

REPORT OF COMMITTEE ON MAINTENANCE COSTS

By H K BISHOP, *Chairman*

SYNOPSIS

A uniform system of maintenance cost keeping was applied to 18,154 miles of roads in 47 States. The report analyzes the data relating to 4,487 miles of high type, 3,796 miles of intermediate, and 1,041 miles of low type roads for maintenance cycles of four to six years within the years 1935 to 1940. To make comparisons possible costs were reduced to a 1925-1929 price index.

The total annual maintenance cost on these roads was \$471.32 per mile, of which \$194.48 was for surface, \$66.67 for shoulders and approaches, \$107.13 for road-sides, drainage and structures and \$103.04 for traffic services. An average of 45 per cent was spent for labor, 21 per cent for materials, 25 per cent for equipment and 9 per cent for overhead.

The normal surface maintenance costs did not exceed \$220 per mile for high type pavements 20 ft wide and \$299 for 18 ft wide. For intermediate type pavements the costs did not exceed \$334 and \$394 per mile for 20- and 18-ft pavements respectively. On low type pavements the cost did not exceed \$420.

The greater cost of maintaining 18-ft pavements over that for 20-ft pavements is attributed to greater age, more frequent edge failures, and shoulder effects due to the narrower width. The data also show increased surface maintenance cost with traffic.

The committee finds that the total annual average highway maintenance cost per mile was \$471.32 on 18,154 miles of roads converted to a 1925-29 price index base and for a maintenance cycle ranging from four to six years (within the years 1935 to 1940). This cost is broken down two ways: (I) by amounts devoted to the various kinds of work performed, and (II) by percentages of the total cost for labor, materials, equipment, and overhead as elements.

traffic of 1,203 vehicles per 24-hour day, and were in an average maintenance condition of 89 throughout the study, using 100 as the base field inspection rating, when all reasonable maintenance repairs were performed.

These costs were traced to work performed in preserving and keeping each type of roadway, roadside, structure and facility as nearly as possible in its original condition as constructed or as subsequently improved, and the operation of highway facilities and services to provide satisfactory and safe highway transportation.

The identification of costs was facilitated by a uniform classification and definition of maintenance operations on specially selected representative rural highway sections, having specific limits, in 47 States and the reporting of data by all State Highway Departments on a common form (Form M-1).<sup>1</sup> The form was designed and supplied by this committee.

I	
	Annual cost per mile
Surface, routine and periodic	\$194.48
Shoulders and approaches	66.67
Roadside, drainage and structures	107.13
Traffic services, including snow removal, ice treatment and guardrail	103.04

II	
	Per cent
Labor	45
Materials	21
Equipment	25
Overhead	9

The roads were of an average of 19.8 ft wide and 6.8 years, carried an average

<sup>1</sup> Report of Committee on Maintenance Costs, *Proceedings, Highway Research Board, Vol 19, p 305 (1939).*

through the Public Roads Administration and called for the following data :

- A Segregation of maintenance expenditures by kinds of work and elements of cost.
- B Surface construction costs, original and subsequent additions, betterments and reconstruction.
- C. Estimated life of surface from field observations.
- D. Traffic, 24-hour count.
- E Descriptive data—location, cross section, mileage, age, etc.
- F Maintenance performed, from field inspection ratings
- G. Remarks as to unusual conditions affecting maintenance costs.

In some States, more so when the study began, construction betterments were performed by maintenance forces, with maintenance equipment and paid for out of maintenance funds. In the study distinction was made to the effect that (a) maintenance preserves but does not increase the capital investment in the highway, while (b) construction betterments are capital charges increasing the investment. Charges of the latter category were therefore, when found, removed from the data presented in this report.

It was noted that price fluctuations had been influencing maintenance costs in comparisons between one year and another. A review of highway price trends over a period of 10 years disclosed a maximum variation of 40 per cent from the low index. This would mean that a \$400 per mile maintenance cost as of one year would equal \$560 per mile as of another year. To neutralize this influence, the costs were converted to a 1925-1929 highway cost base, a period of uniformity in highway price trends

Reference has already been made to a maintenance cycle. There has come into use the concept of "periodic maintenance"

in which certain work is performed only once a year or once in several years, such as bituminous retreatments, stock piles, metal replacements, etc. Our study has been extended on many sections over a period of years sufficient to cover a complete cycle. In instances where this interval between maintenance operations was longer than that covered by the study, the charges were spread back over such a period as to represent the true cost during any one year.

