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Bulletin 158

# *Highway Needs Studies 1957*

## A Symposium



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# ERRATA
# BULLETIN 157
# PHOTOGRAMMETRY AND AERIAL SURVEYS

1. On page 9, line 7, each appearance of the word "to" should read "and."

2. On page 10, Figure 11 is inverted.

3. On page 54, in the discussion by Fred B. Bales, the phrase "between the 16- and 8¼-in. focal lengths" should read "between the 6- and 8¼-in. focal lengths."

4. On page 55, line 11, the phrase "type of photography" should read "type of topography."

5. On page 59, in the remarks by William T. Pryor, third paragraph, line 12, the words "$4,000 for bridges" should read "$400,000 for bridges."

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# Contents

# Traffic Accident Records in Appraising Highway Needs

DAVID M. BALDWIN, J. STANNARD BAKER, J. AL HEAD, and
C. F. MC CORMACK, Staff Coordinator
Section on Uses of Accident Records, Sub-Committee on Highway Needs Studies, Committee on Highway Costs

● HIGHWAY adequacy can be measured by structural condition, the facility of vehicular movement, and accident experience. This paper discusses the use of accident experience as a measure of highway adequacy.

Over past years much has been written about the need for better accident reporting and the engineering use of accident data through maps, files, and other methods. These items are the key to successful use of accident records in appraising highway needs.

In using accident records to appraise highway conditions, the engineer needs two things which he seldom gets: complete or nearly complete reporting of accidents and accurate location descriptions. The two are related because unless the accidents can be located with reasonable accuracy the report is useless to the engineer.

The National Safety Council estimates that, in 1955, there were nearly 300 non-fatal accidents for each fatal accident in the nation. The three states with the highest normal reporting ratios achieve less than 200 to one. Only 30 percent of the states achieve a ratio of 100 or more to one. The actual range in statewide reporting ratios is from 186 to one in New York to 11 to one in Arkansas. On rural state highways, the true ratio probably exceeds 100 non-fatal accidents for each fatal accident. Washington has the highest reporting ratio on rural state highways, 75 to one. Other states are fairly evenly distributed from 60 down to 13 to 1.

Only seven states report more than 350 non-fatal accidents to each fatal accident in cities. The remaining states have city ratios distributed from 300 to one down to three to one.

A current study in Massachusetts, in which the Bureau of Public Roads, the State Department of Public Works and the Registry of Motor Vehicles are attempting to determine the true costs of motor vehicle accidents, bears out the fact that normal accident reporting is far from complete reporting. In 1954, the state reported to the National Safety Council that there were 141 non-fatal accidents reported for each fatal accident. Massachusetts is considered among the better reporting states, but the more detailed study showed that the ratio was actually 416 to one. In rural areas the ratio was 183 to one and in urban areas 510 to one.

The point of this analysis of ratios is not to show variances between states and cities, but to show the failure to achieve complete reporting. In presenting partial results of the Massachusetts study to the Southeastern Association of State Highway Officials in September, Robie Dunman commented, "Even in states with the very best accident-reporting records, unreported accidents run as high as 50 to 60 percent of the total." Even if the estimated 5,400,000 accidents resulting in less than $25 damage were eliminated as inconsequential, the ratio of non-fatal accidents to fatal accidents in 1955 is still nearly 140 to 1 nationwide, and only a few states come close to this figure.

Incomplete reporting makes it impossible to give proper weight to accident experience in identifying highway deficiencies and establishing priorities of improvement. This has tended to depreciate the use of accident records in making highway appraisals. Yet what the records do show is definite and is useful in identifying some hazardous locations; useful, that is, when the engineer can or will use them. It is true that in many cases accident records are not available for engineering use and, yet in other cases the evidence is that engineers attempt too feebly or not at all to use records which are available.

For appraisal purposes, the most useful of the methods in which accident records are kept is the large-scale spot map or strip map. There are many notable examples of each, and it is not necessary to describe them here. Machine tabulation of accidents by location is helpful if the sections covered are not too long and the termini agree with other data section breaks. The basic requirement is to be able to identify the location where each accident occurred and to accumulate a record over a sufficient period of time so that it has significance.

