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Highway Maintenance Studies

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Contents

Report of the Committee on Maintenance Costs

H. A. RADZIKOWSKI, Chairman

● UNIT maintenance costs still continue their upward trend but at a much slower pace than was evident during the years immediately following World War II. The average unit cost of maintenance during the year 1955 rose only 2.5 percent—one of the smallest annual increases experienced in the last decade. The increase during the past three years amounts to only 8.1 percent—an average increase of about 2.7 percent per year. The index now stands at 252.69, 153 percent above the base year 1935. This means that, because of increases in the cost of labor, material and equipment, it now costs $1,018 per mile to perform the same amount of maintenance that could have been performed in 1935 for $403 per mile. It also means that it now requires approximately $650 million to maintain the state highway systems that could have been maintained in 1935 for $257 million. This rise in the unit maintenance cost is not, of course, the only factor that has affected maintenance expenditures. Today's roads are wider, there are more miles of highway, the traffic volume has increased, and the highway user demands more services. These factors have increased the required maintenance effort.

The greatest increase during the past year was in the cost of equipment services which rose 5.4 percent. Labor and overhead increased less than 2 percent and materials costs decreased slightly. The detailed figures on the trend in unit costs since 1935 are shown in Table 1 and are pictorially presented in Figures 1 through 5.

The rise in the maintenance cost index during the past 20 years emphasizes the growing necessity for maintenance engineers to appraise in every way possible the economy of their operations and to eliminate through reconstruction those highway sections that require unusually large maintenance expenditures. It points up the fact it is becoming more and more essential that everything possible be done to conserve the maintenance dollar. An example of what can be done in improving the economy of maintenance operations and in conserving the maintenance dollar was brought out in a recent speech by E.A. Landry, Maintenance Engineer of Louisiana, at the meeting of the A.A.S.H.O. Committee on Maintenance in New Orleans, Louisiana. In the paper, the necessity for establishing a yardstick that can be used to allocate maintenance funds between maintenance districts and between the individual sections of highway within a district was discussed. Several years ago, the allocation of maintenance funds in Louisiana was accomplished on a straight per mile basis. This method of allocation did not take into account the varying maintenance effort required on different sections of highways and did not highlight the economy of maintenance operations in the various districts.

Since then a formula for the allocation of funds on portland cement highways has been devised. This formula takes into account such factors as the age of the pavement, the width of the pavement, the traffic on the section, the soil conditions, and the width of right-of-way. The fund allocation formula was presented to the maintenance engineers of the nation in the hope that they would comment upon it and would suggest a procedure that could be used in varying the formula so that it could be used not only on concrete surfaced highways but also on highways surfaced with other types of materials and so that it could be used in other areas of the country as well as in Louisiana.

The fund allocation formula is based upon the theory that the maintenance of two sections of highway maintained to the same standard of adequacy and meeting the following conditions should cost the same amount of money: (1) same surface type, (2) same cross-section, (3) same width, (4) similar subgrade, (5) same traffic volume, (6) same age, and (7) same right-of-way width. From this was developed the basic mile of highway which met the following conditions: (1) concrete surface, (2) one to four years old, (3) not over 20 ft wide, (4) traffic volume, not over 1,000 vehicles per day, (5) subgrade soil, good, and (6) right-of-way, not over 80 ft wide. It was found that the maintenance of this basic mile would cost about $250 where local material was available and about $300 where material had to be imported. Factors based on the actual age, width, traffic volume, soil conditions, and right-of-way width were then established. These were used to estimate the increase in maintenance cost necessitated by the variance in actual conditions from the "basic mile." The factors are shown in the table on the next page.

Age (years)

1-4	5-6	7-8	9-10	11-12	13-14	15-16	17-20	Over 20
0	0.10	0.20	0.30	0.50	0.75	1.00	1.50	2.00

Surface Width (feet)

20	24	30	40	50	60	80
0	0.20	0.50	1.00	1.30	1.60	2.00

Traffic Volume (v. p. d.)

1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	15,000	20,000
0	0.20	0.30	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.00	3.00

Soil Condition (adjective)

Good	Medium	Poor
0	0.75	2.00

Right-of-Way Width (feet)

80	100	120	150	200	300
0	0.25	0.50	1.00	1.50	2.00

The factors as determined by the conditions existing on the section are added to the basic unit of 1.0 and an over-all factor is obtained. The cost of maintaining the so-called "basic mile" is then multiplied by the over-all factor and the cost per mile of maintenance used in the allocation of funds to each section is obtained.

This formula as it applied to concrete roads was checked against the actual expenditures on the concrete surfaced sections. It was found that the actual expenditures were about $750,000 or about 25 percent higher than the amount that would have been allocated by the formula. Close checking district by district, county by county, and section by section isolated the excess maintenance cost sections. Approximately $500,000 of the excess funds were being spent on two main highways. The surfacing on these highways had deteriorated to such an extent that their maintenance costs were far out of line. The maintenance expenditure on certain sections of these highways was as high as $9,000 per mile. With this information at hand it was not too difficult to prove that immediate reconstruction was essential. After the reconstruction of these two routes, the maintenance expenditures dropped to $3,400,000, over $400,000 less than the average for the previous three years.

The experience in Louisiana points to the need of knowing the exact highway maintenance workload both in total and by control sections. The maintenance workload should not only include a full inventory of the physical highway plant in suitable quantitative units with appropriate modifying factors but also the extent to which the volume and character of the traffic carried will generate maintenance effort. With such over-all data it is possible to develop an annual maintenance "performance budget" in which sufficient work quantities are included to provide for the adequate upkeep and operation of the highway facility. Specific information for each control section will permit the sub-allotment of funds to the highway departments' work subdivisions (division or district) in an amount consistent with their maintenance job load.

When highway maintenance funds are sub-allotted to field divisions solely on the basis of pavement types and mileage,

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
1948	216.63	160.58	176.37	170.62	189.31
1949	223 13	156.04	188.02	176.40	194.95
1950	240.69	157.20	185.03	184.15	202.28
1951	263.83	170.98	206.46	200.77	222.41
1952	282.53	172.92	214.55	209.90	233.72
1953	287.21	174.08	220.65	212.10	237.88
1954	303.20	176.08	225.92	214 31	246.64
1955	309.02	174.62	238.22	218.48	252.69

Figure 1. Cost trends - highway maintenance and operation - labor cost.

the adverse effect is twofold:

1. The performance of excessive maintenance on highways with below average maintenance requirements results in unnecessary expenditures.
2. Lack of full maintenance on highways with above average requirements results in premature deterioration and poor service to the public.

This committee for the past several years has been working on the fundamental and basic data needed to produce such a formula. It was found from a study of the cost of maintaining 11,300 miles of highway over a period of six years, 1942 through 1947, that the maintenance of either gravel or bituminous surface treated gravel surfaces averaged about $150 per mile at a traffic intensity of approximately 100 vehicles per day. That same study also showed that for traffic volumes above 100 vehicles per day, surface maintenance costs increased in a relatively uniform manner. The annual cost of maintaining gravel surfaces increased about 66 cents per daily vehicle. The annual cost of maintaining bituminous surface treated sections increased about 25 cents per daily vehicle. At today's price levels, these would amount to a basic cost of $263 per mile and an increase of $1.15 per daily vehicle for gravel and $0.44 per daily vehicle for the low type bituminous.

