From	To	Length	Constr. Cost	Avg. Annual Maint. Cost 1975	Avg. Annual Maint. Cost 1980	Layer Thickness AC	AB	SM	CST	CSM	SC	Thickness Index	Age (Mo.) Total	Age (Mo.) At Overlay	2nd Overlay	3rd Overlay	EAL-18 Des.	EAL-18 Avg.	EAL-18 Cum.	Survey No.
0064	003-101, C-501	West Virginia State Line	0.451 Mi. W. Callaghan	6.90	252,900	368	3,224	8.0	6.0	9.0				11.9	155	47	95	131	390	157	0.73	8-64-1
0064	003-103, P-401, 402, 404, 405	0.451 Mi. W. Callaghan	WCL Covington	7.73	183,100	260	1,394	8.0	6.0	6.0				11.3	156	108			200	166	0.78	8-64-2
a 0064	003-103, P-403 107-101, P-401	WCL Covington	0.987 Mi. E. ECL Covington	2.39	213,600	136	1,076	8.0	6.0	6.0				11.3	164	128			200	196	0.96	8-64-3
a 0064	003-005, C-501 C-502	0.987 Mi. E. ECL Covington	3.980 Mi. W. WCL Clifton Forge	3.34	232,600	1,522	1,094	7.5	8.0					10.3	187	90			300	266	1.49	8-64-4
0064	003-004, C-501	3.980 Mi. W. WCL Clifton Forge	0.566 Mi. W. WCL Clifton Forge	3.39	280,100	1,476	1,074	7.5	8.0	6.0				11.5	192	107*			300	251	1.45	8-64-5
0064	003-104, P-401 P-404 105-101, P-401	1.209 Mi. W. WCL Clifton Forge	0.004 Mi. W. C&O Underpass	4.39	261,400			9.0	6.0	10.0				13.1	97				700	200	0.58	8-64-6
b 0064	003-104, P-402 P-405	0.016 Mi. E. C&O Underpass	5.788 Mi. W. Alleghany-Rockbridge C. L.	7.74	209,000		0	10.5	6.0	10.0				14.6	11				700	190	0.06	8-64-7
0064	003-104, P-403	5.788 Mi. W. Alleghany-Rockbridge C. L.	Alleghany-Rockbridge C. L.	5.11	194,100		0	10.5	6.0	6.0				13.8	19				600	241	0.14	8-64-8
b 0064	081-101, P-401 P-407	Alleghany-Rockbridge C. L.	2.649 Mi. E. Alleghany-Rockbridge C. L.	2.65	193,000		76	10.5	6.0	6.0				13.8	20				600	241	0.14	8-64-9
0064	081-101, P-403 P-408, P-409, P-410	2.649 Mi. E. Alleghany-Rockbridge C. L.	6.657 Mi. W. Int. Rte. 81	6.95	178,000		74	10.5	6.0	6.0				13.8	21				590	213	0.13	8-64-10
0064	081-101, P-404 P-406	6.657 Mi. W. Int. Rte. 81	Int. Rte. 81	6.64	314,800		34	9.0	6.0	12.0				13.5	45				500	188	0.25	8-64-11
b 0064	007-102, P-401 P-402, P-403	Int. Rte. 81	3.278 Mi. E. Int. Rte. 340	10.72	196,500	54	124	9.5	8.0	12.0				14.7	111				900	456	1.52	8-64-12
b 0064	007-102, P-404	3.278 Mi. E. Int. Rte. 340	Augusta-Nelson C. L.	2.10	258,900	64	128	9.5	6.0	12.0				14.0	103				550	403	1.25	8-64-13
0064	062-101, P-401	Augusta-Nelson C. L.	Nelson-Albemarle C. L.	1.36	173,300	22	952	10.0	6.0	12.0				14.5	103	91			350	436	1.35	3-64-1
0064	002-102, P-401 P-402	Nelson-Albemarle C. L.	0.070 Mi. W. Int. Rte. 250	6.06	197,800	42	1,196	10.0	8.0	6.0				14.0	82	70			380	436	1.07	7-64-1

*EBL only

a FLEX II only

b FLEX II and III

1906

Flexible Pavement Summary (Continued)