Accepted accident record procedures include the filing of accident reports or cross-reference cards by route and location so that they are readily available to the engineer in studying spot improvements or palliative treatments which may eliminate or reduce hazardous conditions; for these purposes, actual reports are indispensable.

In studying over-all highway needs, however, actual reports are not needed. In fact, not studying the reports eliminates the tendency to assign responsibilities. Most accidents involve more than one contributing factor or cause and evaluating primary, secondary and tertiary responsibilities is an involved process which cannot properly be done from most accident reports. Thus, it is better to assume that highway conditions have, at least, partial responsibility in all reported accidents and that improvements to those conditions would reduce the number of accidents.

Recent development of refined techniques in investigating and evaluating contributing factors in motor vehicle accidents, principally by J. Stannard Baker of Northwestern University Traffic Institute, shows that highway and traffic conditions share more in the causes of accidents than past routine tabulations of road defects have indicated. As scientific research continues and expands, the relationships between geometrics and moving traffic may be shown to influence almost all accidents.

What is significant accident experience? There are no standard rates of occurrence which can be applied to these procedures. Oregon is now developing expectancy rates which can be used to compare costs to benefits. Another study is contemplated which will attempt to relate accident occurrence to design features somewhat in the manner attempted by the Bureau of Public Roads and the National Safety Council in 1943, 1944, and 1945. Out of these studies and perhaps others, yardsticks may come which will identify the sections of roads having a disproportionate number of accidents.

In the meantime, there are left such devices as comparing actual experience with average vehicle-mile accident rates for different highway systems or assigning values according to the range in vehicle-mile rates from high to low. There are two disadvantages to dealing with vehicle-mile rates in these matters. They only allow comparison with averages or normals without regard for the fact that either may be too high to be tolerated, and they depreciate the value of the cumulative accident experience in determining urgency with which improvements are needed.

In determining urgency or priority of individual improvements, the accident-per-mile rate must also be considered and shows evidence of being the better yardstick. It recognizes directly the economic and social benefits to be obtained from early improvement of road sections which now experience large numbers of accidents regardless of whether or not the actual number of accidents produces a low vehicle-mile rate on high volume roads. Use of vehicle-mile rates on high volume roads may obscure a situation responsible for numerous accidents, and vehicle-mile rates may over emphasize the importance of a few accidents on low volume roads.

However, none of these uses is actually valid because of the general low level of accident reporting. Without some reliability in the basic data, engineers and administrators must always be skeptical of results indicated by accident records. Of course, the remedy is more complete reporting through stepped-up activities by the police and officials responsible for collecting reports. Continued use by engineers, recognizing the inaccuracies, would put new emphasis on the importance of good accident reporting. It does not stretch the imagination much to see the effect on local officials when they realize highway projects are programmed, in part, according to available accident experience.

There are more engineering uses of accident records than have been touched on here. These are the uses of the costs of accidents in studying the economics of highway transportation in general and in establishing economic warrants for individual improvements. Some scientific work is already underway in these areas. The Massachusetts study ratios has broken the cost-barrier, so to speak, and revealed a better direct cost of passenger car accidents than heretofore available. This study continues and soon will produce the direct cost of truck accidents and the indirect costs of all accidents. When more states follow Massachusetts' lead the actual cost of traffic accidents may be surprising. The importance of the accident history has been stressed in other work. Again the success of that work depends on the completeness of the accident record and its availability to the engineer. But its importance is such that it warrants more than a little effort on the part of the engineer to get it.

# Predicting Traffic Accidents from Roadway Elements of Rural Two-Lane Highways With Gravel Shoulders

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The investigation described in this report represents research by the Oregon State Highway Department to develop equations which can be used to predict accidents on rural 2-lane highways from roadway elements such as ADT, lane width, shoulder width, sight distance restrictions, commercial and residential driveways, and intersections.

A sample of nearly 1,400 miles of 2-lane highways was utilized. The data were analyzed through the use of multiple correlation techniques. The result of the analysis is a series of equations which can be used to predict total accidents on rural 2-lane highways in Oregon.

The more important conclusions which can be drawn from the findings of the study are as follows:

1. Motor vehicle accidents are directly related to vehicle volumes and certain physical features of the highway. This relationship is strong enough in the higher ADT ranges to make possible reasonably accurate predictions of total accidents on the basis of known physical features.

