HIGHWAY RESEARCH BOARD

Bulletin No. 29

Maintenance Costs

1950

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1950

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HIGHWAY RESEARCH BOARD

Bulletin No. 29

MAINTENANCE COSTS

PRESENTED AT THE TWENTY-NINTH ANNUAL MEETING

1949

HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH COUNCIL

Washington 25, D. C. November 1950

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[1]Since this report was presented, Mr. Rex M. Whitton has succeeded Mr. Root as Chairman of the Department of Maintenance.

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PROGRESS REPORT OF THE PROJECT COMMITTEE ON MAINTENANCE COSTS

H. A. Radzikowski, Chairman
Chief, Maintenance Branch
Bureau of Public Roads

SYNOPSIS

A highway department can now adequately maintain only 1,276 miles of average primary roads for one million dollars. The current mileage is even less where the traffic is heavy or the roads are worn or obsolete. In 1940 a highway department could maintain 80 percent more roads or a total of 2,296 miles for the one million dollars. Stated another way, it now requires $784 per mile to perform the same amount of maintenance that could be performed in 1940 for $436 per mile. In terms of the 1940 dollar, the 1949 dollar produces only $0.56 worth of maintenance repairs.

The cost trend of maintenance and operation rose only slightly during the first half of 1949; it now stands at 194.57. This is an increase of a little over one percent from the last half of 1948, 80 percent above the 1940 level, and 94.6 percent above the 1935 base. Even though the cost trend is slightly higher than the previous half-year, it is quite evident that there is a definite tendency towards leveling off. The relative inflexibility of labor and salary rates under Civil Service affected the maintenance price trend, and it did not decline the same as the 1949 construction cost index. Salaries of maintenance employees did not rise as fast in the first place.

The material component of the maintenance price index declined slightly in the first half of 1949; labor, equipment, and overhead rose slightly.

Year	Labor	Material	Equipment	Overhead	Total
1940	112.33	100.30	107.12	110.20	108.13
Last half 1948	220.34	159.88	181.11	170.81	192.10
First half 1949	222.34	157.70	187.98	171.99	194.57

While the maintenance cost trend rose 89 percent since 1935, the Nation's expenditures for highway maintenance and operation rose 125 percent, from 521 million dollars in 1935 to 1,170 million dollars in 1948. It is broken down as follows:

MAINTENANCE EXPENDITURES

	1935	1948	Percent Rise
State highway departments	$183,000,000	$461,000,000	152
County and local roads	192,000,000	407,000,000	112
City and village streets	146,000,000	302,000,000	107

In addition to the increase in price trend, more maintenance expenditures were required due to the increased use and heavier loads on the highways, more service demanded by the highway users and greater repair needs on worn or obsolete pavements. Forty-seven percent of maintenance costs still go to labor which indicates room for further mechanization.

Maintenance expenditures on all classes of roads and streets in the Nation rose from 2.3 mills per vehicle mile in 1936 to 2.9 mills per vehicle mile in 1948. On county, township and other local roads, it rose from 6.2 mills per vehicle mile in 1936 to 8.0 mills per vehicle mile in 1948. The high local road maintenance costs prompted an analysis of some of the operations.

Blading operations on soil-aggregate roads analyzed in six areas in six states disclosed that the frequency of the operation varied from four to as many as 160 times per year and the cost per operation from $1.67 to $7.25 per mile. The minimum annual cost per mile was $18.50, and the average was $93.90, a difference of $75.40 per mile. While the type of aggregates used on the

surface, and the climate could appreciably affect the variation in blading cost, a better understanding of the frequency with which roads should be bladed and of the selection of the most suitable type of equipment for the work, would help to reduce maintenance cost. In view of the existence of over a million miles of county and local roads to be bladed, this saving could be appreciable.

Closer correlation of design and maintenance costs is needed in:

Ditch Cleaning - The frequency of ditch cleaning operations varied from one to three per year, and the cost of a single operation varied from $7.60 to $45.00 per mile, depending on the amount of cleaning that was necessary and the amount and type of mechanical operation utilized in the work. On some of the more modern designed ditches no cleaning operations were required for several years.

Mowing of Roadside - Mowing operations also depended on the nature of ditch and roadside design that was turned over to maintenance. The annual frequency of mowing operations varied from one to four, and the cost per operation per mile varied from $1.60 to $49.26.

Snow Removal - On a section of highway built in 1924 and 1929 on a low grade line, depressed below the surrounding plains in most cases, the annual cost of snow removal was $296.56 per mile. On a second highway section, built to modern grade line, elevated above the surrounding plains, located in the same area, direction and under similar wind and climatic conditions, the annual cost of snow removal was $19.53 per mile. The annual saving in snow removal cost alone, due to this improved section, amounted to $277.03 per year, or in 20 yr would amount to $5,540.60. This is more than the cost of grading the section in the area studied.

In another area studied, snow removal cost on an old low grade line section was $54.50 per mile and involved 25 snow plow trips at $2.17 per mile. A nearly new section with raised grade required only nine trips during the season, at $1.13 a trip-mile, or $10.18 per mile for the season. The old highway was more frequently drifted in, required more plowing, and provided less service than the newer section. The saving of $44.12 each year in snow removal costs would amount to $882.60 in 20 yr. Additional savings would accrue on the section with raised grade, due to better surface drainage during the spring thaw and the wet season. Less spring breakups would occur.

A highway department can now adequately maintain only 1,267 miles of average primary roads for one million dollars. The current mileage is even less where the traffic is heavy or the roads are worn or obsolete. In 1940, a highway department could maintain 80 percent more roads, or a total of 2,296 miles, for the one million dollars. Stated another way, it now requires $784 per mile to perform the same amount of maintenance that could be performed in 1940 for $436 per mile. In terms of the 1940 dollar, the 1949 dollar produces only $0.56 worth of maintenance repairs.