Another study of surface maintenance costs on approximately 560 miles of different surface types over a period of six years indicates that if the traffic, the surface thickness, the base thickness, and the subgrade characteristics are known and the effect of these factors is correctly evaluated, surface maintenance costs can be predicted with reasonable accuracy. From this study, it is possible to set a basic minimum cost for surface maintenance regardless of surface type and to then increase this cost for any particular section in accordance with deficiencies in the actual surface thickness, base and/or subbase thickness, subgrade characteristics, and increases in traffic volume.

Figure 2. Cost trends - highway maintenance and operation - material cost.

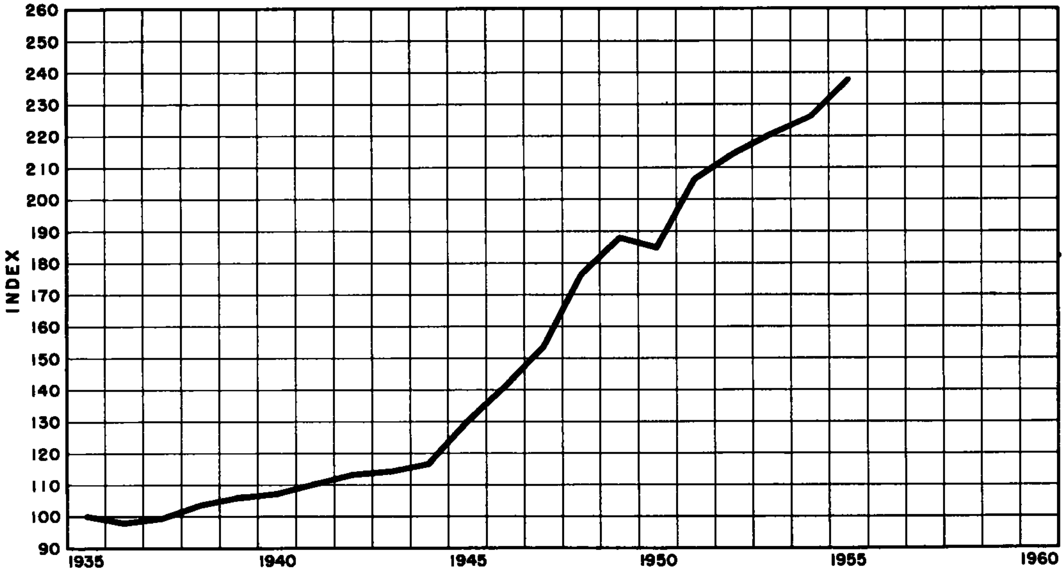


Figure 3. Cost trends - highway maintenance and operation - equipment cost.

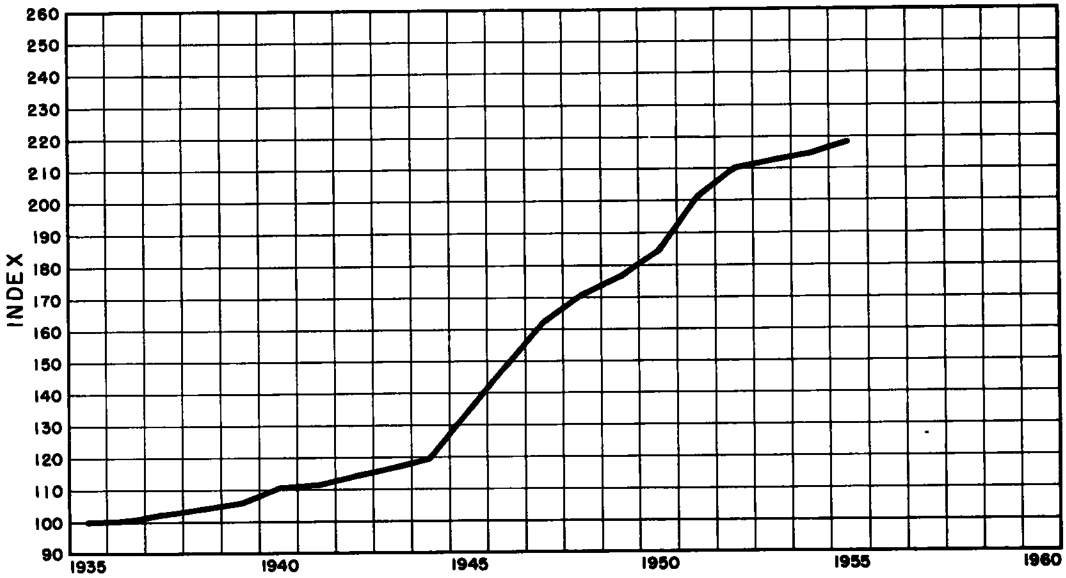


Figure 4. Cost trends - highway maintenance and operation - overhead cost.

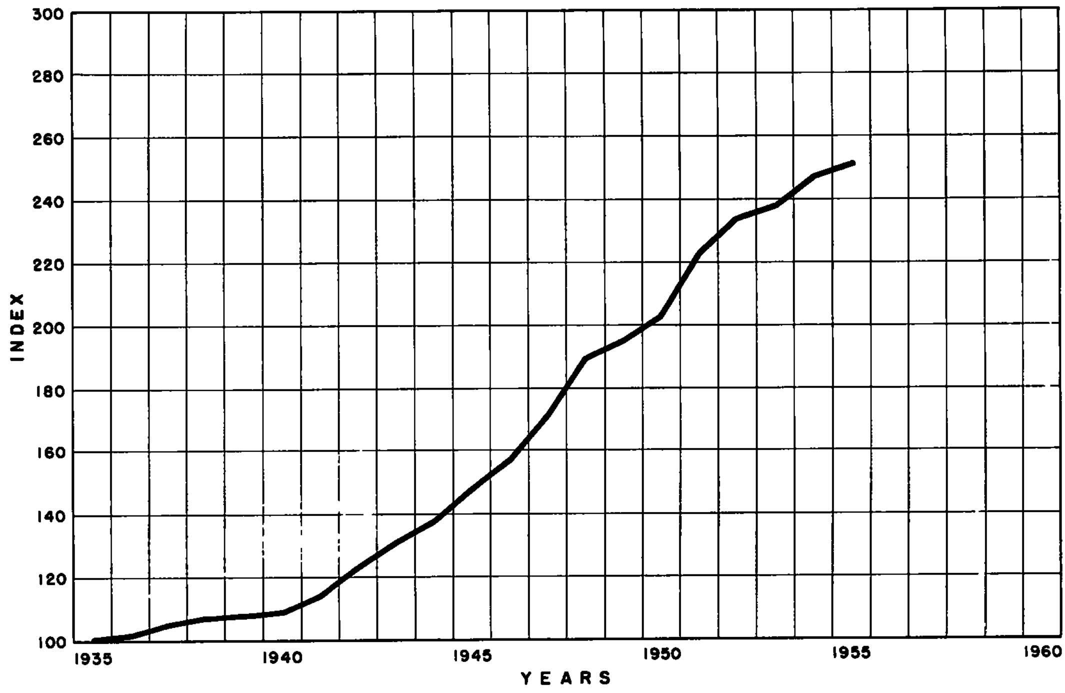


Figure 5. Cost trends - highway maintenance and operation - total maintenance and operating cost.