2. Access to the highway through driveways or intersections is directly related to accidents at all ADT levels. The number of access points is a reasonably good predictive index of the number of potential accidents within an ADT group.

3. Although the highway design elements such as lane width, shoulder width, and sight distance restriction are related to accidents, they do not ordinarily serve as good predictors of the number of accidents. Generally speaking, wider lanes, wider shoulders, and unimpaired sight distance result in a safer highway.

4. An analysis of the data presented in this report confirms the theory that accidents are essentially chance occurrences resulting from errors in judgment. The number of accidents increases with the number of situations presenting a change in conditions, and therefore requiring a decision on the part of the motor vehicle operator. These data confirm this theory in the following ways:

(a). Accidents on low volume roads do not appear to be related to any roadway feature.

(b). Accidents increase when: (1) vehicle volumes increase, (2) access points increase, (3) sight distance is impaired, (4) the cross-section is reduced.

● MODERN HIGHWAYS return to the road user certain monetary benefits from savings in time, travel distance, and operating costs. Many of these individual benefits can be measured or estimated before completion of a given project, and the total benefits derived. This is a common practice for major improvements, and the ratio of benefits to costs serves as a valuable tool for selecting one of two or more alternate routes between common termini.

An important benefit which cannot presently be measured is that which the road user realizes from a safer highway. It is recognized that a wide cross-section, good alignment, control of access to abutting lands, and elimination of intersections at grade result in a safer highway. However, no quantitative analysis has been made which will permit an estimate of the relative benefits accruing to the road user through a reduction in accidents, when an obsolete or congested facility is replaced with one of modern design. To arrive at an estimate of these benefits, it would be necessary to have at hand certain techniques which would permit a prediction of the number of accidents likely to occur both on the new and the old facility. This study was undertaken with the hope that such techniques could be developed.

It was recognized from the outset that the measurable elements such as the design features, ADT, points of access, and usage of abutting lands might not figure heavily enough in accident causation to permit accurate predictions unless other less tangible factors were known. Although accurate predicting equations might not result, it was felt that the study would provide a better understanding of the relationship between accidents and roadway design and usage.

This study is only a portion of the over-all effort. In this portion, the relationship between traffic accidents and roadway elements for rural 2-lane highways with gravel shoulders was investigated. Another study which will investigate the same relationships for urban and suburban highways is currently underway. Presuming that accidents can be predicted with reasonable accuracy for all of the various highway types, a separate study of accident costs will have to be conducted either independently or in cooperation with other agencies.

It was also recognized that the method must be kept simple to permit maximum usage. Throughout the study, a balance between reasonable accuracy and ease of operation was sought. It is entirely possible that more accuracy could be obtained by gathering data on the entering volumes at driveways and intersections, but it is doubtful if the additional time and effort would compensate for the gain in accuracy in the light of the uses to which the results will be put.

The study is based on a sample of 1,374 miles of 2-lane rural highway with gravel shoulders. The accident histories of these sections during the 3-year period from January 1, 1952 to December 31, 1954 were used together with ADT for the year 1953. The lane width, shoulder width, number of commercial driveways, number of residential driveways, number of intersections, and percent of the highway with less than 1,500-ft sight distance were recorded in the field.

These data were analyzed by statistical techniques to determine the relationship between accidents and the various roadway elements. Regression equations were developed and nomographs were drawn to facilitate solution of the individual equations.

Although the predictions obtained from the equations are not precisely accurate, they represent the best information available at this time. It is possible that the accuracy can be improved by further study of various elements, one of which is intersectional accidents. For this reason, predicting equations were developed for non-intersectional accidents, and the analysis of non-intersectional accidents is included in this report is some detail. If and when intersectional accidents can be predicted separately, the non-intersectional accidents can be predicted from the equations (Appendix B) and the two added together for total accidents. Until such time, the equations for total accidents are recommended for use. Their accuracy is such that predictions should only be attempted for periods of three or more years and sections four or more miles in length.

## DATA SOURCES

### Field Data

The field data were obtained on state primary highway routes chosen to include only rural 2-lane roadways with gravel shoulders. Any sections which had new construction beginning in 1952 or later were eliminated. Field observers recorded measurements of the following elements: (1) lane width (LA); (2) shoulder width (SH); and (3) sight distance restriction (SDR). The abbreviations shown were used to describe these elements in all tables and equations. The following is a list of abbreviations used for the other roadway elements.