	Route	Project	From	To	Length	Constr. Cost	Avg. Annual Maint. Cost 1975	Avg. Annual Maint. Cost 1980	Layer Thickness AC	AB	SM	CST	CSM	SC	Thickness Index	Age (Mo.) Total	Age (Mo.) At Overlay	2nd Overlay	3rd Overlay	EAL-18 Des.	EAL-18 Avg.	EAL-18 Cum.	Survey No.
b	0064	054-101, P-402 P-404	0.579 Mi. W. Int. Rte. 15	Louisa-Goochland C. L.	11.35	178,900	24	744	10.0			8.0		6.0	20.4	105	81			2000	325	1.12	7-64-5
b	0064	037-102, P-401 054-102, P-402	Louisa-Goochland C. L.	0.138 Mi. E. Int. Rte. 522	12.05	175,400	2	226	10.0	8.0				6.0	15.2	115	91			750	340	1.17	4-64-1
	0064	037-103, P-401 054-102, P-401	0.138 Mi. E. Int. Rte. 522	8.434 Mi. W. Henrico-Goochland C. L.	7.38	224,700	48	1,060	10.0	8.0				6.0	15.2	129	105			750	339	1.31	4-64-2
	0064	037-101, P-402 P-403 043-102, P-401	8.434 Mi. W. Henrico - Goochland C. L.	0.356 Mi. W. Int. Rte. 250	11.32	215,400	122	1,070	10.0	6.0				6.0	14.5	140	92			750	389	1.63	4-64-3
	0064	047-101, C-503	2.301 Mi. W. York C. L.	James City-York C. L.	2.30	177,200		0	9.5	6.0				6.0	14.0	14				800	506	0.21	5-64-3
b	0064	099-102, C-501 C-502	James City-York C. L.	0.047 Mi. W. Int. Rte. 645	4.16	167,200		0	9.5	6.0				6.0	14.0	13				800	506	0.20	5-64-4
	0066	034-102, P-401 093-102, P-401	Int. Rte. 81	0.052 Mi. E. Int. Rte. 340	6.85	146,100	126	82	10.0	6.0	8.0				13.7	104				650	225	0.70	8-66-1
	0066	093-102, P-402 P-403, P-404	0.016 Mi. E. Int. Rte. 340	1.276 Mi. W. Warren-Fauquier C. L.	3.92	181,100		0	10.5	6.0	12.0				15.0	8				850	214	0.05	8-66-2
	0066	093-102, P-405	1.276 Mi. W. Warren-Fauquier C. L.	Warren-Fauquier C. L.	3.56	214,300		0	10.5	6.0	12.0				15.0	10				850	217	0.07	8-66-3
	0066	030-002, P-401 P-402, P-403, P-404, P-405	Fauquier-Warren C. L.	1.934 Mi. W. Int. Rte. 731	6.30	194,500		0	10.5	8.0	6.0				14.5					750	251	0.08	7-66-1
	0066	030-001, C-502	1.934 Mi. W. Int. Rte. 731	0.587 Mi. W. Int. Rte. 731	1.32	175,900		0	9.5	12.0					13.7	18				320	218	0.12	7-66-2
	0066	030-001, P-1	0.587 Mi. W. Int. Rte. 731	2.489 Mi. W. Int. Rte. 17	3.30	295,600	766	3,646	9.5	6.0				8.0	14.8	217	121	205		650	192	1.25	7-66-3
	0066	030-101, C-501	3.074 Mi. W. Int. Rte. 17	0.404 Mi. W. Int. Rte. 17	2.69	161,940		0	9.5	6.0	6.0				12.8	23				300	335	0.23	7-66-4
	0066	030-101, C-502	2.091 Mi. W. Prince William-Fauquier C. L.	1.279 Mi. W. Prince William-Fauquier C. L.	1.83	216,892		110	10.5	6.0				6.0	15.0	13				700	248	0.10	7-66-6
	0066	030-101, C-503 076-102, C-504 C-505	1.279 Mi. W. Prince William-Fauquier C. L.	1.878 Mi. E. Prince William-Fauquier C. L.	3.14	197,300		0	10.5	12.0					14.7	0				600	248		7-66-7
	0066	029-101, P-1 076-101, P-1	Int. Rte. 29 & 211 Gainesville	0.391 Mi. W. Int. Rte. 29 & 211 Centreville	8.66	279,300	582	800	9.5	6.0			6.0		15.2	213	93	155		580	375	2.39	7-66-9
	0066	029-102, G-301	0.391 Mi. W. Int. Rte. 29 & 211 Centreville	W. End Bridge over Rte. 29 & 211	0.41	329,700	390	312	10.5	6.0				6.0	15.0	201	62			450	389	2.35	7-66-10
	0077	017-102, C-501	Virginia-North Carolina State Line	2.587 Mi. N. Virginia-North Carolina S. L.	2.59	387,600		34	10.5	8.0				6.0	15.7	43				850	434	0.56	2-77-1
	0077	017-102, C-502	2.587 Mi. N. Virginia-North Carolina S. L.	4.145 Mi. N. Virginia-North Carolina S. L.	1.56	367,600		32	10.5	8.0	6.0				14.5	45				600	434	0.59	2-77-2
	0077	017-102, C-504	4.145 Mi. N. Virginia-North Carolina S. L.	0.265 Mi. S. Int. Blue Ridge Parkway	2.76	291,700		32	10.5	8.0	6.0				14.5	46				600	434	0.60	2-77-3

Flexible Pavement Summary (Continued)