Previous data referred to are averages for the United States. There were, of course, extremes and graduations therefrom, depending on the interplay of various factors producing effects on maintenance costs. To study these more closely and to disclose the influence of some of the factors on the averages, the data were broken down by regions, each being composed of States having topographic and climatic similarities. The map of the United States (Fig. 1) shows the distribution of the States among the regions and Table 1 lists the average maintenance costs per mile, surface widths, condition ratings, and traffic densities for highway cost sections located in each region.

The data in Table 1 show the following ranges :

	From—	To—
Total maintenance cost per mile	\$346	\$1,090
Surface	\$152	\$245
Shoulders and approaches	\$28	\$169
Roadside, drainage and structures	\$68	\$265
Traffic service, including snow removal, ice treatment and guardrail	\$14	\$444
Labor	42%	51%
Materials	17%	29%
Equipment	19%	31%
Overhead	5%	12%
Average surface width, feet	18 6	21 9
Traffic per 24 hours	689	3,945
Maintenance rating	85	94

The high and low total maintenance costs in Table 1 may be explained by an analysis of the kinds of work and elements of cost included. First, it will be noted that volume of traffic does not show a consistent relation to surface maintenance cost although the trend is there in some instances. The surfaces having the lowest traffic count, 689 vehicles per 24-hour day, have a cost of \$170 per mile while the surfaces with the highest count, 3,945

little further in the report through the segregation of costs into surface type groups by widths of pavement

The cost per mile for shoulders and approaches (both shoulders included in the mile) is fairly consistent, the average for the United States is \$67, and in six regions it ranges from \$54 to \$89. In the seventh, the West North Central region, it is \$26 per mile, but this is not a complete cost. It was restricted by

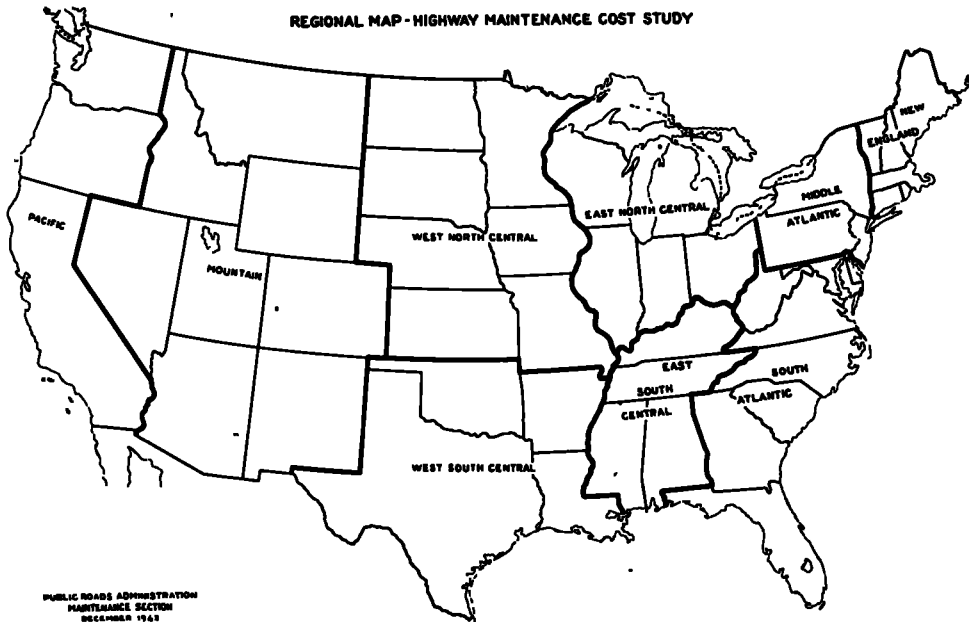


Figure 1

vehicles, have an average cost of \$236 per mile. In between these there is a traffic count of 1,104 with a cost of \$195; also, 1,456 vehicles with a cost of \$213. A consistent relation is, however, disrupted by such varying factors as width of pavement, maintenance performed as reflected by field inspection ratings (the number of points out of a possible complete 100 performance), age of pavement, and the ratio of high, intermediate and low type surfaces included in the mileage. The influence of these factors will be observed a

budget limitations reflected in the table by the lower maintenance performance rating of 87. In the remaining two regions, the Middle Atlantic and New England, the high cost of \$169 and \$136 per mile, respectively, is due to the larger volume of traffic, greater use of the shoulders, and the higher quality of maintenance performed to meet the more extensive demand. This discloses that as long as traffic remains numerically within the capacity of the surface, the shoulder maintenance costs are reasonably constant; beyond this

TABLE 1  
 INTRODUCTORY SUMMARY OF ANNUAL HIGHWAY MAINTENANCE COSTS PER MILE  
 AND PREVAILING FACTORS AFFECTING MAINTENANCE COSTS  
 Average Based on 4- to 6-Year Period—57 Surface Types Included  
 (Costs shown are on 1925-1929 price index base)