Another investigation has shown that the shoulder maintenance cost on two-lane rural highways decreases sharply as the width of surface increases. It was found that at average traffic volumes of 3,000 v.p.d. the annual cost of maintaining gravel shoulders adjacent to a 22-ft surface was $44 per mile less than the cost of maintaining the same type shoulders on roads with 20-ft surfaces.

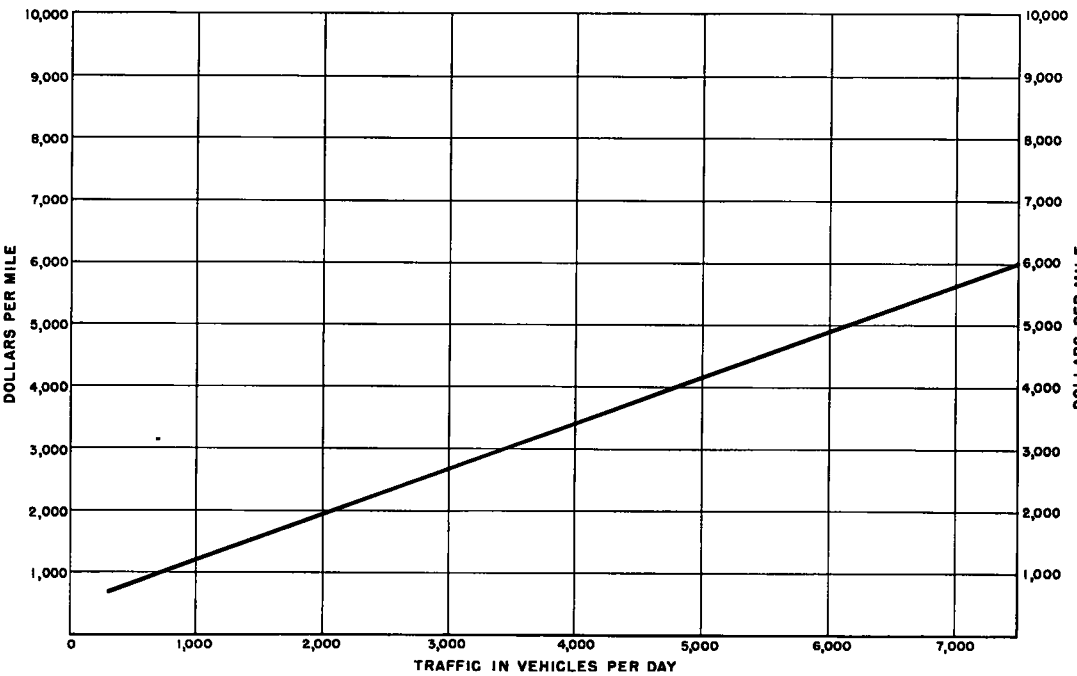


Figure 6. Average annual maintenance expenditures per mile on rural state highway systems versus average traffic in vehicles per day.

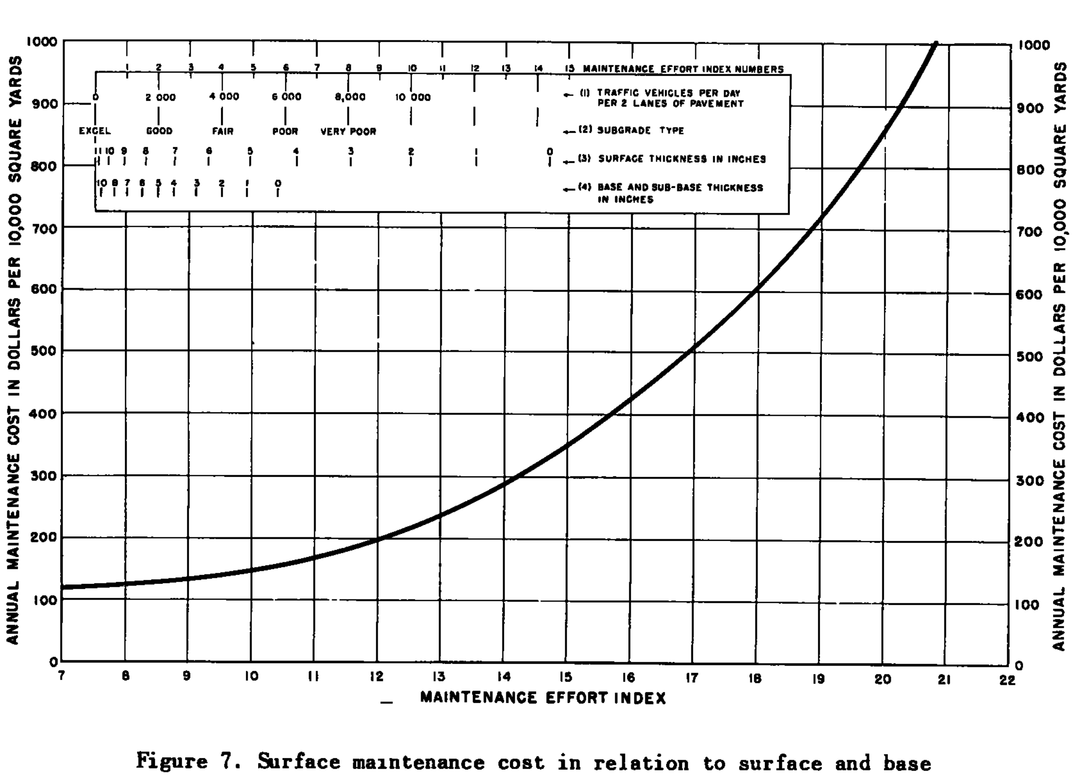


Figure 7. Surface maintenance cost in relation to surface and base thickness, subgrade type and traffic volume.

Records of the actual expenditures for maintenance of rural highways under state control show that the average cost of maintenance in the various states varies from approximately $400 per mile to approximately $8,000 per mile. The average cost, at a traffic volume of 500 vehicles per day, is $840 per mile. The average cost, at a traffic volume of 6,000 vehicles per day, is $4,900 per mile. The annual cost of maintaining the average rural state highway averages about 90 cents per daily vehicle and varies from $1.60 per daily vehicle at low traffic intensities to $0.82 at high traffic intensities. In general, the maintenance costs are less in the southern states where frost action is not a problem and snow removal is not necessary. Figure 6 shows how the total annual maintenance expenditure per mile varies with changes in average traffic intensity.

Using the data obtained over the past years, regarding the variance in maintenance costs with traffic and other factors, two separate methods which will, within practical limits, predetermine the cost of surface maintenance on specific sections of highway have been devised. The first of these two methods uses the basic design factors to predetermine the average cost of maintenance over a period of years. It is, therefore, a very valuable tool in the evaluation of the economics of different designs and in estimating the long range maintenance costs on particular sections. Figure 7 contains the basic data used in estimating maintenance costs by this method.