Route	Project	From	To	Length	Constr. Cost	Avg. Annual Maint. Cost 1975	Avg. Annual Maint. Cost 1980	Layer Thickness AC	AB	SM	CST	CSM	SC	Thickness Index	Age (Mo.) Total	Age (Mo.) At Overlay	2nd Overlay	3rd Overlay	FAL-18 Des.	FAL-18 Avg.	FAL-18 Cum.	Survey No.
0077	017-102, C-503	0.265 Mi. S. Int. Blue Ridge Parkway	1.449 Mi. N. Int. Blue Ridge Parkway	1.71	358,400		32	10.5	8.0				6.0	15.7	45				850	434	0.59	2-77-4
b 0077	017-102, P-403	1.449 Mi. N. Int. Blue Ridge Parkway	4.330 Mi. N. Int. Blue Ridge Parkway	2.88	217,500		54	10.5	8.0				6.0	15.7	28				850	543	0.46	2-77-5
0077	017-101, P-401	4.330 Mi. N. Int. Blue Ridge Parkway	0.129 Mi. S. Int. Rte. 58	3.40	214,200		54	10.5	8.0				6.0	15.7	28				850	585	0.49	2-77-6
b 0077	017-101, P-403 P-404	0.129 Mi. S. Int. Rte. 58	4.047 Mi. N. Int. Rte. 58	4.17	219,500		54	10.5	8.0				6.0	15.7	28				850	588	0.49	2-77-7
0077	017-101, P-402 P-405	4.047 Mi. N. Int. Rte. 58	Wythe-Carroll C. L.	5.22	217,600		52	10.5	8.0				6.0	15.7	26				850	588	0.46	2-77-8
0077	098-101, P-401	Wythe-Carroll C. L.	1.742 Mi. N. Wythe-Carroll C. L.	1.74	191,000		4	10.5	8.0	6.0				14.5	8				800	591	0.14	1-77-1
0077	098-101, P-402	1.742 Mi. N. Wythe-Carroll C.L.	5.663 Mi. N. Wythe-Carroll C. L.	3.95	184,800		4	10.5	8.0	6.0				14.5	8				800	591	0.14	1-77-2
0077	098-101, P-403	5.663 Mi. N. Wythe-Carroll C.L.	Int. Rte. 81 (Near Fort Chiswell)	3.22	189,500		1	10.5	8.0	6.0				14.5	14				800	591	0.25	1-77-3
0077	010-101, P-401 098-102, P-401 P-402	Int. Rte. 81 (near Wytheville)	7.599 Mi. N. Int. Rte. 81	6.90*	173,300	0	5,172	10.0	8.0	6.0				14.0	101	89			650	336	1.02	1-77-4
0077	010-101, C-502 102, C-505	7.599 Mi. N. Int. Rte. 81	0.254 Mi. N. Rtes. 21 & 52	3.86	229,400	70	60	10.0	6.0	6.0				13.3	102	102			620	390	1.19	1-77-5
0077	010-102, C-501	0.182 Mi. S. Int. Rtes. 21 & 52	2.280 Mi. N. Int. Rtes. 21 & 52	2.63	228,700	26	34	10.0	8.0	6.0				14.0	116				650	400	1.39	1-77-6
0077	010-102, P-402 P-403	2.280 Mi. N. Int. Rtes. 21 & 52	9.933 Mi. N. Int. Rtes. 21 & 52	7.64	226,200	26	34	10.0	8.0	6.0				14.0	118				650	396	1.40	1-77-7
0077	010-102, C-504 103, C-501	9.933 Mi. N. Int. Rtes. 21 & 52	0.165 Mi. S. Int. Rte. 61	1.66	250,600	40	26	10.0	8.0	6.0				14.0	111				650	438	1.46	1-77-8
b 0077	010-103, C-502	0.165 Mi. S. Int. Rte. 61	2.184 Mi. N. Int. Rte. 61	2.12	213,700	0	58	10.0	8.0	6.0				14.0	69				650	388	0.80	1-77-9
a 0081	095-013, P-1	Tennessee State Line	3.729 Mi. E. Tennessee S. L.	3.73	241,100	618	1,590	9.5	5.0	5.0				12.3	226	118	190		400	485	3.29	1-81-1
a 0081	095-037	3.729 Mi. E. Tennessee S. L.	4.972 Mi. E. Tennessee S. L.	1.24	286,200	1,040	2,032	9.5	5.0	5.0				12.3	239	131	197		400	539	3.86	1-81-2
0081	095-014, P-401	5.143 (4.972) Mi. E. Tennessee S. L.	3.790 Mi. S. Int. Rte. 611	4.44	244,500	296	1,128	9.5	6.0	12.0				14.0	202	141	166		650	566	3.43	1-81-3
0081	095-014, P-402	3.79 Mi. S. Int. Rte. 611	0.110 Mi. N. Int. Rte. 611	3.90	296,000	62	516	9.5	6.0	10.0				13.6	202	166			580	550	3.33	1-81-4
0081	095-038, P1 P3	0.110 Mi. N. Int. Rte. 611	0.036 Mi. N. Int. Rte. 11 & 58	6.46	272,500	56	482	9.5	6.0	10.0				13.6	217	175			580	532	3.47	1-81-5
0081	095-038, P-402 009, P-401	0.036 Mi. N. Int. Rte. 11 & 58	0.397 Mi. E. Int. Rte. 80	5.56	294,137	14	1,276	10.5	6.0	6.0				13.8	203	155			610	628	3.82	1-81-6

*Does not include 0.8 Mi. Tunnel

1907

Flexible Pavement Summary (Continued)