Item	Region							United States		
	Pacific	Mountain	West North Central	West South Central	East North Central	East South Central	New England		Middle Atlantic	South Atlantic
Total cost	\$593	\$376	\$407	\$346	\$519	\$366	\$1,090	\$966	\$374	\$471
Surface	\$213	\$170	\$216	\$153	\$152	\$220	\$245	\$236	\$195	\$194
Shoulders and approaches	\$75	\$59	\$28	\$73	\$89	\$54	\$136	\$169	\$67	\$67
Roadside, drainage and structures	\$189	\$78	\$68	\$87	\$128	\$78	\$265	\$244	\$81	\$107
Traffic service, including snow, ice and guardrail	\$116	\$69	\$95	\$33	\$150	\$14	\$444	\$317	\$31	\$103
Labor	46%	45%	42%	48%	45%	42%	46%	51%	42%	45%
Materials	19%	17%	21%	21%	17%	23%	21%	22%	29%	21%
Equipment	25%	31%	29%	19%	26%	24%	28%	20%	21%	25%
Overhead.	10%	7%	8%	12%	12%	11%	5%	7%	8%	9%
Miles	1,285	2,678	4,055	2,152	2,008	1,841	1,042	666	2,416	18,143
Surface width, ft	19 6	19 3	21 0	18 6	20 1	18 7	21 9	20 9	18 7	19 8
Traffic, 24-hour	1,456	689	861	1,013	1,728	765	2,364	3,945	1,104	1,203
Total maintenance rating	94	91	87	88	89	85	94	94	91	89

NOTE. 38 States reporting 6 years; 7 States reporting 5 years; 2 States reporting 4 years; 1 State not reporting.

stage the costs increase directly with traffic.

There is no definite yardstick with respect to roadside, drainage and structure maintenance costs other than the performance ratings shown on the table due to the diversity and nature of the operations included within the terms Quantity of traffic only indirectly affects the items through the public opinion it reflects. The higher costs in the table are to a greater extent affected by roadside and landscape developments and the low costs are partly the result of the absence thereof.

The traffic service costs range as widely as the climatic conditions throughout the country. In addition to the maintenance of traffic signs and markers, this classification includes the cost of snow removal and ice treatment. So in the East South Central region the traffic service cost is \$14 per mile, while in New England where refinements in snow removal and ice treatment are demanded by traffic, the average is \$444. In Massachusetts alone snow removal and ice treatment costs have been reported up to \$1,400 per mile in response to the insistent demands of traffic.

The percentage breakdown of costs by regions does not vary much from the average for the country. It may be reasonably concluded that as an average 45 per cent of maintenance money is expended for direct labor, 21 per cent for materials, 25 per cent for equipment, and 9 per cent for overhead.

We now come to a more detailed breakdown of surface maintenance costs, the segments of highway on which the movement of traffic is directly applied. We have broken down these annual costs per mile for the four to six-year period and the maintenance performance ratings associated therewith into three surface type groups, high, intermediate and low.<sup>2</sup> The

costs are submitted on the following pages in (1) graphical form plotted against individual traffic counts for 18- and 20-ft widths and (2) for 20-ft. width in tabular form segregated into three traffic groups—(a) 0 to 750, (b) 751 to 4,000, and (c) 4,001 and over.

Although the points plotted on the graphs which follow represent actual reported costs, the values, as may be observed, are not sufficiently grouped to indicate a relation or the trend thereof between actual costs and volume of traffic. Analysis of the graphs is therefore limited to a discussion of the cost values plotted.

First analyzing the 20-ft. width high-type pavement, we have plotted 180 cost values against traffic on Figure 2. These values represent the same number of sections and cover 2,390 miles of highways distributed throughout the United States. 169 points fall within the \$1.50 to \$220 per mile range on the graph and the entire 180 points range from \$1.50 to \$634 per mile.

A review of the eleven cost points above the \$220 per mile value indicates that the maintenance costs on five sections were affected by poor subgrade or base conditions and damages on three of these were further actuated by heavy weighing truck traffic, two sections were subject to extreme weather conditions, two had expensive bituminous retreatment work, and two had expensive patching due to previous neglect. The sections having extremely low costs were also examined and found to have maintenance performance ratings around the general average. So all that can be said is that these surfaces were constructed under ideal conditions. The remaining cost values were generated by operations usually expected in the normal course of maintenance activities. The

---

Intermediate-type surfaces Oil processed, surface treated stone, gravel, sand-clay, etc

Low-type surfaces Untreated stone, gravel, sand-clay, graded

<sup>2</sup> High-type surfaces Concrete, brick, bituminous concrete-rigid and nonrigid base, bituminous macadam

average maintenance performance represented by all the costs was 90 out of a possible 100 points. The average age of the pavements was 6.5 years.