Four basic factors are considered: (1) the traffic on the section measured in vehicles per day per two lanes of pavement, (2) the type of subgrade soil, (3) the thickness of the surface, and (4) the thickness of the base and/or subbase. These factors are shown in the upper left-hand corner of the graph together with the maintenance effort index numbers with which they can be associated. The maintenance effort index number represents the maintenance effort required under varying design factors. An index number is determined for each of the four factors in accordance with the design of the particular section. These are added together. The result becomes the surface maintenance effort index for the section. The intersect between this surface maintenance effort index (as shown at the bottom of the graph) and the plotted line on the graph determines the estimated annual surface maintenance cost per 10,000 sq yd (approximately one mile of 18-ft two-lane pavement) shown on the left of the graph. This method of predetermining surface maintenance costs should be modified to meet special conditions found in any particular area.

The following example illustrates the application of this method. A two-lane section of road has a traffic of 2,000 vehicles. The maintenance effort index associated with 2,000 vehicles is 2.0. The subgrade is considered fair. The maintenance effort index for a fair subgrade is 4.0. The thickness of the surface is 6 in. which indicates a maintenance effort index of 3.6. The total base and subbase thickness is 6 in. The maintenance effort index for a 6-in. base is 1.5. The addition of these four index numbers, 2.0, 4.0, 3.6, and 1.5 is 11.1. The intersect of the index number 11.1 as shown at the bottom of the graph with the curve shows that the average maintenance cost of this type surface is $160. Had the surface thickness been 2 in. rather than 6 in., the surface index would have been 10.0 rather than 3.6. The total maintenance effort index would therefore have been 17.5 which would make the estimated surface maintenance cost $560 per mile.

The second method of estimating surface maintenance costs is also based on four factors. The four factors used are: (1) the observed physical condition of the surface, (2) the surface width, (3) the traffic expressed in vehicles per day per two lanes of pavement, and (4) the surface type. This method involves the establishing of a basic cost for the maintenance of a particular surface type and then modifying that basic cost in accordance with the known conditions existent on the particular section. This method is similar to the method of rating highway sufficiency that is now in use by the Bureau of Public Roads and many of the states.

In applying this method the surface condition is numerically rated in accordance with the observed surface condition. These numerical ratings 1, 2, 3, 4, and 5 correspond to adjective ratings such as excellent, good, fair, poor, and very poor. The numerical condition rating is converted into a "condition factor" which varies from 1.0 for an excellent surface to 3.0 for a very poor surface in increments of 0.5.

The "surface width factor" is 1.0 for surface of 18-ft or less in width and is increased in accordance with the percentage increase in surface width.

Two determinations are necessary in regard to traffic. The first is the actual traffic on the section expressed in terms of vehicles per day per two lanes of pavement. The second is the "basic traffic" for a particular surface type expressed in the same manner. The "basic traffic" for a particular surface type is the maximum traffic at which minimum maintenance costs are obtained. In other words, decreases in traffic below the "basic traffic" volume will not reduce maintenance costs to any appreciable extent but increases in traffic above the "basic traffic" volume will increase maintenance costs at or about one-half the percentage increase in traffic volume. The "basic traffic factor" is 1.0 when the actual traffic is equal to or less than the "basic traffic" and increase above one at one-half the rate that the actual traffic increases above the "basic traffic." For example, if the "basic traffic" is 1,000 and the actual traffic is 2,000, the "traffic factor" is 1.5.

The "surface type factor" is 1.0 for high type surfaces and increases for other surface types in accordance with the percentage increase in cost of maintaining the type in question under near ideal conditions over the cost of maintaining high type surfaces under near ideal conditions. The surface type factor will vary in different areas in accordance with the cost of maintaining the surface types in use in those areas.

After obtaining the four factors, they are multiplied together and the result is "the composite surface factor." Multiplication is used in this instance instead of addition because it has been found that changes in any one of the "factors" has a corresponding effect on the magnitude of the effect of the other factors. Multiplication accomplishes this result.

The "composite surface factor" is then multiplied by the "basic maintenance cost." The result is the estimated cost per mile of maintaining the surface of the section being investigated. The cost per mile multiplied by the length of the section is the estimated cost of maintaining the section.

Table 2 illustrates the application of this method. The first two columns show the location and length of the section. The first section 1-1 is in poor condition (4) and therefore has a "surface condition factor" of 2.5. Since it is 18 ft wide, the "surface width factor" is 1.0. The "actual traffic" is 2,000 as compared to the "basic traffic" of 1,000. This makes the "traffic factor" 1.5. It is a high type pavement so the "surface type factor" is 1.0. The multiplication of these factors results in a "composite factor" of 3.75. This multiplied by the "basic cost per mile" gives an estimated surface

TABLE 2

SURFACE MAINTENANCE COST ESTIMATING FORM

Hwy Section		Condition		Surface Width		Traffic			Surface Type					
Control No. or Location	Lgth	Code[a]	(A) Factor	Width	(B) Factor	Actual	Basic	(C) Factor	Type	(D) Factor	Composite Factor (AxBxCxD)	Basic Cost	Cost per Mile	Cost per Section
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1-1	2.0	4	2.5	18	1 0	2,000	1,000	1.5	H. T.	1.0	3 75	$120	$ 450	$ 900
1-2	1.5	4	2.5	20	1 1	2,000	1,000	1.5	H T.	1.0	4 13	120	496	744
1-3	3.2	4	2.5	24	1 3	3,000	1,000	2.0	H T.	1.0	6 50	120	780	2,496
1-4	1.8	1	1.0	24	1.3	3,000	1,000	2.0	H. T	1.0	2.60	120	312	562
2-1	3.3	1	1 0	18	1 0	2,000	1,000	1.5	H. T.	1.0	1.50	120	180	594
2-2	1.1	2	1 5	18	1 0	2,000	1,000	1.5	H T	1.0	2.25	120	270	297
2-3	2.5	1	1.0	18	1 0	1,200	600	1.5	I. T.	1.5	2.25	120	270	675
3-1	1 8	3	2.0	24	1 3	1,800	600	2 0	I. T	1 5	7 80	120	936	1,685
3-2	5.4	4	2.5	18	1 0	1,200	600	1.5	I. T.	1.5	5 63	120	676	3,650
3-3	3 7	1	1 0	18	1 0	600	600	1.0	I T.	1.5	1.50	120	180	666
4-1	6.8	1	1.0	18	1.0	400	100	2.5	Gravel	2.0	5 00	120	600	4,080
4-2	5.3	4	2.5	18	1.0	400	100	2.5	Gravel	2.0	12.50	120	1,500	7,950
4-3	4 1	5	3.0	18	1.0	400	100	2.5	Gravel	2.0	15 00	120	1,800	7,380
4-4	3.5	1	1.0	18	1.0	100	100	1 0	Gravel	2.0	2.00	120	240	840

Surface Condition Factor

[a]Code	Adjective	Factor
1	Excellent	1.0
2	Good	1.5
3	Fair	2 0
4	Poor	2.5
5	Very poor	3.0

Surface Width Factor

$$1 + \frac{\text{Actual width} - 18}{\text{Actual width}}$$

(but not less than one)

Traffic Factor

$$1 + \frac{\text{Actual traffic} - \text{basic traffic}}{2\ (\text{Basic traffic})}$$

(but not less than one)

Surface Type Factor

High type	1 0
Inter. type	1 5
Gravel	2 0

cost per mile of $450. Maintenance of the surface of the section which is 2.0 miles long should, therefore, cost $900.