(a) A - motor vehicle accidents
(b) ADT - average daily traffic
(c) CAP - capacity
(d) CDW - commercial driveways
(e) CONG - congestion
(f) INT - intersections
(g) RDW - residential driveways

TABLE 1

DISTRIBUTION OF 1-MILE SECTIONS BY ADT RANGES

| ADT Range | Section of Oregon | Number of 1-Mile Sections |
|---|---|---|
| 0 - 999 | All | 404 |
| 1,000 - 1,999 | All | 343 |
| 2,000 - 2,999 | Western | 190 |
| 3,000 - 3,999 | Western | 73 |
| 4,000 - 4,999 | Western | 57 |
| 5,000 - 5,999 | Western | 41 |
| 6,000 - 7,999 | Western | 42 |
| 2,000 - 2,999 | Eastern | 173 |
| 3,000 and over | Eastern | 51 |
| | | 1,374 |

A detailed description of the field procedure, along with a sample field sheet appears in Appendix A. No field data were recorded for those sections which were speed zoned or which were obviously non-rural in nature, as in the case where high congestion and an excessive number of commercial driveways existed. With the exception of these sections, the observers recorded the required field data for each consecutive 1-mile section. In this way, over 1,400 miles of highway were surveyed and constitute the broadest possible sample.

## Traffic Data

In the analysis described in the text, the roadway elements and accident relationships were considered within traffic volume groups, thus, the 1,374 usable 1-mile sections of highway were grouped in terms of ADT. The average daily traffic, ranging from 100 to 8,000 was taken from Traffic Volume Tables for 1953 published by the Oregon State Highway Department. The 1953 data corresponded to the mid-year of the 3-year accident data employed, and ADT was assigned to each 1-mile section. If more than 10 percent traffic volume change occurred within a given 1-mile section, the section was excluded from further consideration. The result of this procedure was a breakdown of the 1,374 1-mile sections into convenient ADT ranges. This breakdown of the total sample into ADT ranges is shown in Table 1.

Traffic data were considered especially important for two reasons: (1) the rather obvious direct relationship between accident occurrence and traffic volumes made it probable that this factor would be one of the most important characteristics in terms of accident prediction; and (2) it was necessary to control, or at least to take into account, the joint effects of ADT with other roadway features such as lane width and shoulder width which were evaluated in terms of their separate contributions to accident frequency. Without such controls, it would be virtually impossible to isolate the effects of these roadway features on accident data. For example, if it were found that accident frequency increases with lane width, this might be, at least partially, because lane width is one roadway element that is frequently altered to accommodate the de-

TABLE 2

THE RANGES AND MEANS OF THE ROADWAY FACTORS WITHIN AVERAGE DAILY TRAFFIC GROUPS[a]

| ADT Range | Section of Oregon | Shoulder Width (SH) ft | Lane Width (LA) ft | Sight Restriction (SDR) % | Commercial Driveways (CDW) | Residential Driveways (RDW) | Intersections (INT) |
|---|---|---|---|---|---|---|---|
| 0 - 999 (500) | All | 1 to 7 (2.84) | 8 to 11 (9.39) | 0 to 100 (58.17) | 0 to 7 (0.49) | 0 to 11 (0.86) | 0 to 4 (0 45) |
| 1,000 - 1,999 (1,450) | All | 1 to 10 (4.14) | 8 to 12 (10.15) | 0 to 100 (71.97) | 0 to 11 (0.94) | 0 to 32 (2 00) | 0 to 6 (1.13) |
| 2,000 - 2,999 (2,360) | Western | 1 to 11 (5.42) | 9 to 12 (10.77) | 0 to 100 (71.63) | 0 to 14 (1.69) | 0 to 18 (0 95) | 0 to 5 (1 00) |
| 3,000 -3,999 (3,340) | Western | 2 to 13 (6.84) | 9 to 13 (10.88) | 0 to 100 (59.45) | 0 to 13 (2.08) | 0 to 21 (3.93) | 0 to 7 (1 64) |
| 4,000 - 4,999 (4,370) | Western | 3 to 14 (8 04) | 9 to 13 (11.18) | 0 to 100 (49 47) | 0 to 41 (4 14) | 0 to 22 (4.58) | 0 to 7 (1 75) |
| 5,000 - 5,999 (5,340) | Western | 3 to 12 (7 49) | 10 to 14 (11 05) | 0 to 100 (57 44) | 0 to 16 (4.68) | 0 to 37 (3 54) | 0 to 7 (2 07) |
| 6,000 - 7,999 (6,840) | Western | 3 to 14 (9.17) | 10 to 13 (11 17) | 0 to 100 (40.83) | 0 to 14 (3.17) | 0 to 28 (2 76) | 0 to 6 (2.02) |
| 2,000 - 2,999 (2,350) | Eastern | 1 to 10 (4.98) | 9 to 13 (10.70) | 0 to 100 (29 83) | 0 to 7 (0.50) | 0 to 22 (1 52) | 0 to 5 (0.90) |
| 3,000 and above (3,400) | Eastern | 1 to 7 (4 49) | 10 to 12 (10.88) | 0 to 100 (28 24) | 0 to 13 (2 25) | 0 to 22 (4.59) | 0 to 4 (1.29) |