Route	Project	From	To	Length	Constr. Cost	Avg. Annual Maint. Cost 1975	Avg. Annual Maint. Cost 1980	Layer Thickness AC	Layer Thickness AB	Layer Thickness SM	Layer Thickness CST	Layer Thickness CSM	Layer Thickness SC	Thickness Index	Age (Mo.) Total	Age (Mo.) At Overlay	2nd Overlay	3rd Overlay	EAL-18 Des.	EAL-18 Avg.	EAL-18 Cum.	Survey No.
0081	095-009, C-502	0.397 Mi. E. Int. Rte. 80	0.931 Mi. E. Int. Rte. 91	5.10	259,300	1,258	974	9.5	6.0	10.0				13.6	202	130	172		580	646	3.91	1-81-7
0081	095-009, C-503 010, C-501	0.931 Mi. E. Int. Rte. 91	0.800 Mi. E. Int. Rte. 751	2.53	250,400	1,400	1,982	9.5	6.0	10.0				13.6	200	129	188		580	597	3.58	1-81-8
0081	086-003, P-401 095-010, P-401	0.800 Mi. N. Int. Rte. 751	0.180 Mi. W. Int. Rte. 645	6.26	252,600	608	2,768	9.5	6.0	12.0				14.0	201	69	189		610	584	3.52	1-81-9
0081	086-003, C-501 C-502	0.180 Mi. W. Int. Rte. 645	2.442 Mi. W. WCL Marion	2.61	303,700	746	2,972	9.5	6.0	12.0				14.0	205	73	193		610	638	3.92	1-81-10
0081	086-003, P-403 P-404	2.442 Mi. W. WCL Marion	0.015 Mi. W. Int. Rte. 11	6.20	242,100	886	2,938	9.5	6.0	12.0				14.0	203	83	191		610	531	3.23	1-81-11
0081	086-003, P-405 004, P-401	0.015 Mi. W. Int. Rte. 11	4.655 Mi. W. Smythe-Wythe C.L.	4.97	249,800	48	550	9.5	6.0	12.0				14.0	201	153			610	521	3.14	1-81-12
b 0081	086-004, P-402	4.655 Mi. W. Smythe-Wythe C. L.	Wythe County Line	4.70	207,300	1,700	1,498	9.5	6.0	12.0				14.0	188	116	164		610	609	3.43	1-81-13
b 0081	098-001, P-401	Smythe County Line	0.974 Mi. W. Int. Rte. 680	2.24	224,700	1,140	794	9.5	6.0	12.0				14.0	189	105			610	655	3.71	1-81-14
b 0081	098-001, P-402	0.974 Mi. W. Int. Rte. 680	0.346 Mi. E. Int. Rte. 666	5.44	219,500	1,150	798	9.5	6.0	12.0				14.0	188	104			610	655	3.69	1-81-15
0081	098-001, P-403	0.346 Mi. E. Int. Rte. 666	0.290 Mi. W. Reed Creek	2.66	215,400	1,164	848	9.5	6.0	12.0				14.0	189	93			610	667	3.78	1-81-16
0081	098-002, P-401 P-402	0.290 Mi. W. Reed Creek	0.347 Mi. W. N&W RR Overpass	0.60	211,400	34	1,504	9.5	6.0	12.0				14.0	178	142			610	761	4.06	1-81-17
0081	098-101, C-503	1.100 Mi. W. Int. Rte. 52	1.230 Mi. E. Int. Rte. 52	2.35	293,200	26	324	9.5	8.0	12.0				14.7	139	*			800	854	3.56	1-81-18
0081	098-008, P1	1.081 Mi. E. Int. Rte. 52	1.718 Mi. W. Wythe-Pulaski C.L.	4.18	268,400	734	616	9.5	6.0	9.0				13.4	205	93			550	675	4.15	1-81-19
0081	098-008, P-402	1.718 Mi. W. Wythe-Pulaski C.L.	Wythe-Pulaski County Line	1.73	290,200	642	498	9.5	6.0	9.0				13.4	215	95			550	774	4.99	1-81-20
a 0081	077-011, P-401	Wythe-Pulaski County Line	0.854 Mi. W. Int. Rte. 11 & 100	1.78	308,400	216	1,502	9.5	6.0	9.0				13.4	215	179			500	729	4.70	2-81-1
0081	077-008	0.854 Mi. W. Int. Rte. 11 & 100	0.358 Mi. E. Int. Rte. 11 & 100	1.21	285,800	724	1,760	9.5	6.0	9.0				13.4	239	107	203		500	659	4.73	2-81-2
a 0081	077-001, 002 005	0.358 Mi. E. Int. Rte. 11 & 100	0.487 Mi. W. Int. Prop. Rte. 99	3.50	264,400	884	1,428	9.5	6.0	9.0				13.4	239	107	203		500	852	6.11	2-81-3
0081	077-010, P-401	0.487 Mi. W. Int. Rte. 99	2.202 Mi. E. Int. Rte. 99	2.71	262,900	1,050	976	9.5	6.0	9.0				13.4	229	107			500	859	5.90	2-81-4
0081	077-101, C-501	2.202 Mi. E. Int. Rte. 99	0.405 Mi. W. Int. Rte. 682	2.18	228,200	1,628	1,956	9.5	6.0	9.0				13.4	180	96	132*		500	1008	5.44	2-81-5
0081	077-101, C-502	0.405 Mi. W. Int. Rte. 682	0.403 Mi. E. Int. Rte. 660	2.76	230,000	398	1,894	9.5	6.0	9.0				13.4	177	129			500	835	4.43	2-81-6
0081	077-101, C-503	0.403 Mi. E. Int. Rte. 660	1.915 Mi. W. Montgomery C. L.	1.64	254,900	206	2,212	9.5	6.0	9.0				13.4	186	126			500	836	4.66	2-81-7
0081	077-101, C-504	1.915 Mi. W. Montgomery C. L.	0.15 Mi. W. Montgomery C. L.	1.76	262,500	1,372	3,364	9.5	6.0	9.0				13.4	187	127	187		500	836	4.69	2-81-8
0081	060-101, P-401	0.16 Mi. W. Pulaski-Montgomery County Line	4.57 Mi. E. Pulaski-Montgomery County Line	4.77	225,900	70	2,160	9.5	6.0	9.0				13.4	166	118			500	829	4.13	2-81-9
0081	060-101, P-402	4.57 Mi. E. Pulaski C. L.	2.09 Mi. E. Int. Rte. 8	6.87	230,546	68	2,250	9.5	6.0	9.0				13.4	179	149			500	858	4.61	2-81-10
0081	060-102, C-501	2.090 Mi. E. Int. Rte. 8	0.090 Mi. E. Int. Rte. 11 & 460	2.05	232,900	70	1,806	9.5	6.0	9.0				13.4	176	152			500	852	4.50	2-81-11

*Less than 50% project overlaid

Flexible Pavement Summary (Continued)