COST TRENDS

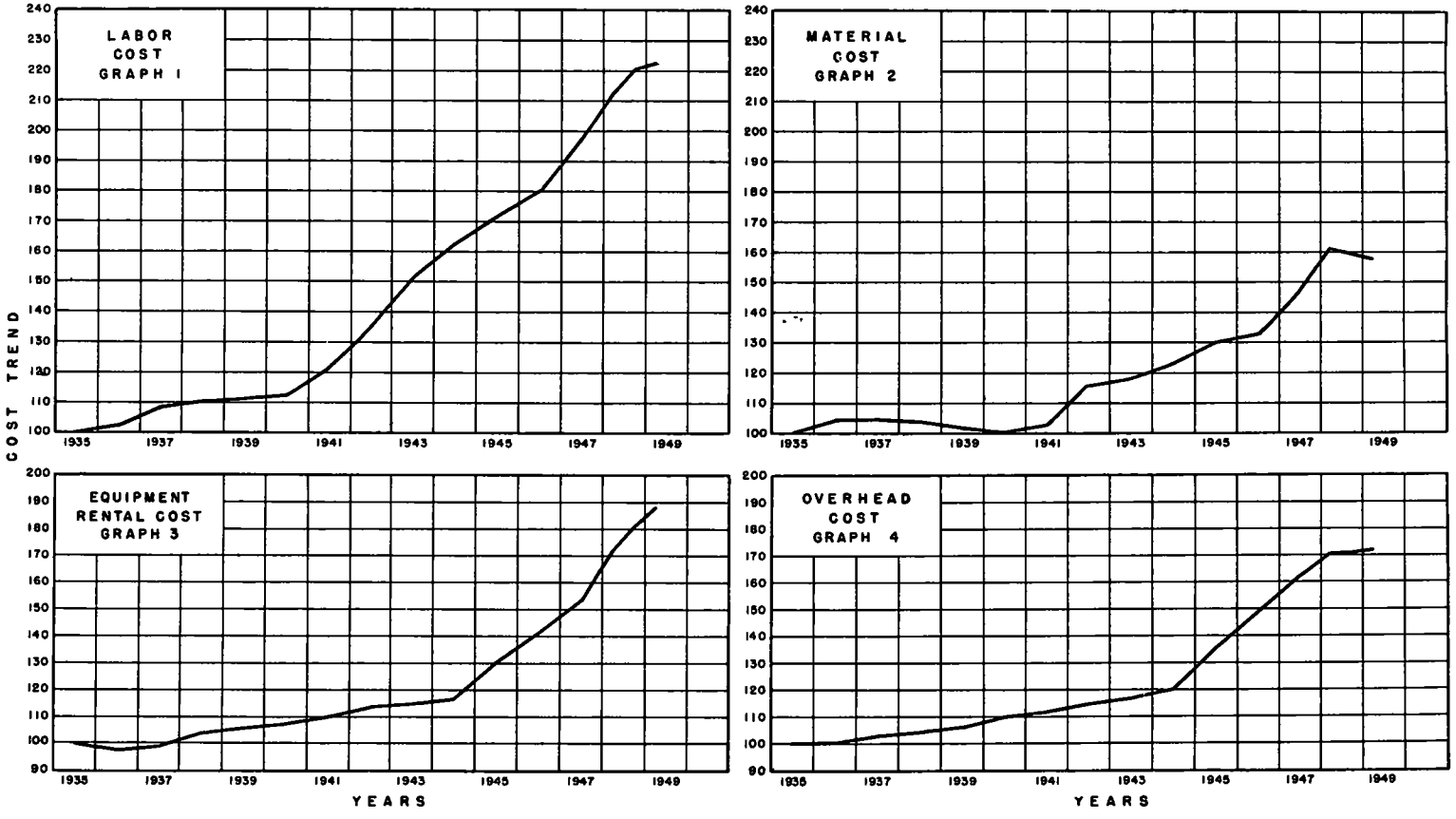
The cost trend of highway maintenance and operation, the computation of which was described fully in the Committee's 1947 maintenance cost report, is still rising slightly. For the first half of 1949, it stands at 194.57, a rise of slightly over one percent from the last half of 1948, 80 percent above the 1940 level, and 94.6 percent above the 1935 base. Even though the cost trend is slightly higher than the previous half-year, it is quite evident that there is a definite tendency toward a leveling off.

This is somewhat at variance with the construction cost index, which has now declined 10 percent, from 165.3 in the last quarter of 1948 to 148.7 in the third quarter of this year. The nature of the indices accounts for a large part of the difference. Since highway construction is generally performed by contract, the construction cost index is based on contract prices. The maintenance cost index is based on the actual cost to governmental units of maintenance work. This cost reflects actual payments for labor, material and equipment.

Under these conditions, the maintenance cost index can be expected to hold more steady. It will not rise as fast or as high during an inflationary period. It will follow the price peaks rather than lead them. Also, it will not drop as quickly or as far in a period of deflation. Another factor that has a definite effect on the maintenance cost trend is the relative inflexibility of labor and salary rates under Civil

COST TRENDS

HIGHWAY MAINTENANCE AND OPERATION



Service.

From 1940 to 1946 the maintenance cost index (graph 5), Table 1, rose gradually from 108.13 to 156.40, an increase of 48.27 points in six years, slightly more than 7 percent each year.

components. It will be noted that labor rates increased steadily from 1940 to the last half of 1948. The labor-cost component increased from 112.33 in 1940 to 220.34 in the last half of 1948, an increase of 108 points or 96 percent

TABLE 1

COST TRENDS

HIGHWAY MAINTENANCE AND OPERATION

Year	Labor	Material	Equipment	Overhead	Total
1935	100.00	100.00	100.00	100.00	100.00
1936	102.19	104.31	97.97	100.29	101.24
1937	108.48	104.42	99.31	102.50	104.46
1938	110.17	103.73	103.51	103.97	106.36
1939	111.29	101.64	105.87	105.83	107.23
1940	112.33	100.30	107.12	110.20	108.13
1941	121.16	102.86	110.11	111.33	113.30
1942	134.93	115.68	113.27	113.93	122.83
1943	151.82	117.76	114.46	116.87	130.88
1944	162.42	123.22	116.77	119.81	137.34
1945	171.16	130.10	129.89	135.01	147.52
1946	180.56	132.62	141.28	148.30	156.40
1947	198.40	145.83	153.39	162.38	171.28
First ½ 1948	212.74	161.20	171.60	170.42	186.42
Last ½ 1948	220.34	159.88	181.11	170.81	192.10
First ½ 1949	222.34	157.70	187.98	171.99	194.57

From 1946 to 1948 the index rose from 156.40 to 189.31, a rise of 32.91 points in two years, or about 10 percent each year. The rise during the past year (first half of 1948 to first half of 1949) has been only 8.15 points, about 4-1/2 percent, and, as stated previously, only one percent during the past six months. These are very strong indications that maintenance costs are, at least, stabilizing.