The conclusion to be drawn from Figure 2 is that the normal annual maintenance cost per mile does not exceed \$220 per mile for high-type surfaces 20 ft. wide. This covers a range from zero traffic, where the need for repairs is

pavements 20 ft wide and covering 2,095 miles of highways 109 points fall within the \$15 to \$334 per mile range and all the points are plotted within \$15 to \$609 per mile limits.

Of the 18 surface maintenance costs plotted above \$334 per mile, 10 were affected by surface and base failures resulting from weak subgrade and reports state that damages were further extended on

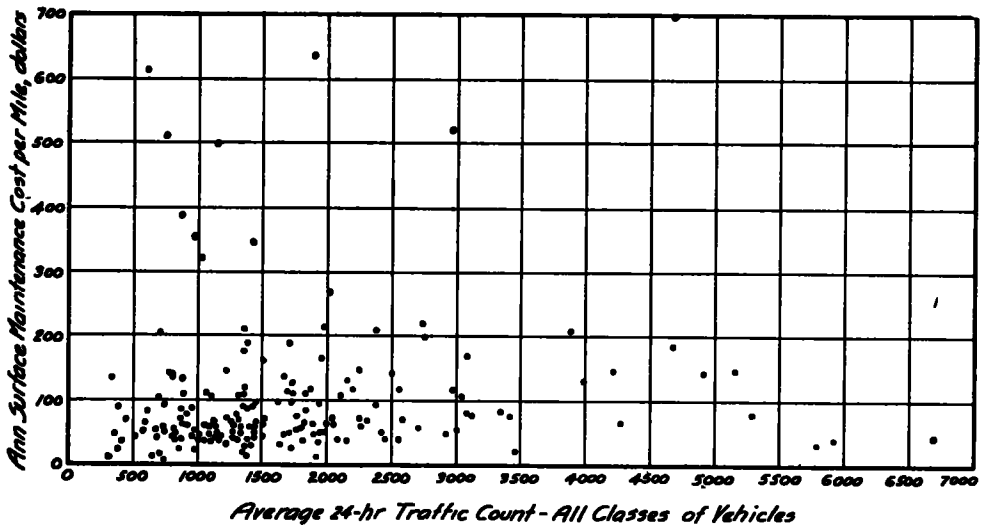


Figure 2. 20-Ft. Width, High Type Surface in All Regions. Annual Highway Surface Maintenance Cost Per Mile by 24-Hr. Traffic Count. Maintenance Performance Represented by the Costs Was 90 Out of a Possible 100 Points. 4 to 6-Year Period (Within the Years 1935-1940). Costs Converted to 1925-1929 Price Index Base.

attributable to natural forces, and changes therefrom for traffic values up to 6,700 vehicles per 24-hour day. The average of all the points plotted below the normal maximum is \$70 per mile. An exact maintenance cost for a specific surface type and traffic volume is not considered desirable as experience shows that even with these factors constant, surface maintenance costs still vary between locations due to subsoil conditions, durability built into pavement, drainage, temperature and rainfall changes, etc.

On Figure 3 are plotted 127 maintenance cost values for intermediate-type

three of these sections by heavy weighing truck traffic, two sections had expensive retreatment work, three were subject to extreme weather conditions, and three had extensive patching due to previous neglect and a long haul on materials. The low values had high performance ratings, indicating that necessary repairs were made. The remaining values below \$334 per mile represent maintenance activities normally to be expected. The average maintenance performance represented by all the costs was 89 out of 100 points. The average age of the pavements was 4.5 years.

Figure 3 accordingly discloses that nor-

mal annual surface maintenance costs for intermediate-type pavements 20 ft. wide do not exceed \$334 per mile for traffic values up to 1,500 vehicles per 24 hours. The average of all the points plotted below the normal maximum is \$175 per mile.

On Figure 4 are plotted 54 maintenance cost values for low-type pavements 18 and 20 ft. wide and covering 1,041 miles of highways. Here are combined two surface widths in order to secure enough values

of points which end at \$420 per mile. Two of these had unstable base and heavy weighing truck traffic, one was subject to extremely cold weather, one had extensive gravel replacements due to excessive winds, and the remaining three had considerable gravel replacements each year for reasons not reported. Three of the five lowest values had a performance rating of 60, and the remaining two had a normal rating of 90.