[a] The mean values for each roadway element appear in parenthesis immediately below the range of values for that particular element.

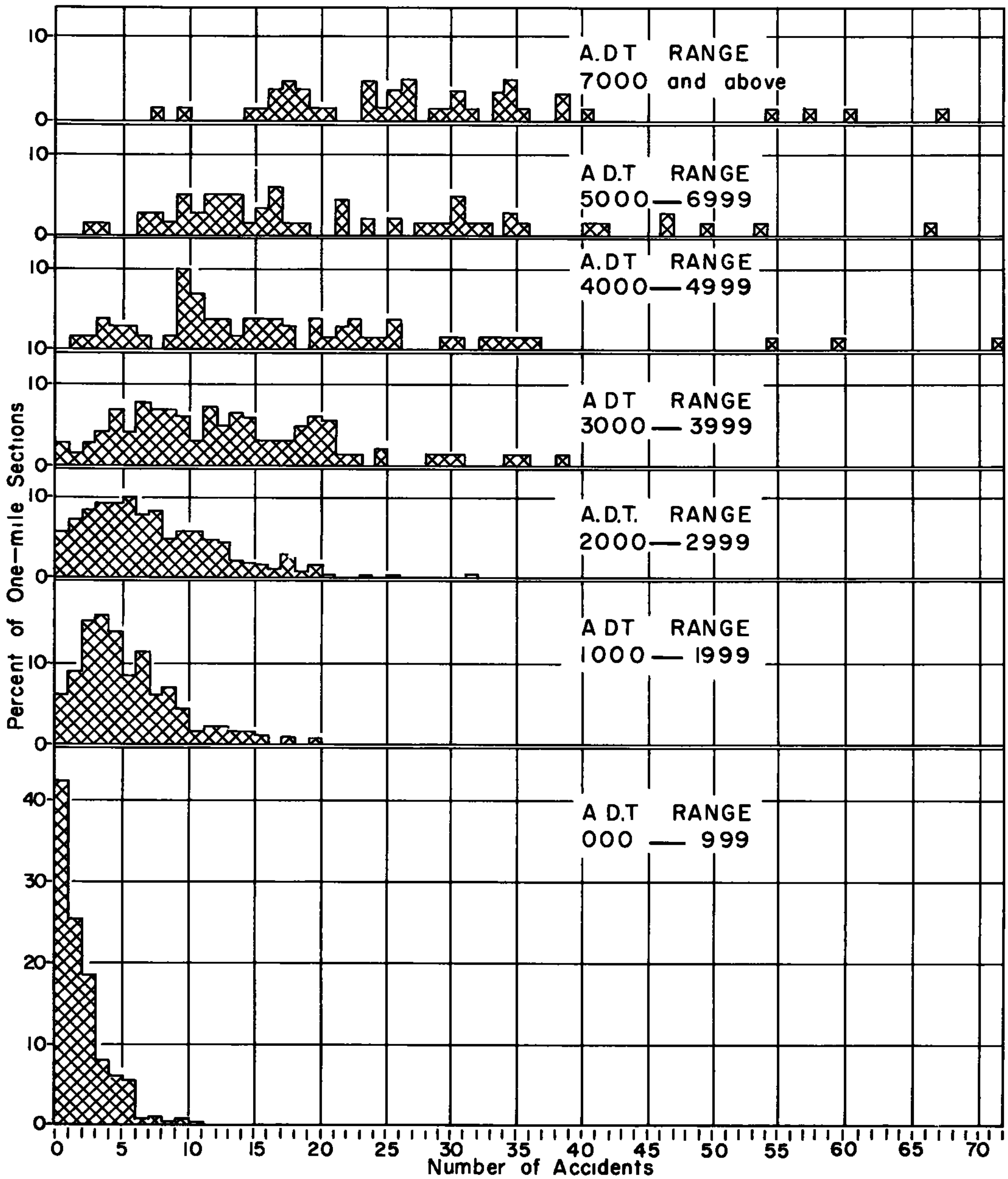



Figure 1. The percentage distribution of 1-mile sections by number of total accidents for various ADT ranges.

mands of traffic volumes; thus, a strong relationship between accident frequency and lane width might actually reflect the influence of the higher volumes which are generally encountered on highways with wide lanes. A rough picture of the various factors in each ADT range is given in Table 2.

In this table, the ranges and means of the roadway factors within each ADT group are presented. Examination reveals that both shoulder width and lane width tend to increase from the lower ADT ranges to the higher ones. No very obvious trend for the various ADT ranges occurs for sight restrictions. Commercial driveways, on the other hand, appear to increase directly with the ADT range involved. No such systematic trend appears for residential driveways. Intersections, like commercial driveways, however, tend to increase in the higher ADT groups. The tendencies of shoulder width, lane width, commercial driveways and intersections to increase with ADT points to the necessity for analyzing the data within the different ADT ranges.

## Accident Data

The accident data used in this study were available from office records. Total accidents for the years 1952, 1953, and 1954 were used because of the variation in the number of accidents from year to year for a given section of highway. The 3-year total tends to give less variation in the data.

The accidents were tabulated by location, either intersectional or non-intersectional, and by severity; that is, property damage, personal injury, and fatal accidents. For the major share of the analysis, all types and locations were added together and referred to as total accidents. At all times the number of accidents quoted here are in terms of 3-year totals for a 1-mile section of highway, except when treating with accident prediction equations.