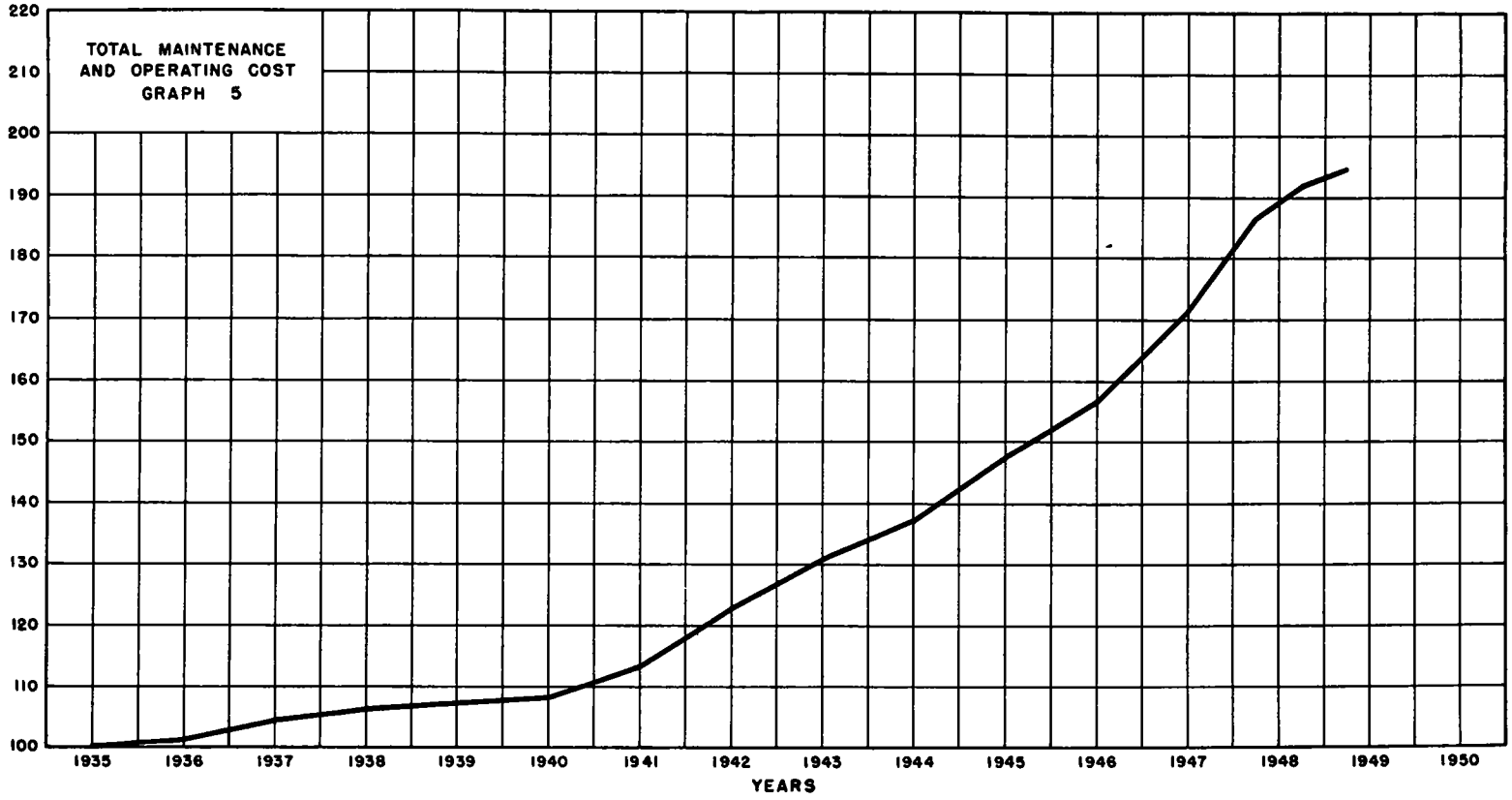
A glance at graphs 1, 2, 3, and 4 and Table 1 shows the increase that has occurred in the cost of the labor, materials, equipment and overhead

in the eight-year period, almost 9 percent each year. The increase in the last six-month period amounts to less than one percent.

The following table illustrates more specifically the increase in maintenance employment and the wage rise in one State from 1941 to 1948. The maintenance department of this State now has 18 percent more employees than in 1941, and the maintenance payroll has increased 130 percent. The monthly wage of the average employee has increased 95 percent since 1941, from $127 to $248 a month (See Table 2).

COST TRENDS

HIGHWAY MAINTENANCE AND OPERATION



Material cost increased from 100.30 in 1940 to 161.20 in the first half of 1948, an increase of only 61 percent. Since then the index has declined, until in the first half of 1949 it was 157.70, a decrease of two percent.

Overhead costs, made up to a large extent of professional, sub-professional and clerical salaries, have increased only 56 percent from 1940 to date. The bulk of this increase occurred during the 1944 to 1948 period.

Equipment rental rates rose very slowly from 1940 to 1944, only 9 percent in the entire four-year period. Since then, due no doubt to the acquisition of new equipment at the higher present-day prices, the rental rates rose much more sharply, from 116.77 in 1944 to the present level, 187.98, an increase of over 60 percent in 4-1/2 years. It is probable that there will still be some rise in these rates as the older low-cost equipment is retired in the next few years.

The States that have not replaced their old equipment may be paying an increased cost due to inefficient operation of the older equipment. As an illustration, a very complete analysis of paving plant costs covering the various operations, the cost of materials and the equipment rental has been made in a western State. This analysis is by plants, ten in number, which vary in the type of equipment and age. Six plants are of the old type with two drums and no pugmill. The other four plants are modern, having one drum and one pugmill and greater capacity. Cost of production using the new plants was lower by $1.44 a ton. Since the six old plants produced 61,800 tons in 1948, and the difference between the cost of production in the old plants and the new plants is $1.44 per ton, a saving of $89,000 could be made.

TABLE 2

NUMBER AND AVERAGE WAGE OF MAINTENANCE PERSONNEL

Year	Number Employed	Employment Index 1941 Base	Monthly Payroll	Average Monthly Wage	Percentage Increase Over 1941
1941	1597	100	202,717	$127.00	-
1942	1298	81	197,489	152.00	20
1943	1233	77	206,159	167.00	31
1944	1152	72	204,696	177.00	40
1945	1349	84	251,104	186.00	47
1946	1498	94	293,398	196.00	54
1947	1725	108	360,798	209.00	65
1948	1885	118	467,030	248.00	95