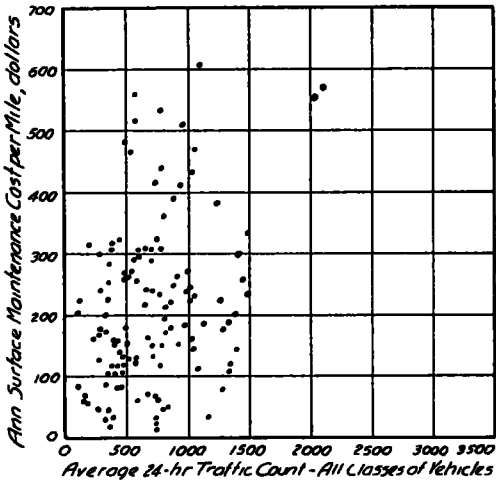


Figure 3. 20-Ft. Width Intermediate Type Surfaces in All Regions. Annual Highway Surface Cost Per Mile by Average 24-Hr. Traffic Count. Maintenance Performance Represented by the Costs Was 89 Out of a Possible 100 Points. 4 to 6 Year Period (Within the Years 1935 to 1940). Costs Converted to 1925-1929 Highway Price Index Base.

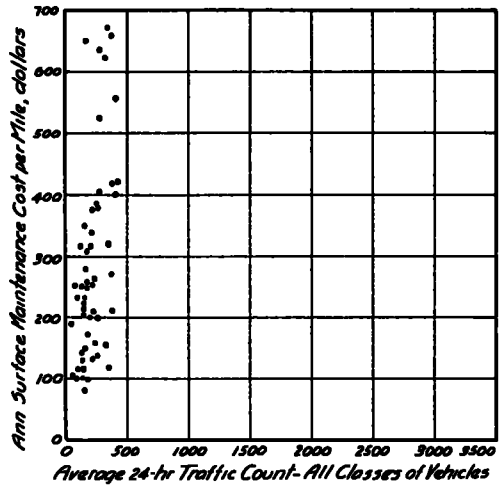


Figure 4. 18 and 20-Ft. Widths in All Regions. Annual Highway Surface Maintenance Cost Per Mile by Average 24-Hr. Traffic Count. Maintenance Performance Represented by the Costs Was 79 Out of a Possible 100 Points. 4 to 6 Year Period (Within the Years 1935 to 1940). Costs Converted to 1925-1929 Highway Price Index Base.

for conclusive results. When the study began numerous sections of each width were selected. However, State policies have been to surface treat or oil process this type of surface as budgets permitted, and what often started out as a low-type surface has now been advanced to the intermediate class.

The low-type surface values range from \$81 to \$670 per mile. Seven cost values on Figure 4 are above the general cluster

The remaining expenditures up to \$420 per mile were made for average maintenance activities. This work, however, did not adequately repair the roads as all of the cost values on the graph reflect an average performance of only 79 out of a possible 100 points. This is a performance ten or eleven points lower than that reported for high or intermediate type pavements. As an opinion based on a review of all reports, it would take an average of

about \$75 per mile of additional expenditures for repairs to bring the low-type average maintenance performance rating up to a parity with the 89 and 90 ratings given to the other two classes of pavements.

Adding the \$75 per mile as a compensation for the low maintenance performance rating to the highest cost representing

against average 24-hour traffic counts. These sections extended over 3,107 miles located in all regions of the United States.

188 values on the graph range from \$1 to \$299 per mile and the remaining 14 values extend up to \$650 per mile. Three of the latter values were principally affected by unstable base and reports on two of these state that deteriorations were