Route	Project	From	To	Length	Constr. Cost	Avg. Annual Maint. Cost 1975	Avg. Annual Maint. Cost 1980	Layer Thickness AC	AB	SM	CST	CSM	SC	Thickness Index	Age (No.) Total	Age (No.) At Overlay	2nd Overlay	3rd Overlay	EAL-18 Des.	EAL-18 Avg.	EAL-18 Cum.	Survey No.
0081	060-102, P-402 P-403, P-406	0.090 Mi. E. Int. Rte. 11 & 460	5.288 Mi. W. Montgomery-Roanoke County Line	6.60	175,900	0	738	10.0	6.0	6.0				13.3	96	*			450	1435	4.13	2-81-12
0081	060-102, P-404 P-405, P-407	5.288 Mi. W. Montgomery-Roanoke County Line	2.490 Mi. E. Montgomery-Roanoke County Line	7.82	200,500	0	40	10.0	6.0	6.0				13.3	99				450	1409	4.18	2-81-13
a 0081	080-102, P-401 080-101, C-502	0.615 Mi. W. Rte. 927	0.085 Mi. E. Int. Rte. 777	1.78	285,100	1,410	998	9.5	6.0	9.0				13.4	188	*			600	1015	5.72	2-81-14
a 0081	080-001, P-402 P-403, P-405	0.085 Mi. E. Int. Rte. 777	Roanoke-Botetourt C. L.	12.58	241,000	1,422	1,710	9.5	6.0	9.0				13.4	187	97			600	1009	5.66	2-81-15(a)
					274,700			9.5	4.0		4.0		6.0	17.3					2000	1009	5.66	2-81-15(b)
0081	011-008, P-401	0.019 Mi. N. Int. Rte. 636	0.843 Mi. N. NCL Buchanan	6.33	220,100	1,684	2,054	9.5	6.0	9.0				13.4	203	89			380	842	5.13	2-81-19
0081	011-001 thru 006	0.843 Mi. N. NCL Buchanan	0.274 Mi. S. Int. Rte. 610	4.95	231,000	1,392	2,410	9.5	6.0	9.0				13.4	235	91	163		380	777	5.47	2-81-20
a 0081	011-008, P-402	0.274 Mi. S. Int. Rte. 610	Botetourt-Rockbridge C. L.	1.03	206,700	1,896	3,492	9.5	6.0	9.0				13.4	181	61	109	169**	380	958	5.20	2-81-21
0081	081-001, P-401	Botetourt-Rockbridge C. L.	4.127 Mi. N. Botetourt-Rockbridge C. L.	4.20	206,700	52	1,776	9.5	6.0	9.0				13.4	181	145			610	958	5.20	8-81-1
0081	081-001, P-403	4.127 Mi. N. Botetourt-Rockbridge C. L.	Int. Rte. 684	2.59	271,800	3,964	2,866	9.5	6.0	9.0				13.4	188	56			610	913	5.15	8-81-2
0081	081-101, P-404	Int. Rte. 684	1.020 Mi. S. Int. Rte. 60	7.88	182,500	58	276	9.5	6.0	9.0				13.4	152				610	1041	4.75	8-81-3
b 0081	081-101, P-402 P-403	1.020 Mi. S. Int. Rte. 60	0.018 Mi. N. Int. Rte. 11	7.43	185,200	80	406	9.5	6.0	12.0				14.0	152				640	1079	4.92	8-81-4
0081	081-101, P-405 102, P-403	0.018 Mi. N. Int. Rte. 11	3.405 Mi. S. Rockbridge-Augusta C. L.	7.03	199,800	498	1,322	9.5	6.0	9.0				13.4	155	69	119		610	1127	5.38	8-81-5
0081	007-102, P-401 081-102, P-402	3.405 Mi. S. Rockbridge-Augusta C. L.	1.875 Mi. N. Rockbridge-Augusta C. L.	5.27	196,000	722	906	9.5	6.0	9.0				13.4	162	84			610	1149	5.58	8-81-6
0081	007-102, C-502	1.875 Mi. N. Rockbridge-Augusta C. L.	0.699 Mi. N. Int. Rte. 11	6.52	245,300	1,298	1,228	10.0	6.0	15.0				15.1	162	78			1220	1197	5.82	8-81-7
0081	007-103, C-502	0.699 Mi. N. Int. Rte. 11	3.648 Mi. S. Int. Rte. 250	4.93	185,700	1,614	1,520	10.0	6.0	6.0				13.3	142	94			540	1277	5.44	8-81-8
0081	007-103, C-505	3.648 Mi. S. Int. Rte. 250	0.965 Mi. N. Int. Rte. 250	4.64	235,100	240	1,226	10.0	8.0	8.0				14.4	134	98			780	1314	5.28	8-81-9
b 0081	007-103, C-506	0.965 Mi. N. Int. Rte. 250	0.449 Mi. S. Int. Rte. 612	3.76	197,667	210	1,188	10.0	6.0	6.0				13.3	144	98			540	1233	5.33	8-81-10
0081	007-103, C-510 P-401, P-403, P-404	0.449 Mi. S. Int. Rte. 612	1.559 Mi. S. Rockingham-Augusta C. L.	8.23	246,776	190	1,118	10.0	6.0	9.0				13.9	153	107			750	1173	5.38	8-81-11
0081	007-103, P-401 P-402	1.559 Mi. S. Rockingham-Augusta C. L.	3.931 Mi. S. Int. Rte. 33	8.16	225,900	1,580	1,326	10.0	6.0	9.0				13.9	161	89			750	1138	5.50	8-81-12
0081	082-103, P-409 082-017 (Old 8082-17)	3.931 Mi. S. Int. Rte. 33	2.057 Mi. S. Int. Rte. 33	1.88	311,500	826	668	9.5	6.0	12.0				14.0	241	121			740	843	6.09	8-81-13

*Less than 50% project overlaid
**NBL only

1910

Flexible Pavement Summary (Continued)