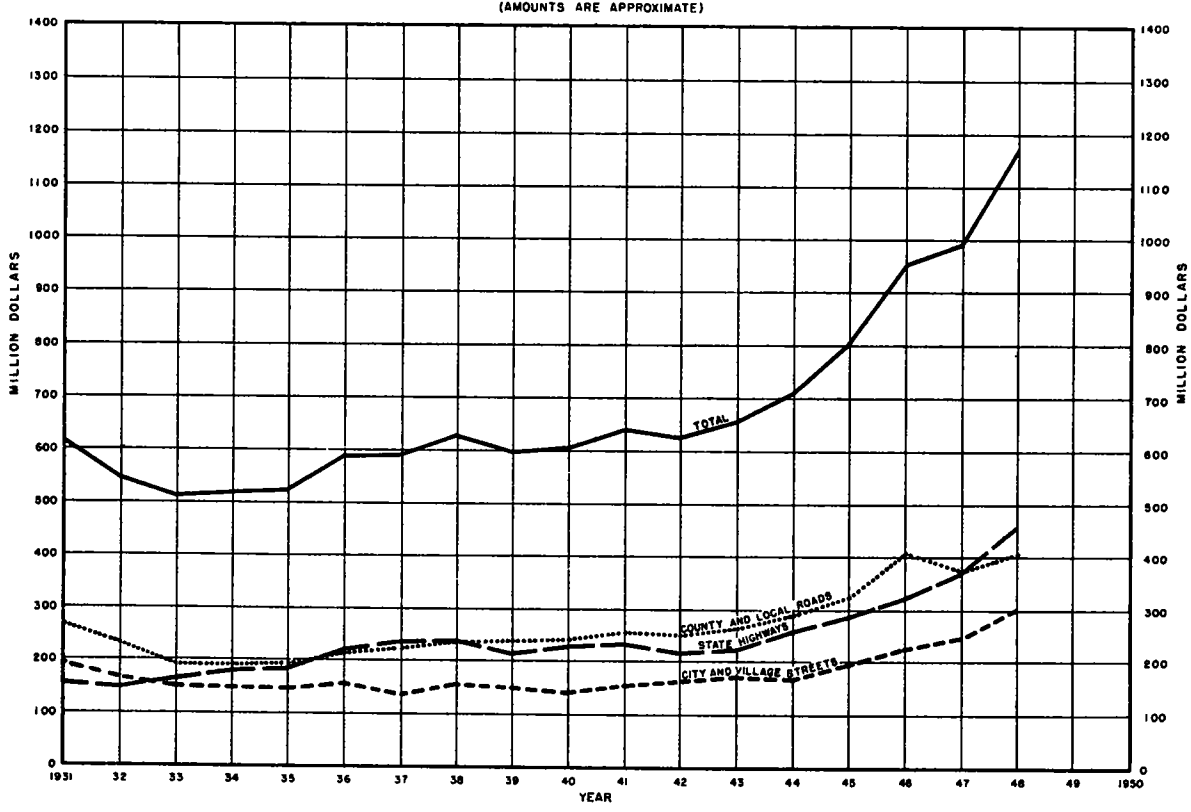
MAINTENANCE EXPENDITURES

The rise in unit costs is only one part of the total increase in the cost of maintaining our Nation's highway system. Graph 6 shows the expenditure for maintenance from 1931 to 1948. While the cost trend changed from a 1935 base of 100 to 189.31 in 1948, a cost rise of 89 percent, the country's highway maintenance bill rose from $521,000,000 in 1935 to a current $1,170,000,000, an increase of 125 percent. In more detail, the expenditure for State highway maintenance and operation rose from $183,000,000 in 1935 to $461,000,000 in 1948, an increase of 152 percent. The expenditure for county and local road maintenance and operation has risen from $192,000,000 in 1935 to $407,000,000 in 1948, an increase of

GRAPH 6

EXPENDITURES FOR MAINTENANCE ON ALL ROADS AND STREETS IN THE UNITED STATES

(AMOUNTS ARE APPROXIMATE)



112 percent. The cities and villages expended $146,000,000 on the maintenance and operation of their streets in 1935 and $302,000,000 in 1948, an increase of 107 percent. In analyzing these figures, consideration should be given to the fact that the States have, during this period, assumed the maintenance of many miles of main county and local roads and main city and village streets. In 1935, the States maintained 523,000 miles of roads and now maintain 585,000 miles.

Obviously, other factors besides the unit-cost increase have affected this rise. The increased use and heavier loads on the highways, more service demanded by the highway users, and the greater repair needs on the accumulated worn or obsolete pavements required more maintenance money. This increase in maintenance expenditures would have been even greater but for the offset resulting from improved productivity of maintenance forces through more efficient mechanization. There is even more room for improvement here as 47 percent of maintenance costs still go to labor.

The increase in traffic, both quantity and weight, has been very substantial, especially on the main highways. It has increased on all highways and streets from 252 billion vehicle miles in 1936 to 398 billion vehicle miles in 1948, and to an estimated 417 billion vehicle miles in 1949. Registration has increased from 26 million in 1935 to an estimated 43 million in 1949.

In 1936, the total maintenance expenditure on all roads and streets amounted to 2.3 mills per vehicle mile. The maintenance expenditure in 1948 had increased to 2.9 mills per vehicle mile, 26 percent as compared to the increase of 87 percent in the maintenance cost index during the same period. We do know that deficiencies have been accumulating on our highways over a period of years. These, in some cases, may be due to a lack of maintenance. If maintenance expenditures per vehicle mile had increased in accordance with the maintenance cost trends, the 1948 maintenance expenditure would have amounted to 4.3 mills per vehicle mile, and our total maintenance expenditure would have been almost 550 million dollars higher.

In addition to traffic volume, the weight of traffic has an effect on maintenance costs. In 1936, traffic studies showed that only 13 out of each 1,000 trucks traveling the main rural roads in the United States had axle loads of 18,000 lb or more. In 1948, the studies showed that 93 out of each 1,000 trucks on these roads had axle loads of 18,000 lb or more. This represents an increase of 615 percent in the heavily loaded vehicles.

In one State, for which detailed data is available, the average total weight of all types of loaded and empty trucks rose from 10,981 lb in 1936 to 17,749 lb in 1948 (See Table 3).

TABLE 3

AVERAGE TOTAL WEIGHT OF ALL TYPES OF LOADED AND EMPTY VEHICLES COMBINED

Year	Pounds
1936	10,981
1942	13,986
1943	14,346
1944	15,316
1945	15,082
1946	14,836
1947	16,673
1948	17,749

Out of 449 heavy vehicles checked in 1948 for violations in this State, 157, or 35 percent, violated State law limitations as to weight. Comparing the maximum overloads at the same weighing stations in 1947 and 1948 shows the following extensive increase in overloads in one year. It also spotlights one reason why maintenance costs are increasing.

Max Overload	1947 (lb)	1948 (lb)
single axle	11,000	15,000
tandem axles	13,600	22,800
any axle group	15,900	22,800

While the maintenance price index throughout the Nation rose 32 percent from 1945 to 1949, the expenditures for general maintenance in the State for which the weights were cited rose 73 percent, from $2,633,400 in 1945 to $4,547,000 in 1949.

The increased volume of traffic has caused the poorer sections of our highways to become a burden on our maintenance budgets. The higher traffic intensity, in combination with wide truck bodies, has caused more frequent use of the shoulder and increased the shoulder maintenance cost. Higher traffic intensities have also increased the need for more traffic services, signs, signals, guard rails, etc., and the more frequent renewal of center-line and other markings.

INCREASE IN SERVICE REQUIRED

Another cause for increased maintenance expenditures, one that affects the local land service roads as much if not more than the main roads, is the increased mechanization of agriculture, industry and mining. This mechanization has made the frequent and uninterrupted use of all our roads a necessity to our economy. Today's farmer needs frequent delivery of his supplies which move by truck. All-year-round access to the farm must be provided for milk transportation. Other products are shipped and supplies are received by motor truck. The demand for this all-year-round, uninterrupted access to our remote farms and ranches is becoming greater each year as mechanization becomes more and more prevalent. The trend is most evident in snow removal, and in demands to keep the low type surfaces from becoming impassable in wet weather.

EXTENT OF RURAL ROAD PROBLEM

Most discussions of maintenance costs emphasize higher type surfaces and the problems prevalent on that type of road. There are in this country 2,384,000 miles of rural roads under the control of counties or other local sub-divisions and 120,000 miles of local rural roads under State control. Of these, 1,374,000 miles are unsurfaced and 922,000 miles are stabilized, gravel or stone-surfaced. The remainder is bituminous surface treated or other paved surfaces. The maintenance cost per vehicle mile, as is to be expected, is the highest on the county and local rural roads. The 1936 expenditure amounted to 6.2 mills per vehicle mile and in 1948 had increased to 8.0 mills. The maintenance expenditure in 1948 for all classes of roads in the Nation was earlier mentioned as 2.9 mills per vehicle mile. The fact that these county and local rural roads take a relatively higher portion of the maintenance dollar, in respect to the traffic they serve, than the State highways or city streets, increases the importance of finding ways and means to more economically maintain this large part of our total road mileage.