It will be noted that the field work of establishing the surface maintenance cost estimating system is relatively simple. The engineer making the field investigation simply fills in the location (control section number), length, condition code, surface width, and surface type. The remaining operations can be readily performed in the office. After the system has been established, it is only necessary for the engineer making the field investigation to note changes that have occurred since the last investigation.

The other elements of maintenance: shoulders, roadside, drainage traffic services, and bridges, can be estimated in a similar manner. The work of establishing guides for the estimating of these costs under particular conditions is proceeding and it is expected that the results of that work can be presented at next year's meeting.

In summary then, the unit cost of maintenance is now 153 percent above the 1935 level. In other words, it now requires about $2.50 to perform the work that could be performed for $1.00 in 1935. The size of this rise makes it imperative that the maintenance engineers do everything possible to reduce the maintenance effort and to increase the economy of maintenance activities. A very important part of this effort is the establishment of a good maintenance budget. A good maintenance budget will provide the highway administrator with a tool with which he can correctly allocate funds in accordance with need, with which he can isolate those highway sections that are draining away his maintenance funds, and with which he can determine the economy of his own organization. A start in the establishment of such a system has been made and is presented herein for discussion by the nation's highway maintenance engineers. It is intended that, during the coming year, the Committee on Maintenance Costs will be able to further amplify this work and to present for the use of the maintenance engineers, in the near future, a complete method of estimating maintenance costs and allocating maintenance funds.

Maintenance Study of County Roads in Minnesota

E. S. WARD, County Highway Engineer, Kandiyohi County, Willmar, Minnesota

●MINNESOTA counties have a uniform accounting system which has been in operation for about ten years. It was established primarily as a fiscal accounting procedure so that the public might know that our expenditures were legal and proper. Probably not enough consideration was given to cost accounting. Now, after a few years' experience with our uniform system, our expenditures are accounted for, and our books balance, but our cost accounting on maintenance expenditures has not fared that well.

At various times, since the establishment of this accounting system, engineers in their district meetings have attempted to compare maintenance costs. In each instance, large variations in the cost for similar work was encountered which did not appear reasonable.

During the needs appraisal completed in 1954, the maintenance expenditures as shown in the engineers' Annual Reports for 1953 were tabulated for each item of maintenance operation. This tabulation was also studied by grouping the counties and their costs into the eight construction districts which generally reflect like conditions. These tabulations again showed a lack of uniformity on similar maintenance operations between counties. The county engineers recognized that the existing variations were greater than the difference in the maintenance service provided and could result from: (1) failure to make similar accounting charges of the different maintenance functions in each county, (2) maintenance practices in the various counties not being related to a uniform standard of maintenance, and (3) differences in the economy, topography, climate, soils conditions and traffic volumes.

It was therefore agreed that a study should be made to determine what constitutes a reasonable standard of maintenance under various road and traffic conditions.

Organization of the Study

During the December 1954 Annual Institute of County Engineers, the maintenance problem of the counties was discussed by the entire membership. As a result of this discussion and interest, the Executive Committee of the County Highway Engineers Association appointed a committee to make a study of county maintenance problems. It was the duty of the committee to determine the existing deficiencies in the present accounting system, suggest methods to correct both reporting and accounting procedure, and to explore methods of establishing standards for maintenance operations.

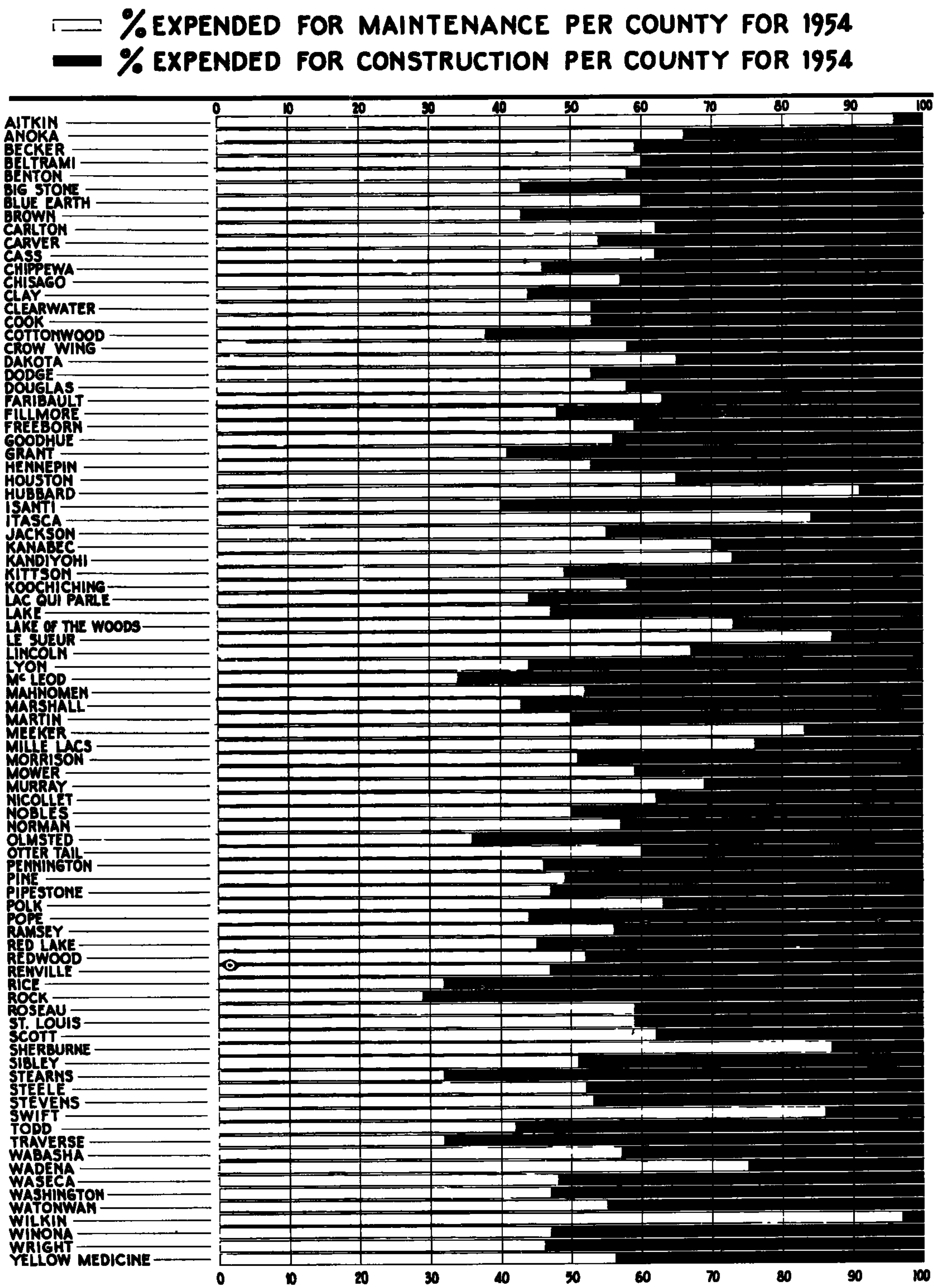
This committee arranged for meetings with about half of the county engineers in district groups. In these meetings we explored the variations in accounting by asking individual engineers how each item of routine maintenance was actually charged and recorded in their records. It was found that many different interpretations were being applied to the standard code, with the result that similar items were charged to entirely different accounts.