Route	Project	From	To	Length	Constr. Cost	Avg. Annual Maint. Cost 1975	Avg. Annual Maint. Cost 1980	Layer Thickness AC	AB	SM	CST	CSM	SC	Thickness Index	Age (Mo.) Total	Age (Mo.) At Overlay	2nd Overlay	3rd Overlay	EAL-18 Des.	EAL-18 Avg.	EAL-18 Cum.	Survey No.
0081	082-006, etc. (Old 8082-06)	2.057 Mi. S. Int. Rte. 33	3.601 Mi. N. Int. Rte. 33	5.66	252,400	720	624	9.5	6.0	12.0				14.0	240	120			740	819	5.90	8-81-14
0081	082-027, C-501	3.601 Mi. N. Int. Rte. 33	6.562 Mi. N. Int. Rte. 33	2.97	249,100	1,100	804	9.5	6.0	12.0				14.0	183	63			740	958	5.26	8-81-15
0081	082-102, P-401	6.562 Mi. N. Int. Rte. 33	0.825 Mi. N. Rte. 798	6.07	207,200	162	2,384	9.5	6.0	12.0				14.0	169	157			740	926	4.69	8-81-16
0081	082-102, P-402 085-103, P-401	0.825 Mi. N. Rte. 798	1.011 Mi. N. Rockingham-Shenandoah C. L.	4.90	202,400	212	1,452	10.0	6.0	9.0				13.9	172	160			730	913	4.71	8-81-17
0081	085-103, P-402 P-404, P-407	1.011 Mi. N. Shenandoah-Rockingham C. L.	3.378 Mi. S. Int. Rte. 675	10.95	221,700	198	1,570	10.0	6.0	6.0				13.3	157	139			540	1019	4.80	8-81-18
0081	085-103, C-503 C-506	3.378 Mi. S. Int. Rte. 675	0.404 Mi. S. Int. Rte. 42	7.00	240,500	140	2,094	10.0	6.0	12.0				14.5	157	127			860	1024	4.82	8-81-19
0081	085-102, P-401 P-402	0.404 Mi. S. Int. Rte. 42	0.640 Mi. N. Int. Rte. 653	8.05	243,800	116	194	10.0	6.0	12.0				14.5	165				860	1022	5.06	8-81-20
0081	085-102, P-403 P-405	0.640 Mi. N. Int. Rte. 653	0.028 Mi. S. Rte. 11 (NBL)	7.38	212,900	266	1,940	10.0	6.0	12.0				14.5	157	*			860	1082	5.10	8-81-21
a 0081	085-102, C-506	0.028 Mi. S. Rte. 11	0.030 Mi. S. Shenandoah-Warren County Line	0.72	297,300	222	226	9.5	6.0	12.0				14.0	181				610	960	5.21	8-81-22
a 0081	034-001, P-404 093-101, P-401	0.030 Mi. S. Warren-Shenandoah C. L.	4.109 Mi. S. Int. Rte. 277	4.11	222,800	208	268	9.5	6.0	12.0				14.0	176				830	851	4.49	8-81-23
0081	034-001, P-407	4.109 Mi. S. Int. Rte. 277	0.556 Mi. S. Int. Rte. 277	3.62	229,200	208	656	9.5	6.0	12.0				14.0	176	140**			830	797	4.21	8-81-24
0081	034-101, P-405 P-410, P-411	0.556 Mi. S. Int. Rte. 277	Int. Rte. 11 (N. Winchester)	11.41	231,700	698	1,060	9.5	6.0	12.0				14.0	176	134			830	915	4.83	8-81-25
0081	034-001, P-403	Int. Rte. 11 (N. Winchester)	West Virginia-Virginia S. L.	6.50	235,800	164	1,218	9.5	6.0	12.0				14.0	176	128			830	844	4.46	8-81-26
0085	058-101, P-401	Virginia-North Carolina S. L.	0.372 Mi. N. Int. Rte. 637	4.77	246,800	1,462	978	9.0				6.0	6.0	17.4	179	89			920	484	2.60	4-85-1
0085	058-101, P-402 P-403	0.372 Mi. N. Int. Rte. 637 (Near Bracey)	0.372 Mi. N. Int. Rte. 58	8.12	229,200	1,702	1,930	9.0				6.0	6.0	17.4	175	97			920	609	3.20	4-85-2
0085	058-101, C-504	0.372 Mi. N. Int. Rte. 58	0.504 Mi. N. Int. Rte. 1	2.50	248,500	48	1,596	9.0				6.0	6.0	17.4	175	145			920	513	2.69	4-85-3
0085	012-101, P-401 058-101, P-405 P-406	0.028 Mi. N. Int. Rte. 1	6.121 Mi. N. Brunswick-Mecklenburg C. L.	10.32	214,600	44	784	9.0			6.0		6.0	17.4	118	82			920	626	2.22	4-85-4
0085	012-101, P-402 P-403, P-406	6.121 Mi. N. Brunswick-Mecklenburg C. L.	5.796 Mi. S. Brunswick-Dinwiddie C. L.	8.82	184,500	54	122	10.0				6.0	6.0	18.4	115				2000	615	2.12	4-85-5
0085	012-101, P-404	5.796 Mi. S. Brunswick-Dinwiddie C. L.	1.217 Mi. S. Brunswick-Dinwiddie C. L.	4.57	191,500	50	42	10.0			6.0		6.0	18.4	119				2000	649	2.32	4-85-6
0095	091-004, C-501	1.130 Mi. N. Norfolk and Western Rwy.	1.265 Mi. N. Int. Rte. 645	3.44	193,300		0	10.0	8.0				6.0	15.2	8				1100	1303	0.31	5-95-1

*Resurface less than 50% project
**NBL only

Flexible Pavement Summary (Continued)