SURFACE MAINTENANCE

Blading is, of course, one of the more important maintenance operations on soil-aggregate surfaces. The cost of this operation per mile is dependent to some extent on the width of the surface, but to a much greater degree on the frequency with which operations must be performed. The blading operations in six widely separated areas in six different States were studied. It included the operations of all highway departments in the area, State, county and township.

Table 4 has been prepared from the study. This table shows the frequency with which gravel or soil roads are bladed in these areas. The frequency of this operation varied from as few as 4 to as many as 160 times per yr, and from $1.67 to $7.25 per mile for a single round-trip blading operation.

The minimum annual cost per mile was $18.50, the max. was $340.08, and the average for all six areas was $93.90. The variation between the min and the average blading cost in the areas studied was $75.40 per mile of soil-

aggregate surfaces. There are over a million miles of soil-aggregate and earth surfaced roads which require blading each year. In some areas of the country it is necessary to use local surface materials that are not the most suitable, but there is also room for economy in the blading operations through a good understanding of the frequency with which a road should be bladed and in the selection of the most suitable types of mechanical units to perform the work. At present, light, medium and heavy motor graders, pull-type graders, trucks, underbody blades, and other machines are being used for the purpose.

There are differences of opinion as to the size of motor grader that is most economical for the work. Some engineers prefer the heavy motor graders even though they cost in the vicinity of $12,000 each. They claim that with high wages of operation money can be saved by doing a more thorough job in one blading cycle. Other engineers who have a large mileage of soil-aggregate

TABLE 4

COST OF BLADING SOIL-AGGREGATE SURFACES
IN VARIOUS AREAS THROUGHOUT THE UNITED STATES

Year 1948

Area	Annual Frequency	Cost per Operation per Mile	Annual Cost per Mile
1.			
County A - All Roads	26	$3.00	$78.00
County B - Main Roads	12	7.25	87.00
County B - Side Roads	4	7.25	29.00
State Highway	156	2.18	340.08
2.			
Main County Roads	50	2.85	142.50
Other County Roads	25	2.85	71.25
3.			
Main County Roads	35	2.60	91.00
Other County Roads	15	2.60	39.00
State Roads	35	5.25	183.75
4.			
County A - All Roads	20	1.80	36.00
County B - Main Roads	50	2.08	104.00
County B - Other Roads	10	2.08	20.80
5.			
State Roads	25	2.00	50.00
Main County Roads	20	2.40	48.00
Other County Roads	15	2.40	36.00
6.			
State Roads	160	2.00	320.00
State-Aid Roads	30	1.67	50.10
County-Aid Roads	17	2.30	39.10
Township Roads	5	3.70	18.50
AVERAGE	37	$2.54	$93.90

or earth surfaces to maintain prefer the light $3,000 to $4,000 motor grader, claiming that they can obtain a larger number of motor graders and that a reasonably satisfactory performance is obtained. A thorough study is needed of the operating costs of different sizes of motor graders tied in with the quality of work performed on the various types of soil-aggregate surfaces and under various traffic, drainage, and climatic conditions.

In studying the blading operations in the six areas previously mentioned, it was further disclosed that savings in maintenance costs on low-cost roads can also be made through better management. In one of the areas where surface blading operations were studied, two segments of gravel road on one maintenance patrol section were separated by 18 miles of paved road. Seventy-two hr of productive blading time were lost per month by dead-heading the grader over the paved section between the two gravel surfaces. A cooperative agreement for blading operations with the county that had equipment stationed near

TABLE 5

COST OF DITCH CLEANING
IN VARIOUS AREAS THROUGHOUT THE UNITED STATES

Year 1948

Area	Annual Frequency	Cost per Operation per Mile
1.		
County A - All Roads	1	$12.00
County B - Main Roads	2	15.00
County B - Other Roads	1	15.00
County A - State Roads	1	14.79
County B - State Roads	1	16.33
2.		
County Roads	1	20.00
State Roads	1	45.00
3.		
Main County Roads	3	8.57
Secondary County Roads	2	8.57
Other County Roads	1	8.57
State Roads		14.17
4.		
County A - All Roads	1	15.00
County B - Main Roads	2	12.00
County B - Other Roads	1	12.00
5.		
Main State Roads	2	15.00
Other State Roads	1	7.60
Main County Roads	2	15.00
Other County Roads	1	8.20
6.		
State Roads	1	22.00

one of the gravel sections would have eliminated the loss of production time over the paved surface.

reducing the necessity for constant ditch cleaning. Also, on narrow and shallow ditch sections each heavy rain

TABLE 6

COST OF MOWING ROADSIDES
IN VARIOUS AREAS THROUGHOUT THE UNITED STATES

Year 1948

Area	Annual Frequency	Cost per Operation per Mile
1.		
County A - State Roads	2	$44.84
County B - State Roads	2	49.26
2.		
Main County Roads	3	1.50
Other County Roads	2	1.50
State Roads	2	25.00
3.		
Main County Roads	3	2.81
Other County Roads	1	2.81
State Trunk Lines	4	5.25
Other State Roads	1	5.25
4.		
Main State Roads	4	3.10
Other State Roads	2	3.10
County Roads	2	3.00
5.		
State Roads	2	14.00
County Roads	1	11.00
6.		
State Roads	1	1.60

COST CAN BE LOWERED THROUGH DESIGN AND MAINTENANCE CORRELATION

A closer correlation between maintenance and design can not only cut surface maintenance costs through surface stabilization, but can also effect economies in ditch cleaning, mowing and snow removal operations.

Ditch Cleaning - The nature of the use of the area surrounding a highway is a factor in the frequency of ditch maintenance. Good erosion control on adjacent land will assist materially in

will fill some portions of the drainage ditches and erode others so severely that the road surface may be undermined. Where the design provides for wider and deeper flat ditches, a small deposit of soil does not cause too much damage, and erosion is neither so likely to occur nor to cause damage to the surface if it does occur. On this type of construction, ditch cleaning is infrequent. The rising cost of ditch cleaning or pulling makes it more necessary to balance at the design stage the annual cost of ditch maintenance against the initial cost of wider and deeper ditches, so that the greatest

economy can be obtained.

Table 5 lists the annual frequency and the cost per operation per mile of ditch cleaning. The frequency varied from one to three per yr, and the cost of a single operation varied from $7.60 to $45.00 per mile depending on the amount of cleaning that was needed and the amount and type of mechanical operations utilized in the work. On some of the more modern designed ditches the area maintenance studies disclosed that no cleaning operations were required for several years.

Mowing of Roadside -Mowing operations also depend on the nature of ditch and roadside design that is turned over to maintenance. Table 6 discloses the cost of the operation per mile of highway and the frequency of the performance in a number of areas studied. The annual frequency of mowing operations varied from one to four, and the cost per operation per mile varied from $1.60 to $49.26.