It was decided that although a good, uniform accounting system was in use in all the counties, individual interpretations of cost items were creating individual systems in many counties.

The following figures, compiled from the reported maintenance expenditures in Minnesota counties, show the present unrealistic variations in recorded maintenance charges.

Figure 1 shows the percentage of total budget expenditures for both maintenance and construction for each Minnesota county for the year 1954 and does not include any federal aid secondary funds. The open bars show the percentage spent for construction and the solid bars, the percentage charged as maintenance.

As Figure 1 indicates, one county reported 97 percent of its budget was spent for maintenance, and at the other extreme, one county reported only 28 percent for the same charge. There is little, if any, relation in the percentages reported to the wealth, traffic density, or general road conditions. This figure would lead one to believe that more variation exists because of accounting practices than because of operational differences.



FEDERAL FUNDS USED ON COUNTY PROJECTS ARE <u>NOT</u> INCLUDED
COUNTY MATCHING FUNDS <u>ARE</u> INCLUDED

Figure 1.

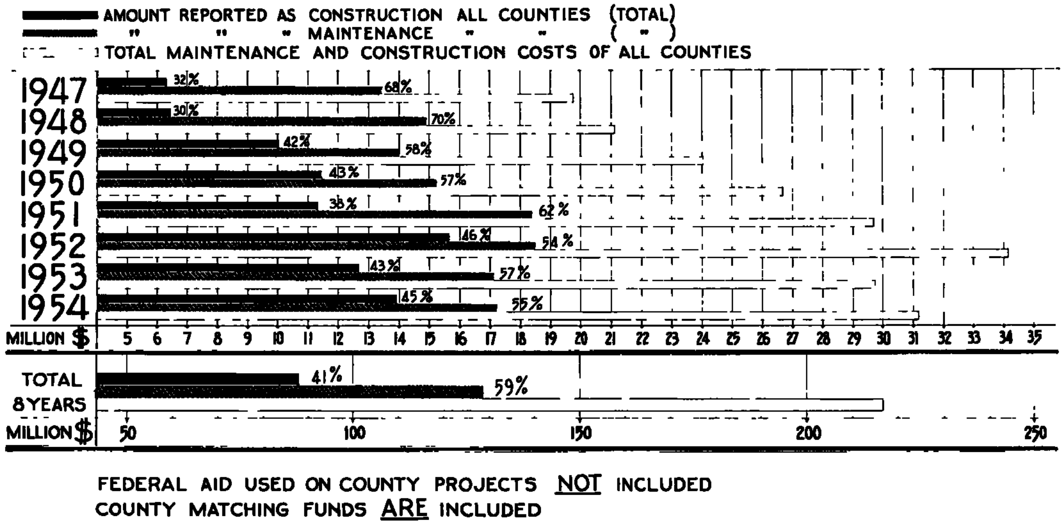


Figure 2. Yearly expenditures showing breakdown of maintenance and construction costs.

Figure 2 shows the reported yearly expenditures, except for federal aid secondary funds, of all the counties in Minnesota from 1947 to 1954. The total expenditures for each year are shown by the open bars and the percentage spent for construction by the solid bars, with the percentage for maintenance represented by the hatched bars. The lower group of bars show the total statewide expenditures for the eight year period by the same symbols.

These two figures indicate that maintenance operations consume the largest part of the available highway funds. During the eight year period, out of a total budget of $218 million, not including federal aid, 59 percent of this amount, or $129 million, was charged as maintenance, while 41 percent, or $89 million, was reported as construction. The 1954 reported cost of maintenance was 17. 2 million dollars, and if even a 5 percent savings could be accomplished through the adoption of uniform standards of operation, the saving would pay the salaries of the 87 county engineers and their accountants.

Figure 3 shows the reported costs per mile for the routine maintenance of state aid gravel surfaced roads in 38 counties. These reported costs vary from $104 to $402 per mile. There exists no pattern to justify this variation either by location, resources, or the amount of road users in the counties.

This figure does emphasize that variations do exist which cannot be explained or justified. If the reported expenditures are correct, it is apparent that some counties are spending too little for this function, or other counties are spending far too much.

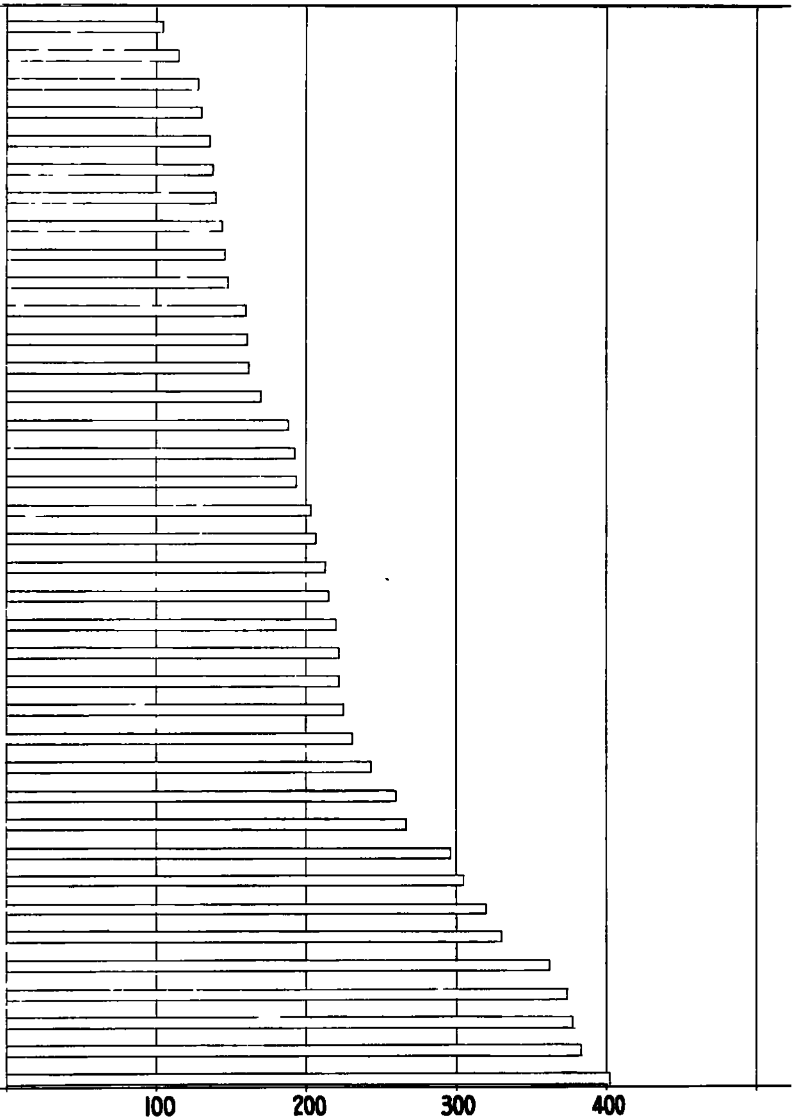
Figure 4 is an analysis of routine maintenance costs on state aid gravel roads within one construction district. These counties are very similar regarding soil, wealth, topography and traffic volumes. Three counties in this district do not report separate routine items and no comparison of individual items of routine maintenance is possible. Total routine costs vary in this group of counties from a low of $166 to a high of $351 per mile, showing an extreme variation of $185 per mile.