Route	Project	From	To	Length	Constr. Cost	Avg. Annual Maint. Cost 1975	Avg. Annual Maint. Cost 1980	Layer Thickness AC	AB	SM	CST	CSM	SC	Thickness Index	Age (Mo.) Total	Age (Mo.) At Overlay	2nd Overlay	3rd Overlay	EAL-18 Des.	EAL-18 Avg.	EAL-18 Cum.	Survey No.
a 0095	074-001, 003	0.731 Mi. S. Int. Rte. 35	0.056 Mi. S. Int. Rte. 626	5.40	235,300	996	1,860	9.5	6.0	6.0				12.8	226	106	202		720	758	5.14	4-95-1
	005-006, 011																					
a 0095	074-013, P-1	0.056 Mi. S. Int. Rte. 626	0.042 Mi. S. SCL Petersburg	3.70	175,600	770	914	9.5	6.0	6.0				12.8	214	94	184		720	763	4.90	4-95-2
0095	074-010	0.042 Mi. S. SCL Petersburg	1.624 Mi. N. SCL Petersburg	1.67	253,800	610	658	9.5	6.0	6.0				12.8	213	93			720	763	4.88	4-95-3
	123-070, C-1																					
0095	042-003, P-401	0.368 Mi. N. Int. Rte. 54	4.582 Mi. N. Int. Rte. 54	4.24	221,300	1,278	964	10.0		6.0			7.0	14.0	190	100			870	2840	16.19	4-95-6
0095	042-003, P-402	4.588 Mi. N. Int. Rte. 55	0.033 Mi. N. Caroline-	4.64	228,400	1,278	964	10.0		6.0			7.0	14.0	190	94			870	2800	15.96	4-95-7
			Hanover County Line																			
0095	016-002, P-401	0.033 Mi. N. Caroline-	3.537 Mi. N. Int. Rte. 207	6.87	228,400	958	2,810	10.5	6.0				7.0	15.4	193	73	157		1500	2510	14.53	6-95-1
	P-403	Hanover C. L.																				
b 0095	100-104, C-501*	0.212 Mi. E. Int. Rte. 1	W. End Woodrow Wilson Br.	0.66	328,800	0	440	17.5						16.6	73				2100	3202	7.01	7-95-8
0264	064-001, P-401	0.219 Mi. W. N&W RR	0.155 Mi. E. Victory Blvd.	3.34	349,600	306	1,224	9.5	6.0				6.0	14.0	187	87			800	318	1.78	5-264-1
	P-402																					
0264	124-071, C-501	0.155 Mi. E. Victory Blvd.	0.036 Mi. E. Des Moines Ave.	2.47	385,600	476	470	9.5	6.0				6.0	14.0	187	133			800	249	1.40	5-264-2
0264	124-071, C-502	0.036 Mi. E. Des Moines Ave.	Int. Washington St.	0.95	351,300	586	548	9.5	6.0				6.0	14.0	163				800	164	0.47	5-264-3
0264	122-101, C-501	0.015 Mi. E. Int. Main St.	0.151 Mi. W. Int. Rte. 460	0.72	357,000	0	3,410	10.0	6.0			6.0		15.7	95	47			970	528	1.50	5-264-4
0381	095-004	Int. Rte. 81	0.585 Mi. N. Tennessee-	1.45	286,200	656	618	9.5	5.0	5.0				12.3	239	131			400	218	1.56	1-381-1
	102-070		Virginia S. L.																			
0581	080-001, P-401	Int. Rte. 81	0.298 Mi. S. Int. Rte. 117	1.59	232,290	4	358	9.5	6.0	9.0				13.4	187	139			600	543	3.05	2-581-1
0581	080-001, P-402	0.298 Mi. S. Int. Rte. 117	0.347 Mi. N. Int. Rte. 460	3.69	251,500	1,638	1,236	9.5	6.0	9.0				13.4	181	110			600	700	3.80	2-581-2
	128-070, P-401																					
	P-403																					
0581	128-070, C-504	0.347 Mi. N. Int. Rte. 460	0.187 Mi. S. Rte. 460	0.53	320,000	180	1,298	9.5	6.0	9.0				13.4	178	130			600	670	3.58	2-581-3
b 0581	128-070, C-502	0.187 Mi. S. Int. Rte. 460	0.098 Mi. S. Int. Rte. 11	0.31	323,100	200	410	9.5	6.0	9.0				13.4	167	119			600	601	3.01	2-581-4
0581	128-070, C-505	0.098 Mi. S. Int. Rte. 11	0.006 Mi. N. Elm Avenue	0.63	343,200	330	1,322	9.5	6.0	9.0				13.4	153	105			600	561	1.57	2-581-5

*Originally built as Route 413

1912

APPENDIX B

FLEX III DATA

FLEX III Projects' Annual
Cumulative Cost and ESAL-18 Data

	Project I		Project II		Project XI	
	Cost[1]	Kips[2]	Cost	Kips	Cost	Kips
1966-67	58	0.035	0	0.098	0	0.302
67-68	1,574	0.083	965	0.164	16,301	0.433
68-69	4,571	0.1355	3,633	0.2295	21,850	0.584
69-70	5,429	0.189	3,633	0.314	23,569	0.7475
70-71	5,429	0.2535	5,358	0.405	94,220	0.9205
71-72	6,091	0.318	8,438	0.488	159,766	1.105
72-73	6,091	0.3775	83,525	0.5685	161,384	1.2945
73-74	8,334	0.446	167,677	0.65	161,819	1.4855
74-75	8,845	0.52	220,352	0.7345	167,401	1.6835
75-76	9,363	0.60	223,164	0.8295	202,648	1.921
76-77	9,913	0.688	242,076	0.9405	420,462	2.212
77-78	50,633	0.78	246,753	1.0615	450,743	2.5635
78-79	51,865	0.871	247,593	1.1845	452,253	2.9945
79-80	51,865	0.965	247,696	1.3055	454,524	3.4595