The cost is, of course, dependent upon the type of roadside under maintenance. The area to be mowed is important, but no more important than the topography of the roadside section. With the newer type mowers, a wide cross section with reasonable slopes can be mowed at no greater cost than a much narrower section on which hand mowing is necessary. In one area studied, a single power mower could mow over three times as much area per hr on smooth streamlined sections as on the old rough sections. The older or poorly designed sections with steep slopes and rough contours require tiresome, slow and expensive hand mowing and clearing. Either the cost of mowing will be excessive or, as is much more likely, the performance of the mowing and clearing operations will be severely curtailed. This will result in debris clogged ditches and, in the Northern States, in excessive snow removal costs.

To some extent the practice of mowing of local roadsides by abutting property owners is still followed. In two northcentral areas studied the law requires that each abutting property owner mow the roadside within his property lines between specified dates in the fall. In one of these areas if the property owner fails to do this, the township may perform the work and charge him up to $15.00 per mile of roadside (one side of road). In other areas the maintenance authorities have seeded the roadsides to good hay crops. The nearby farmers are quite willing to mow and harvest this type of roadside.

Snow Removal - The correlation of road design with maintenance in northern snow country can be most effective. Area maintenance studies have developed some very useful data on snow removal costs. In one area the cost of snow removal on two similarly located sections was analyzed. One of these sections was constructed between 1924 and 1929 and now has a low grade line, depressed below the surrounding plains in most cases. The other section was built in 1947 to a modern grade line, and is elevated above the surrounding plains. The snow removal and control cost on the modern section during the calendar year 1948 was $19.53 per mile. On the older section the cost was $296.56 per mile. The annual saving in snow removal costs alone, due to this improved section, amounted to $277.03 per yr, or in 20 yr would amount to $5,540.60. This is more than the cost of grading the section in this area.

A further example of the saving in snow removal costs through improvement of construction standards was found on the county roads of another State. On one section of road, constructed to a modern cross section and profile, only nine separate snow plowing trips were necessary during the year. These nine trips with a Motor Patrol V Plow and Wing over the 12.7 mile section involved 27 hr of time and cost $129.33. The cost on this section was, therefore, $10.18 per season-mile or $1.13 per trip-mile. On another older and poorly graded section the snow removal costs amounted to $385.60 for the season and involved 25 trips that consumed 80-1/2 hr of operating time. Since this section was only 7.1 miles in length, the season-mile cost was $54.30

and the trip-mile cost $2.17. A mile of local road improvement in this section, therefore, saved $44.12 each yr in snow removal costs alone. In 20 yrs this saving would amount to $882.60.

Each item of lowered maintenance cost mentioned in this report, while small in itself, takes on a larger importance when the extensive mileage of soil-aggregate and earth surfaces in existence in this Nation is considered. It also illustrates the need for closer correlation of highway programs with the problems of the maintenance engineer in order to check the Nation's mounting highway maintenance expenditures.

COUNTY ROAD MAINTENANCE AND OPERATION COSTS

Roger H. Willard, County Road Engineer
Frederick County Roads Board

This paper deals with the maintenance and operation costs of the county road system of Frederick County, a typical County in the State of Maryland. Similar conditions exist throughout the State, except in portions of Southern Maryland and the Eastern Shore of Maryland.

Frederick County is made up of a farming area of fertile rolling land through which flows the Monocacy River, one of the larger tributaries of the Potomac River, it being possibly the tributary that empties more silt into the Potomac River than any other. The County is divided into two valleys by the Catoctin Mountain Range, which rises north and south across the County. The rolling hills create an erosion problem which greatly affects our maintenance costs.

The area of Frederick County is 668.7 sq miles, with an average of 1.95 miles of road per sq mile of area. This well-established network of roads totaling in all 1308 miles, exclusive of the 85 miles of streets maintained by the incorporated towns and cities, is made up of 298 miles of State road, 16 miles of Frederick City Water Shed roads and 994 miles of County roads. The maintenance and operation costs of the County roads are being dealt with in this paper.

This 994 mile system of county roads gives the rural farming area access to the markets in the various cities and towns of the County. These roads do not carry an abundance of traffic, the travel for the entire system averages less than 100 vehicles per road section per day. The traffic, however, is essential, being made up of milk and produce trucks, mail delivery, school busses, farmers' and farm laborers' cars and cars of industrial workers who live in the rural areas. The majority of the travel is essential to the farming industry which is the economic backbone of Frederick County.

The changeover to complete mechanization by the farmer and the overall use of the automobile and truck by all classes has occurred so rapidly that the need for all-weather roads has far surpassed the ability of the various counties to provide them. Schools have been rapidly consolidated, delivery trucks and milk trucks have threaded their way to the remote areas, with the result that every county in the State of Maryland and possibly throughout the Nation, has had thrust upon it the gigantic task of constructing and maintaining a county road system to cope with the mechanized travel. During the past few decades many counties, and Frederick is no exception, have dumped stone, gravel or any available granular material haphazardly on the roads, without thought of grading or correct drainage, in a desperate effort to keep the rural travel moving throughout the year. Many of these rough stone roads were surfaced with macadam by County officials who did not have the benefit of engineering advice, or failed to hear the pleas of the engineer to properly grade and drain the road before placing the finished macadam surfacing. So we come to the topic of the day - the maintenance cost of this typical County road system.

A county must decide first to what extent it should carry out its maintenance. Should the roads be maintained to the satisfaction of all, or should they be maintained adequately to meet the need of the travel on the various roads? We in Frederick County adhere to the latter. We recognize the fact that our road system is not completely maintained since we meet only the basic needs. Much must be left undone even though the traveling public is inconvenienced to a certain degree.

We in Frederick County maintain our road system as economically as possible

and yet try to give the traveling public adequate service. Improved roads and bridges are not allowed to deteriorate even though a limited budget is allowed for maintenance. The Frederick County road system has been under qualified

994 miles is classified into 274 miles of macadam road, 370 miles of stone-surfaced road and 350 miles of unimproved or dirt road. Of the macadam roads approximately 100 miles are obsolete, having been built without