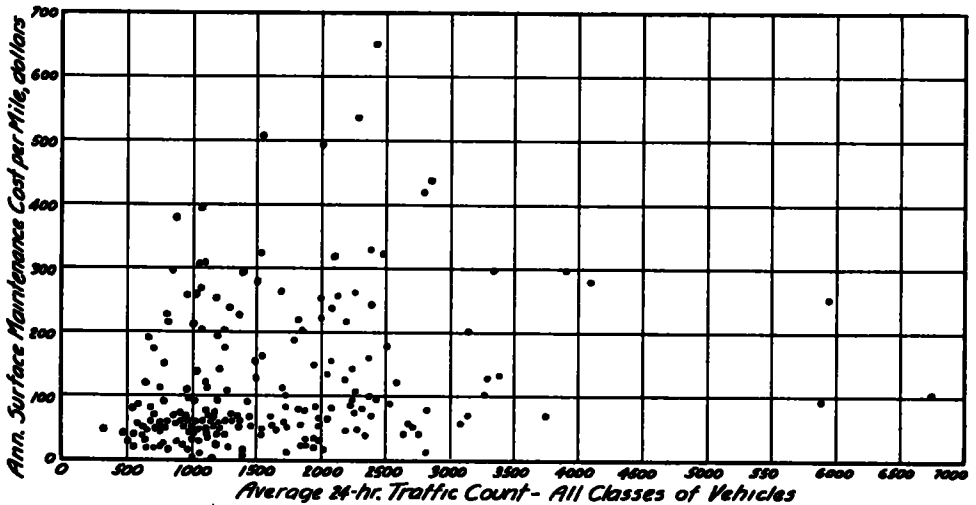


Figure 5. 18-Ft. Width High Type Surfaces in All Regions. Annual Highway Surface Maintenance Cost Per Mile by 24-Hr. Traffic Count. Maintenance Performance Represented by the Costs Was 88 Out of a Possible 100 Points. 4 to 6 Year Period (Within the Years 1935 to 1940). Costs Converted to 1925-1929 Highway Price Index Base.

a normal maintenance activity, \$420 per mile, it may be concluded from Figure 4 that the normal annual surface maintenance costs for low type pavements 18 and 20 ft wide do not exceed \$495 per mile for traffic values up to 430 vehicles per 24 hours. The average of all the points plotted below the normal maximum is \$313 per mile. The average age of the low-type surfaces was 7.9 years including surfaces on which normal replacements of materials were made.

Figure 5 shows the surface maintenance cost per mile for high-type pavements 18 ft. wide on 202 highway sections, plotted

further increased by heavy weighing traffic; four sections required extensive surface patching for reasons not reported, five had expensive retreatment work, one had surface blow-ups caused by high summer temperatures, and one had surface settlements caused by excessive rains. The low cost values have field inspection ratings which indicate normal maintenance was performed. Maintenance performance on all the sections was rated an average of 88 out of 100 points. The average age of the pavements was 9.4 years.

A check of the remaining values on



Figure 5 indicates that the normal maintenance cost for high-type pavements 18 ft wide does not exceed \$299 per mile for traffic counts up to 6,744 vehicles per day. The average of all the points plotted below the normal maximum is \$86 per mile

Figures 2 and 5 both present maintenance costs on high-type pavements, the former on surfaces 20 ft. wide and the latter on surfaces 18 ft wide. Comparing the two graphs for traffic values up to 6,700 vehicles per day it is found that the average for all cost values plotted below the normal maximum of \$220 on 20-ft pavements is \$70 per mile; on 18-ft pavements it is \$86 per mile for all values below the normal maximum of \$299. The higher cost on narrow pavements is to a considerable extent attributable to greater age and more frequent edge failure, distorted shoulder run-off and lateral seepage through broken water seals between surface and shoulders caused by vehicles riding the latter.

Figure 6 shows surface maintenance costs per mile for intermediate-type pavements 18-ft wide on 110 sections in relation to traffic. They cover 1,701 miles of highways. Eighty-seven values ranged from \$13 to \$394 per mile, and 23 values from \$394 to \$956 per mile. Of the latter, five were affected by frost damage, two by water seepage under oil mats, six had unstable base for reasons not reported, eight had expensive retreatment work, one required considerable surface repair after use of the section as a detour and one required extensive patching due to heavy log hauling. The low-cost values showed a reasonable maintenance performance during the field inspections. Maintenance performance represented by all the costs was rated as averaging 88 out of 100 points. The average age of the pavements was 5.4 years.

A check of the remaining values on Figure 6 indicates that the normal maintenance cost for intermediate-type pavements

18 ft. wide does not exceed \$394 per mile for traffic counts up to 1,483 vehicles per 24-hour day. The average of all the points plotted below the normal maximum is \$206 per mile.

Comparing the costs on Figures 3 and 6, intermediate-type pavements up to a traffic of 1,483 vehicles per day, the aver-