	Project XII		Project XIV		Project XV	
	Cost	Kips	Cost	Kips	Cost	Kips
1966-67	0	0.331	12,863	0.356	9,051	0.709
67-68	10,752	0.491	13,410	0.5095	10,205	0.9045
68-69	14,410	0.6705	14,085	0.674	11,629	1.121
69-70	15,541	0.8585	24,545	0.848	61,316	1.3535
70-71	62,141	1.054	28,400	1.03	69,454	1.597
71-72	105,375	1.269	36,601	1.23	86,769	1.8645
72-73	106,443	1.575	41,578	1.375	97,278	2.1495
73-74	106,730	1.893	50,808	1.6505	141,122	2.547
74-75	110,412	2.159	55,066	1.9355	150,108	2.9055
75-76	133,660	2.4965	80,951	2.24	204,756	3.2465
76-77	277,325	2.9025	105,900	2.6485	257,426	3.6655
77-78	297,297	3.3715	149,068	3.175	350,259	4.1695
78-79	298,293	3.8625	154,691	3.773	362,128	4.7785
79-80	299,791	4.359	158,902	4.455	371,017	5.4675

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[1] Cost per 24 ft. wide lane mile.
[2] Cumulative ESAL-18's in millions.

	Project XVI		Project XVII		Project XVIII	
	Cost	Kips	Cost	Kips	Cost	Kips
1966-67	15	0.2165	3,256	0.2025	779	0.241
67-68	30	0.403	7,335	0.3805	839	0.42
68-69	40	0.598	10,227	0.569	25,928	0.6065
69-70	91	0.83	22,582	0.7845	28,199	0.801
70-71	163	1.1155	40,362	1.03	51,901	1.049
71-72	833	1.4765	206,162	1.3175	61,739	1.394
72-73	3,317	1.9055	820,787	1.686	61,755	1.8135
73-74	3,854	2.337	953,507	2.102	62,313	2.25
74-75	3,856	2.7705	953,795	2.517	100,542	2.6805
75-76	3,884	3.2405	960,571	2.9555	102,780	3.146
76-77	3,894	3.7675	963,140	3.472	103,098	3.6475
77-78	3,937	4.403	973,899	4.06	103,827	4.181
78-79	4,202	5.118	1039,632	4.73	106,098	4.757
79-80	5,939	5.836	1469,404	5.436	106,487	5.3235

	Project XX		Project XXI		Project XXII	
	Cost	Kips	Cost	Kips	Cost	Kips
1966-67	55	0.185	303	0.181	0	0.4725
67-68	334	0.3635	1,321	0.3495	882	0.6535
68-69	439	0.549	2,002	0.528	3,970	0.841
69-70	1,548	0.7395	2,441	0.7125	149,910	1.042
70-71	1,732	0.95	4,163	0.898	299,150	1.265
71-72	2,270	1.214	4,597	1.0915	330,343	1.518
72-73	2,321	1.5965	15,537	1.3235	331,060	1.804
73-74	7,169	2.044	15,565	1.614	331,060	2.104
74-75	7,198	2.4905	29,132	1.9885	334,289	2.4115
75-76	7,254	2.972	30,920	2.4565	334,447	2.6585
76-77	9,335	3.5155	33,031	2.9715	334,536	3.0545
77-78	25,312	4.1375	53,615	3.531	450,256	3.4815
78-79	29,428	4.79	61,903	4.122	474,137	3.958
79-80	43,386	5.3685	63,663	4.6915	576,377	4.4435

1916 FLEX III Data (continued)

	Project XXIII	
	Cost	Kips
1966-67	0	0.4725
67-68	1,018	0.6535
68-69	2,903	0.934
69-70	27,664	1.228
70-71	91,012	1.451
71-72	92,145	1.7085
72-73	93,157	1.999
73-74	93,157	2.299
74-75	93,539	2.6065
75-76	93,539	2.9575
76-77	94,187	3.3575
77-78	112,672	3.7845
78-79	122,731	4.261
79-80	123,717	4.747

APPENDIX C

SAMPLE COMPUTER PRINTOUT

Sample Computer Printout

The following is a sample computer output— in this case for Project XIV Cost vs. Kips.

As mentioned earlier, the estimated coefficients, t-statistics, and R^2's were examined for each equation specification for each project.

For this project, the R^2 is quite high and indicates that there is a strong statistical relationship between the dependent and independent variables. The t-statistics show that kips have a significant influence on costs. Conversely, the omitted variables (C) do not have a significant influence on costs (the minus sign can be disregarded— it's the result of the negative estimated coefficient).

EQUATION 5
###########

SMPL VECTOR
1 14

ORDINARY LEAST SQUARES

VARIABLES...

XIVC
XIVK
C

INDEPENDENT VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC
XIVK	42144.8	2485.54	16.9560
C	-11763.0	5505.58	-2.13655

R-SQUARED = .9599

F-STATISTIC(1, 12) = 287.505

DURBIN-WATSON STATISTIC (ADJ. FOR 0 GAPS) = 1.1824

NUMBER OF OBSERVATIONS = 14

SUM OF SQUARED RESIDUALS = .154014E+10

STANDARD ERROR OF THE REGRESSION = 11328.9

ESTIMATE OF VARIANCE-COVARIANCE MATRIX OF ESTIMATED COEFFICIENTS

.618E+07	-.114E+08
-.114E+08	.303E+08

LINE 34
OLSQ

1919

1920

APPENDIX D

SAMPLE ESTIMATE CALCULATION

Here again, Project XIV's data will be used. The authors selected the cumulative annual kip figure closest to 1.0 kip. This figure identified the year for which the cost estimate would be derived. The actual, annual cumulative maintenance cost figure for that year could then be used for comparisons.

<u>Project XIV</u>

For 1970-71: Kips = 1.03

Cost = $28,400

Estimated Coefficients: For Kips = 42144.8

For C = -17763.0

y = m x + b

Cost = Est. coef. for kips (kips) + est. coef. for c

Cost = 42144.8 (1.03) + (-11763.0)

Cost = $31,646.

$31,646 is 11% more than the actual cost figure of $28,400.