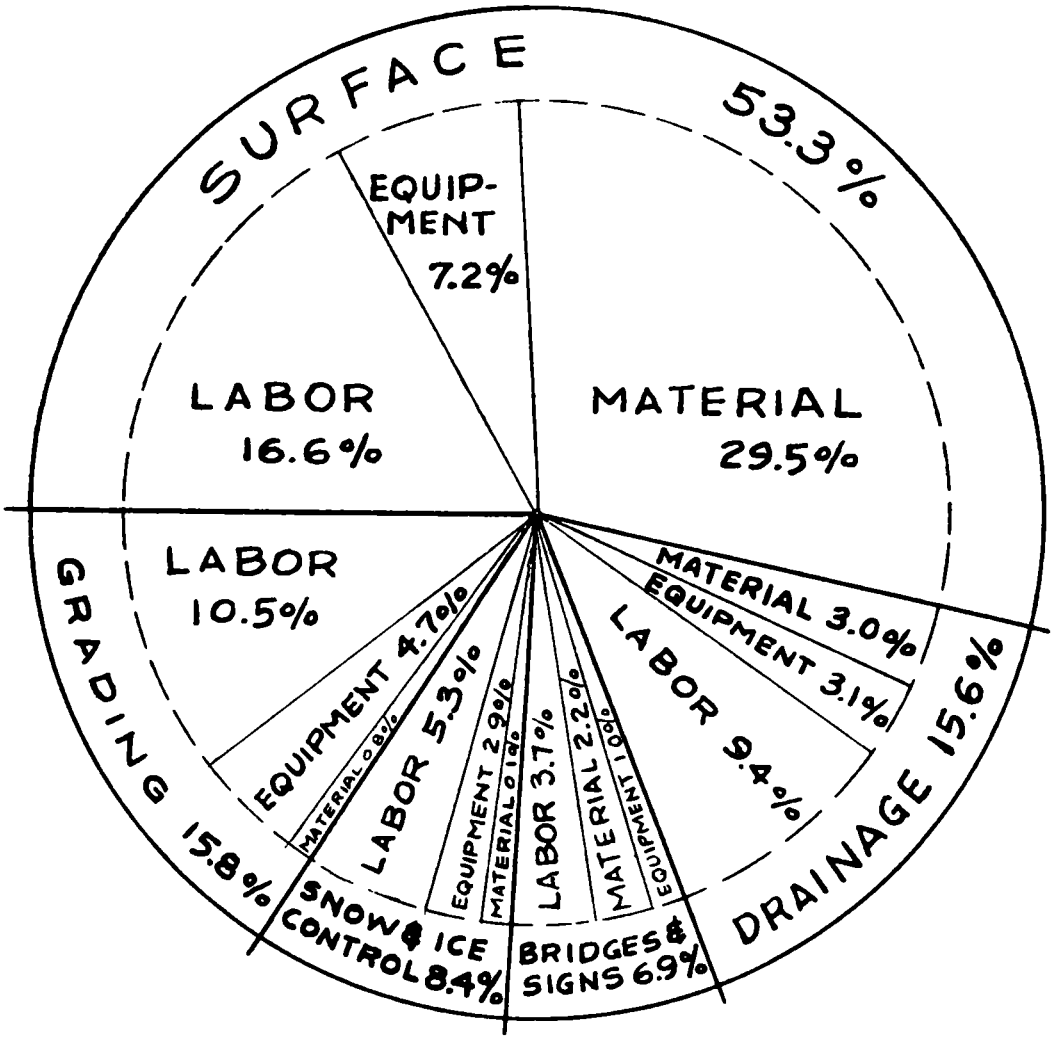


Chart 1. The Maintenance Dollar - Maintenance and Operation Costs of Frederick County, Maryland, County Road System, 1949

engineering supervision for the past ten years with the result that present road construction and maintenance has been in keeping with good engineering principles.

Frederick County's road system of

engineering, and of the stone roads only approximately 65 miles have been properly graded and drained before the stone surface was applied. On the dirt or unimproved roads a sprinkling of stone has been added at many places.

Frederick County is fortunate in having two commercial limestone quarries well located within the County. Some gravel in small quantities is obtained from deposits along the tributaries of the Monocacy and Potomac Rivers. The soil of the County is diversified - a large portion is clay studded with limestone and flint - a section is of red shale formation and the remainder is of a brown shale and chestnut soil, with shale and sandstone rock formations. The soil throughout the County contains many boulders and small stones, which creates a maintenance problem in maintaining the unimproved roads. The loose stones can be gathered together and used as a base on some roads where the soil conditions are bad. This was done to a great extent years ago when labor costs justified the hand knapping of these stones. At present portable crushers are used in the winter months to crush stone ridges and stone piles that have accumulated for generations in clearing the land. These crushers are located far remote from commercial stone plants, and they provide work for the maintenance men when the weather is not fit for regular maintenance work. This helps to keep our organization intact and gainfully employed. The crushed stones are stock piles for future use.

In the year 1948 a total of $151,979.18 was spent to maintain the 994 mile County road system, or an average cost of $152.90 per mile.

Maintenance costs are kept for the three types of roads, namely, dirt, stone and macadam. The cost on each of these various types of roads is broken down into surface repairs, drainage, grading, (that is, scraping and shaping the surface and shoulders) bridge repairs and snow removal. Chart 1 shows how the maintenance dollar is spent and proportioned over the various types of operations.

DRAINAGE OF ROADS

Let us first consider drainage on the stone and dirt roads. Equipment plays a very important role in keeping the maintenance costs at a low level. Table 1 indicates that a large part of the maintenance cost of each operation is equipment. The rising cost of labor as well as the shortage of labor during the war years made it necessary for the County to make use of labor-saving machinery of all kinds. Too much emphasis cannot be placed on the conveyor-type loader that removes debris and silt deposits from the road ditches and deposits it on trucks. It is still necessary, however, to use a blade machine to remove the silt from the ditches and windrow it along the shoulder. The maintenance of ditches and drainage pipes presents the major problem to our maintenance organization. Much stress must be placed on the importance of soil conservation measures as a direct factor in road maintenance. Where strip farming and contour plowing is practiced, along with sodded water ways, diversion ditches and permanent pasture on the steep slopes, a decided decrease is noted in the maintenance costs of roads. The silting of ditches and pipes not only creates a large maintenance cost item in drainage, but also results in a large cost item of surface maintenance to stone and dirt roads when the drainage facilities fail to function and washing of road surfaces results. Road engineers throughout the Nation should lend their support in urging the expansion of soil conservation practices.

The drainage facilities of the stone and dirt roads are periodically cleared in the early spring and again in the fall by use of motor patrol graders and a small group of men. In the spring the clearing of ditches and pipes is done in conjunction with the grading of the road surface. Where excess silt deposit and debris from bushes and trees is abundant it is necessary to remove the material by windrowing it on the road surface with motor patrol graders and loading it on trucks with a conveyor-type loader. Pipe inlets and outlets must be maintained by hand labor. In the fall the leaves from trees in the wooded areas cause an added drainage problem since they become deposited in the ditches and

culvert inlets and outlets. Mowing of the road shoulders and the cutting of bushes is considered a drainage item, and is done periodically.

TABLE 1

DRAINAGE

	Macadam Roads		Stone Roads		Dirt Roads	
Labor	$4,809.51	55.8%	$3,575.89	68.3%	$5,930.39	60.6%
Material	$ 966.62	11.3%	$ 853.36	16.3%	$2,773.99	28.3%
Equipment	$2,838.25	32.9%	$ 804.95	15.4%	$1,084.66	11.1%
TOTALS	$8,614.38	100.0%	$5,234.20	100.0%	$9,789.04	100.0%
Cost per Mile	$31.44		$14.95		$26.45	

The maintenance of drainage facilities of the macadam roads is a matter of periodic hand work when the need arises. Silt deposits from the adjoining fields following the heavy rains that are numerous during the summer months make it necessary to clear and remove silt from the drainage ditches frequently, using grading and loading equipment. The extent of this siltation depends upon the degree and type of cultivation in the adjacent fields. Table 1 shows the cost per mile for drainage on the various types of roads and the breakdown of the cost into percentages of labor, equipment and material used.

distributor with hand hose attachment, 5-ton three-wheel road rollers and the necessary stones and chips. The macadam roads are surface-treated every four to six years, depending upon the need. From 1/4 to 1/3 gal of cut-back asphalt or light emulsion per sq yd is used, covered with from 20 to 25 lb of limestone chips per sq yd. The cost of this treatment varies from .08 to .12 per sq yd, depending upon the distance necessary to haul the stone chips.