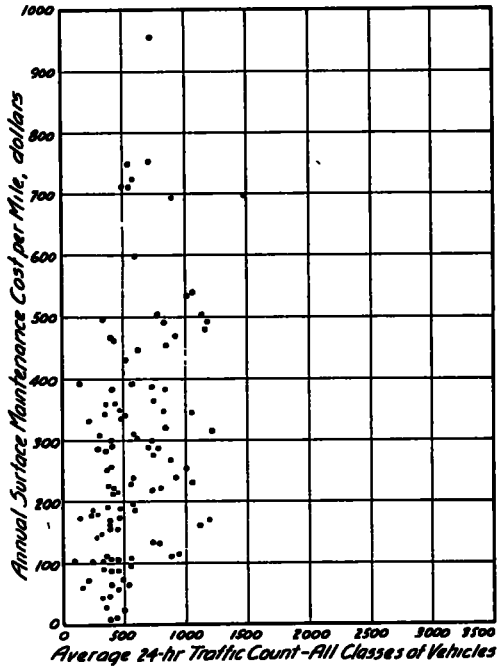


Figure 6. 18-Ft. Width Intermediate Type Surfaces in All Regions. Annual Highway Surface Maintenance Cost Per Mile by 24-Hr. Traffic Count. Maintenance Performance Represented by the Costs Was 88 Out of a Possible 100 Points. 4 to 6 Year Period (Within the Years 1935 to 1940). Costs Converted to 1925-1929 Highway Price Index Base.

age maintenance cost on 20-ft surfaces is \$175 per mile for all cost values plotted below the \$334 normal maximum; on 18-ft. pavements it is \$206 per mile for all values below the normal maximum of \$394. The higher maintenance cost on narrow surface widths is again attribut-

TABLE 2  
 AVERAGE ANNUAL SURFACE MAINTENANCE COSTS PER MILE, MILEAGE, AND  
 MAINTENANCE RATINGS, BY SURFACE TYPE AND TRAFFIC DENSITY  
 GROUPS, SURFACES 20 FT WIDE

COSTS CONVERTED TO 1925-1929 HIGHWAY PRICE INDEX BASE  
 (Average annual maintenance costs based on records for 4- to 6-year period 1935-1940)

Region	Traffic density—vehicles per 24-hour day								
	0 to 750			751 to 4,000			4,001 and over		
	Miles	Surface maintenance		Miles	Surface maintenance		Miles	Surface maintenance	
		Cost per mile	Performance rating		Cost per mile	Performance rating		Cost per mile	Performance rating
<b>HIGH-TYPE SURFACES</b>									
Pacific	52	\$ 48	96	167	\$193	93	28	\$104	93
Mountain				64	174	90			
West North Central	80	52	92	596	70	91			
West South Central	41	48	95	275	92	91			
East North Central	70	65	86	514	81	86	36	98	95
East South Central	16	43	85	92	98	90			
New England	7	83	92	89	84	91	9	70	92
Middle Atlantic				53	145	94			
South Atlantic	42	20	87	159	53	92			
United States	308	50	90	2,009	92	90	73	97	94
<b>INTERMEDIATE-TYPE SURFACES</b>									
Pacific	93	\$111	94	97	\$253	95			
Mountain	896	166	93	320	217	89			
West North Central	146	394	82	42	310	90			
West South Central	29	163	90	79	332	92			
East North Central				37	299	96			
East South Central	29	410	92	94	396	88			
New England	13	238	94	12	315	93			
Middle Atlantic	4	32	93	10	236	92			
South Atlantic	111	208	91	83	394	85			
United States	1,321	196	89	774	285	90			
<b>LOW-TYPE SURFACES</b>									
Pacific									
Mountain									
West North Central	266	\$305	66						
West South Central	15	273	82						
East North Central									
East South Central									
New England									
Middle Atlantic									
South Atlantic									
United States	281	303	67						

able to greater age and edge failures, distorted run-offs and broken water seals between surface and shoulders

Table 2 shows the above surface maintenance costs for pavements 20 ft wide broken down by regions and traffic density groups.

The data in Table 2 generally show an increase of surface maintenance costs with traffic. It further discloses by comparison the regional effects of climate, topography and maintenance performance on cost data. Especially noticeable is the increase in maintenance cost with rising traffic and lowering of surface type quality. The table shows the following average surface maintenance cost for the United States on surfaces 20 ft wide: High-type surface, \$50 per mile for 0 to 750 vehicles per day, \$92 per mile for 751 to 4,000 vehicles per day, and \$97 per mile for 4,001 vehicles and over per day; intermediate-type surface, \$196 per mile for 0 to 750 vehicles per day, \$285 per mile for 751 to 4,000 vehicles per day; low-type surface, \$303 per mile for 0 to 750 vehicles per day.

Although both the graphic and tabular comparisons show increases in maintenance costs with the lowering of surface type standards, it is not an indication of the relative economy of expenditures. Preliminary to the construction of highway surfaces there is always a selection to be made as to whether the pavement should have a high first cost durability built into the pavement and subsequent low maintenance costs, or a low first cost and higher maintenance expenditures. This depends on the quantity and type of traffic expected. Experience indicates that normal maintenance costs attributable to each surface-type group are most economical within certain traffic count limits.