The variations between items of routine maintenance expenditures are such that they cannot be reconciled. The lower or hatched portion of the bars indicates the cost per mile of blading or smoothing gravel surfaces. The low cost for this item is $72 per mile and the high cost is $220 per mile. If the gravel roads on the state aid system in the county with the highest cost were bladed at the lower figure, a saving of $40,000 would result. These are adjoining counties in which this item should be comparable.

With these facts in mind, the committee felt that the study would have to cover both the cost accounting and the extent of maintenance service provided. An outline was prepared for both of these investigations.

The first section attempts a refinement of the present reporting and accounting procedure. After investigation, it was decided that the present accounting system was adequate and if properly used and charges were made uniformly, this system would give accurate results. It was acknowledged that the major deficiency in using the system was the lack of a uniform interpretation of maintenance charges between the counties. In order to provide uniformity between all counties, instructions were sent to all

COUNTY	COST PER MILE
HOUSTON	104
WADENA	115
HUBBARD	128
KOOCHICHING	130
STEVENS	136
MAHNOMEN	138
POPE	140
ISANTI	144
CASS	146
SWIFT	148
TRAVERSE	160
YELLOW MEDICINE	161
STEARNS	162
PIPESTONE	170
MARSHALL	189
DODGE	192
MARTIN	193
WILKIN	203
FILLMORE	207
LYON	213
DOUGLAS	215
COTTONWOOD	220
BENTON	222
COOK	222
MC LEOD	225
CHISAGO	231
POLK	243
TODD	260
LAC QUI PARLE	267
RICE	296
ITASCA	305
BLUE EARTH	320
FARIBAULT	330
CARVER	362
CARLTON	374
WINONA	377
NICOLLET	383
GOODHUE	402



AVERAGE COST (38 COUNTIES SHOWN) $ 222 PER MILE
MEDIAN COUNTY 207 TO 213

Figure 3. Variations in total routine costs of state aid (gravel surfaced) roads - 1953.

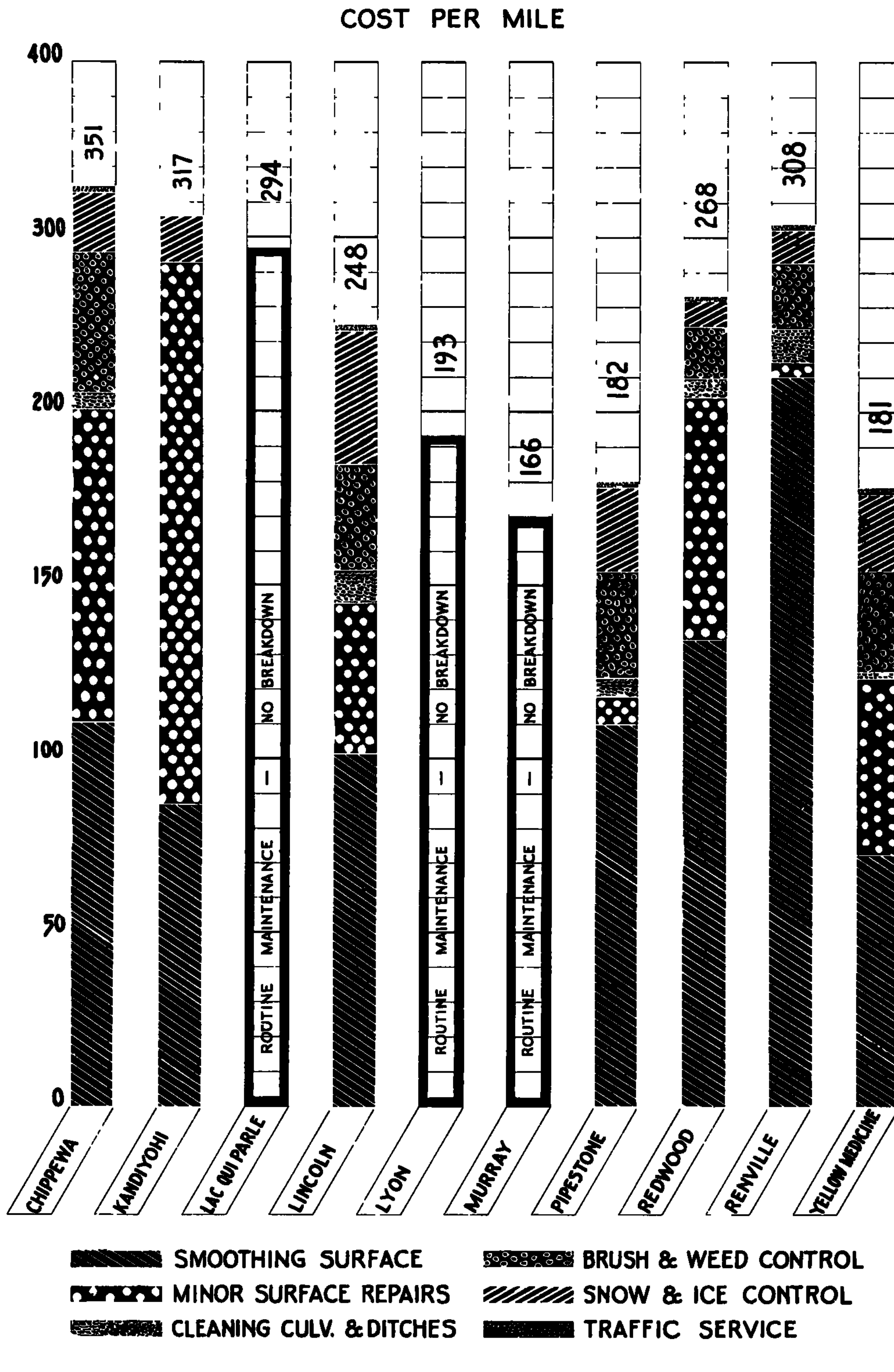


Figure 4. Analysis of routine maintenance on state aid roads within one district - 1954.

counties specifically describing the routine maintenance items and spelling out how charges should be made. As the study progresses, further instructions will be included, and eventually a complete accounting manual will be compiled. This manual is being written with the aid of the accountants so that the completed manual will be technically correct and readily understood by those who have the responsibility for this work.

The committee, aware of the importance of accurate reporting by operators in the field, has attempted to strengthen this part of the work by asking the engineers to take personal responsibility for all field reports, to carefully instruct the men and impress upon them the importance of their individual reports in the accounting procedure of the county.

The second section is designed to obtain the measurement of existing maintenance operations and permit the establishment of desirable standards of maintenance. Although it is known that some of the variations in maintenance costs between counties result from inaccurate accounting procedure, other variations are known to be the result of the extent of maintenance operations themselves. Different counties maintain roads to various standards, and no desirable standard exists that can be used as a guide. From the figures shown, it is apparent that if maintenance standards existed, more attention would be given to control these operations within reasonable limitations, and the variations would be less extreme between neighboring counties.