Stone and dirt road surface repairs constitute the adding of stone to fill the holes and replace that which is worn or washed away. The surfaces are bladed periodically and some rolling is done where the volume and type of travel warrant it. Some calcium chloride is used on the more important stone-stabilized roads, an application of 2 lb per sq yd is used. The type of traffic and the volume of traffic govern to a great extent the surface maintenance needs on the unimproved roads. Table 2 shows the cost per mile of surface maintenance on the various types of road and the percentage breakdown of costs.

TABLE 2

SURFACING

	Macadam Roads		Stone Roads		Dirt Roads	
Labor	$11,588.39	24.5%	$ 4,641.65	24.3%	$ 8,938.51	61.8%
Material	$29,933.24	63.3%	$12,549.57	65.6%	$ 2,387.95	16.5%
Equipment	$ 5,791.72	12.2%	$ 1,937.10	10.1%	$ 3,141.58	21.7%
TOTALS	$47,313.35	100.0%	$19,128.32	100.0%	$14,468.04	100.0%
Cost per Mile	$172.67		$54.65		$39.10	

SURFACE REPAIRS

Road surface repair is the largest of all the maintenance operations. This covers the spring and fall patching of the macadam roads, which is done by using a cut-back asphalt from an 800-gal tank

GRADING COSTS

Grading or the shaping of road surfaces and shoulders is done largely with motor patrol graders accompanied by trucks and men to remove the loose stones that roll to the surface. The unimproved or dirt roads become rutted, especially in the spring and fall seasons when freezing and thawing occurs. The grading operation levels and closes the ruts and reshapes the roads. Stone roads likewise may be affected by frost action and need periodic reshaping.

The edges and shoulders on the macadam roads are bladed when needed. Table 3 shows the cost of grading per mile for the various types of roads and the percentage breakdown of cost.

TABLE 3

GRADING

	Macadam Roads		Stone Roads		Dirt Roads	
Labor	$1,024.98	74.5%	$6,753.38	68.9%	$ 8,140.87	62.8%
Material	$ 246.97	17.9%	$ 735.82	7.5%	$ 144.75	1.1%
Equipment	$ 104.62	7.6%	$2,306.45	23.6%	$4,675.75	36.1%
TOTALS	$1,376.57	100.0%	$9,795.65	100.0%	$12,961.37	100.0%
Cost per Mile	$5.02		$27.98		$35.03	

create a continuous maintenance operation of floor repair and replacement. Painting and repairing of walls is also a continuous maintenance operation. The growing tendency toward larger trucks and heavier loads being carried to and from the farms is being looked upon with much concern since most of the bridges are only of H-10 capacity. Even though the bridges are well posted as to their capacity, they too frequently are overloaded and will without doubt create a reconstruction problem in the future.

Snow removal is a variable maintenance operation in Frederick County. The amount of snowfall has been light in the past few years, yet it is necessary to be prepared for the heavy snows that we occasionally have. About 20,000 ft of snow fence is erected along the primary County roads. All trucks, motor patrols and tractors are equipped with snow plows for immediate use if needed.

Ice control costs usually exceed the actual snow removal costs. Table 4 shows the cost per mile as well as the breakdown percentages of the costs.

TABLE 4

MAINTENANCE COSTS FOR TOTAL OPERATION

	Macadam Roads		Stone Roads		Dirt Roads		Bridges		Snow	
Labor	$17,422.88	30.4%	$14,970.92	43.8%	$23,009.77	61.8%	$ 5,643.76	53.5%	$ 8,063.95	63.4%
Material	$31,146.83	54.3%	$14,173.75	41.4%	$ 5,306.69	14.2%	$ 3,410.59	32.3%	$ 141.91	1.1%
Equipment	$ 8,734.59	15.3%	$ 5,048.50	14.8%	$ 8,901.99	24.0%	$ 1,489.39	14.2%	$ 4,513.66	35.5%
TOTAL	$57,304.30	100.0%	$34,193.17	100.0%	$37,218.45	100.0%	$10,543.74	100.0%	$12,719.52	100.0%
Cost per Mile	$209.13		$97.69		$100.59		$10.60		$12.80	

BRIDGE MAINTENANCE AND SNOW AND ICE CONTROL

Although there are nearly 350 bridges on the County road system, varying from small steel-beam bridges to large truss bridges, the average cost of $10.60 is not excessive. Practically all of the bridges have plank decks which

In summarizing, it has been shown that the total maintenance cost of the County Road System is broken down into: 45.5 percent labor, 35.6 percent material and 18.9 percent equipment costs.

The total costs per mile including the average bridge and snow removal costs are - macadam, $232.54 - stone, $121.09 - dirt, $123.99.

The maintenance cost per mile of stone road and unimproved or dirt is about the same, while that of macadam is slightly less than double the costs of the unimproved road. So we recognize the fact that as we gradually construct more new roads and our road system becomes more highly developed our road maintenance costs will increase rapidly. As our maintenance costs increase our construction program will become smaller and smaller, since there will be less money left for construction work after the maintenance budget has been fulfilled. In order to meet the public demand for a county road system in keeping with present-day travel, there must be an increase in the funds made available for county road construction and maintenance, and this increase cannot justly be derived from local property tax.

NATIONAL RESEARCH COUNCIL

The National Academy of Sciences is a private organization of eminent American Scientists, chartered under a special act of Congress in 1863 to "investigate, examine, experiment, and report on any subject of science or art." The Academy maintains the National Research Council as its operating agency.

The Council, organized with the cooperation of the scientific and technical societies of America, enjoys the voluntary services of more than 2600 scientists making up over 400 standing committees, boards, and panels in all fields of the natural sciences; its membership includes representatives of business and industry. The Council provides advisory and administrative services for research, and attempts to stimulate and coordinate research effort.

DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH

The National Research Council operates through eight divisions covering fundamental and applied natural sciences, as well as matters of international relations in scientific research. The Division of Engineering and Industrial Research is concerned with the stimulation and correlation of research in a wide variety of fields in engineering and the applied sciences.

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HIGHWAY RESEARCH BOARD

The Highway Research Board is organized under the auspices of the Division of Engineering and Industrial Research of the National Research Council. Its purpose is to provide a national clearing house for highway research activities and information. The membership consists of 42 technical, educational, industrial, and governmental organizations of national scope. Associates of the Board are firms, corporations, and individuals who are interested in highway research and who desire to further its work.

The purposes of the Board are: "To encourage research and to provide a national clearing house and correlation service for research activities and information on highway administration and technology, by means of: (1) a forum for presentation and discussion of research papers and reports; (2) committees to suggest and plan research work and to correlate and evaluate results; (3) dissemination of useful information and (4) liaison and cooperative services."