Where the transition should take place from one surface type to another, to effect savings in maintenance costs, depends on a comparison between surface types of the

average annual surface maintenance cost combined with an annual charge for writing off the construction investment. The latter item is controlled by the life of pavement and anticipated salvage value. Other studies are being made of these two factors and a comparison of the relative economy of the surface maintenance costs presented in this report with reference to surface type groups will have to await the outcome of those studies.

TABLE 3

## HIGHWAY SURFACE PRICE INDEX—PERIOD 1925 TO 1929

Year	Index
Base period 1925 to 1929	100 00
1922	102 72
1923	109 49
1924	108 32
1925	106 42
1926	103 09
1927	103 31
1928	94 52
1929	92 67
1930	84 10
1931	75 58
1932	65 23
1933	75 18
1934	85 92
1935	85 49
1936	86 29
1937	84 98
1938	77 40
1939	77 92
1940	76 01
1941	85 08

The data reported herein are on a 1925-1929 price index base and may be converted to any one year by multiplying the costs by the highway price index for the specific years shown in Table 3.

## CONCLUSIONS

1 The total annual highway maintenance cost as a national average for the years 1935-1940, based on a 1925-1929 price index, is \$471 32 per mile for a

maintenance performance rating of 89 out of a possible 100 points when all reasonable repairs have been made

2 The annual surface maintenance cost, representative of all major surface types, is \$194 40 per mile for an average width of 19 8 ft and traffic of 1,203 vehicles per 24-hour day In some instances costs included in this average were adversely affected by moisture content of base or subgrade.

3. The annual maintenance cost of shoulders and approaches is \$66 67 per double-strip mile. This does not vary extensively as long as traffic density remains within traffic capacity of surface. Beyond this limit it varies directly with increase in traffic.

4 The annual average maintenance cost for roadside, drainage and structures is \$107 13 per mile. These costs vary with budget limitations and local public opinion

5. The annual average maintenance cost for traffic services is \$103 04 This includes snow removal and ice treatment The cost therefore varies directly with climatic conditions.

6 An average of 45 per cent of highway maintenance money is expended for direct labor, 21 per cent for materials, 25 per cent for equipment, and 9 per cent for overhead.

7. The normal surface maintenance cost for high-type pavements 20 ft wide does not exceed \$220 per mile for traffic counts up to 6,700 vehicles per 24-hour day, the highest value for which costs were submitted. The average of all the plotted points below the normal maximum is \$70 per mile. These costs represent a performance of 90 out of a possible 100 points when all reasonable repairs have been made The average age of the pavements was 6.5 years.

8. The normal surface maintenance cost for intermediate-type pavements 20 ft. wide does not exceed \$334 per mile for traffic counts up to 1,500 vehicles per day

and the average of all the plotted points below the normal maximum is \$175 per mile The average maintenance performance rating represented by these costs was 89 The average age of the pavements was 4 5 years

9. The normal surface maintenance cost for low-type pavements, 18 and 20 ft wide, does not exceed \$420 per mile for traffic counts up to 430 vehicles per 24-hour day and the average of all the plotted points below the normal maximum is \$238 per mile These costs represent a maintenance performance of only 79. As an opinion based on a review of reports, it is estimated that an additional expenditure of \$75 per mile would be necessary to bring the performance rating up to a parity with the high and intermediate type pavements. This would raise the \$420 per mile maximum referred to above to \$495 per mile and the average to \$313 per mile The average age of the surfaces was 7 9 years including surfaces on which normal replacements of materials were made

10. The normal surface maintenance cost for high-type pavements 18 ft wide does not exceed \$299 per mile for traffic counts up to 6,744 vehicles per 24-hour day and the average of the plotted points below the normal maximum is \$86 per mile Average maintenance performed with these costs was rated as 88 during field inspections The average age of the pavements was 9 4 years

11 The normal surface maintenance cost for intermediate-type pavements 18 ft wide does not exceed \$394 per mile for traffic counts up to 1,483 vehicles per 24-hour day The average of all the plotted points below the normal maximum is \$206 per mile Maintenance performance was rated as 88 The average age of pavements was 5 4 years

12 Comparing the average surface maintenance costs between pavements 18

and 20 ft wide on high-type pavements, 0 to 6,700 vehicles, and intermediate-type pavements, 0 to 1,483 vehicles, for values shown on graphs within the cost limitations stated in conclusions 7, 8, 10, and 11, it is found that the 18-ft pavements cost more to maintain. The narrower high-type pavements cost \$16 more per

mile, the narrower intermediate types cost \$31 more per mile. The difference is attributed to greater age, more frequent edge failures, distorted shoulder run-off and lateral seepage through broken water seal between surface and shoulders caused by vehicles riding off the narrower pavements.