Test sections have been established in about half of the counties which will give an accurate measurement of present operations. Selection of the test sections was left to the local county engineer subject to the instructions set up by the committee. A test section data sheet is filed for each test section giving all the factual data required by the committee. Separate accounts are maintained by the county engineer for each test section, giving both labor and equipment time, in addition to the number of operations performed for each item of routine maintenance. Monthly reports for each test section will be sent to the central office where they will be tabulated for the committee, and from this data will be developed an initial set of standards for the major road types and traffic volumes. It may be necessary to develop standards by districts or areas to reflect the differences in cost due to topography, soils and economic considerations.

In 1957 these initial standards will be used on the test sections and operations or standards adjusted, where necessary, to provide adequate maintenance for each section. These standards can be used on other roads and by other county engineers as a measuring stick for their operations and expenditures.

Uniform reporting of maintenance charges by all Minnesota counties, and a standard by which to plan operations, should result in improved maintenance performance. Comparisons between counties will be realistic and possible. Better planning of operations by standards, will result in more uniform costs between counties and could result in a substantial reduction of maintenance expenditures.

ESTABLISHMENT OF TEST SECTIONS

How to Choose Your Test Section

You are asked to choose five test sections in your county. The following types of sections are suggested but will have to be adjusted to the conditions in your county. Each section should be at least five miles in length, except in incorporated areas, or for some other special reasons.

A. Bituminous surface in a rural area.
B. Bituminous surface in an incorporated area.
C. Gravel or rock surface with high A. D. T. above 100.
D. Gravel or rock surface with medium A. D. T. above 50.
E. Gravel or rock surface with low A. D. T. 0 to 50

You are to choose from your own roads, sections that will meet these requirements and to furnish, for each section, a complete data sheet. In choosing these sections, several other requirements should be kept in mind. For gravel surfaced road sections you will probably want the section under an operator who can understand the purpose of the study and will submit accurate reports. The section should also be studied from an operational standpoint and should be a section over which you can obtain control of operations.

One of the facts we would like to obtain on gravel surfaced roads is the annual replacement of gravel. With this in mind, your section might possibly be chosen as a newly constructed road on which, under construction, you now have an adequate gravel surface, or on which you have records of the amount of gravel replacement since it was constructed.

A road should not be chosen as a test section if you anticipate a change in the surface type within a year or two.

The test sections should reflect average conditions rather than exceptional conditions.

Long test sections are more desirable than short ones.

In each county it is desirable to have one test section which will reflect maintenance costs on low traffic volume roads, below 25 A. D. T. Actual traffic count may not be available for these sections, but the engineer can reasonably estimate traffic for sections of this type.

Special Sections. It is desirable to have test sections on which the use of chemicals to consolidate gravel or crushed rock surfaces are employed. If you have roads on which you now use or plan to use calcium chloride, salt or other chemicals, it would be beneficial to include these roads as test sections.

DIRECTIONS FOR COMPLETING TEST DATA

A. County Name. Location, show section on county map in color. Sections should be at least 5 miles in length. Except in incorporated areas. Give beginning and termination of section. Length of section in miles to the nearest tenth of a mile.

B. Classification.
Check existing system of section.
If section is in an incorporated town, give the population.
Check main use or uses of section.

C. Inventory.
1. Check terrain type.
2. Give year when road was graded.
3. Check design type of roadway—modern design type is streamlined section.
4. Give soil classification of roadway (subbase).
5. If roadway contains frost boil areas or unstable areas, indicate.
6. Give roadway grade width and surface width.
7. Surface type.
PCC - Portland Cement Concrete
PMB - Plant-Mixed Bituminous
RMB - Road-Mixed Bituminous
STB - Surface Treated Bituminous
GR - CR - Gravel - Crushed Rock Untreated
GRS - CRS - Gravel - Crushed Rock Stabilized with Soil
GRSC - CRSC - Gravel or Crushed Rock Stabilized with Calcium Chloride
GRSS - CRSS - Gravel or Crushed Rock Stabilized with Salt
Gravel or crushed rock surface depths—depths of present surface measured in inches obtained by digging sufficient holes in the section to determine the average depth. Gravel or rock depths will be considered as the distinct point between the gravel and soil of the road.
8. Base type.
SC - Soil Cement
GR - CR - Graded Gravel - Crushed Rock
SA - Sand
9. Seal type.
Light seal 0. 15 gallon or less of bituminous material per square yard.
Heavy seal more than 0. 15 gallon of bituminous material per square yard.
10. Surface age. Applies to concrete, bituminous and chemical treated gravel or crushed rock.
11. Surface condition. Seal condition. Indicate by good, fair, poor, existing con-

dition of both surface and seal condition for bituminous.
Surface condition only for concrete. Does not apply to gravel or crushed rock surfaces.

12. Give A. D. T. for 1955 and indicate if truck traffic is low, normal or high.
13. Give average summer traffic 1955 if section is classified as recreational.
14. For use on road sections below 25 A. D. T. check service functions.
15. Give spring load restrictions and indicate if restrictions are enforced.

MINNESOTA MAINTENANCE STUDY
Test Section Data Sheet

A. Identification

County ______________ Date ______________ No. __________

Location ____

Length ______________ miles

B. Classification

( ) State Aid
( ) County Aid
( ) F. A. S.
( ) Township
( ) Rural

( ) Urban type not incorporated
( ) Incorporated
( ) Agricultural use
( ) Recreational use
( ) Industrial use

__________ Population

C. Inventory

1. Terrain: ( ) Flat ( ) Rolling ( ) Hilly
2. Year graded __________ 3. Design type: ( ) Modern ( ) Old
4. Soil classification
5. Has frost boil areas ( ) Yes ( ) No
6. Grade width ________ ft. Surface width ________ ft.
7. Surface type __________ Thickness __________ in.
8. Base type __________ Thickness __________ in.
9. Seal type __________
10. Surface age __________ yr. Seal age __________ yr.
11. Surface condition __________ Seal condition __________
12. Traffic A. D. T. 1955 __________
    Truck traffic: ( ) Low ( ) Normal ( ) High
13. Traffic avg. summer 1955 __________
14. Service function: ( ) Mail Rte. ( ) S. Bus ( ) Milk Rte.
15. Spring load limits __________ Are they enforced? __________

THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare. The ACADEMY itself was established in 1863 under a congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the federal government in scientific matters. This provision accounts for the close ties that have always existed between the ACADEMY and the government, although the ACADEMY is not a governmental agency.

The NATIONAL RESEARCH COUNCIL was established by the ACADEMY in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the ACADEMY in service to the nation, to society, and to science at home and abroad. Members of the NATIONAL RESEARCH COUNCIL receive their appointments from the president of the ACADEMY. They include representatives nominated by the major scientific and technical societies, representatives of the federal government, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the research council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the ACADEMY and its RESEARCH COUNCIL thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the government, and to further the general interests of science.

The HIGHWAY RESEARCH BOARD was organized November 11, 1920, as an agency of the Division of Engineering and Industrial Research, one of the eight functional divisions of the NATIONAL RESEARCH COUNCIL. The BOARD is a cooperative organization of the highway technologists of America operating under the auspices of the ACADEMY–COUNCIL and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the BOARD are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.