The distribution of total accidents within each ADT range is shown in Figure 1. Examination of this figure reveals that on low volume roads (that is, 0-999 ADT) the bulk of the sections had 5 or less accidents. In marked contrast, the majority of the sections in the ADT range above 5,000 had 10 or more accidents per section. Not only the typical number of accidents, but also the variability of the accident data increased as the ADT increased. The lowest volume group had a range of 0 to 10 accidents. By contrast, the range was from 7 to 67 accidents in the highest ADT group. This represents an increased range of accidents of approximately 6 to 1 as volumes increased from the lowest to the highest ADT groups.

# ANALYSIS

Several methods of analysis were attempted during the study. The one to be described below gave the most usable results. No attempt will be made at this point to describe the detailed techniques used in the various analyses. The procedures described therein were common to all of the analyses. Appendix B contains a complete description of the various attempts to analyze the data which did not yield usable results or which did not yield results as satisfactory as those described below.

The first step in the analysis was to group the data by ADT and subdivide the various highway sections according to their location. Thus, seven ADT groups were obtained for sections in western Oregon and two were obtained for sections in eastern Oregon. The analysis of the data for sections with less than 2,000 ADT followed the same procedures described below, but did not yield usable results. Further efforts to obtain usable results are described later.

The zero order correlation coefficients between the various roadway elements and accidents were calculated (Table 3). ADT has a positive correlation with accidents in all ADT ranges, although the relationship varies in strength.

Sight distance restriction is generally positively correlated with accidents, indicating that more accidents can be expected on sections of highway with a high percentage of sight restriction. However, when sight distance restriction was included in the re-

TABLE 3

ZERO ORDER CORRELATIONS BETWEEN ROADWAY ELEMENTS AND TOTAL ACCIDENT OCCURRENCES IN ADT GROUPS

| Group Identification | | | Accident-Roadway Elements Correlations | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Part of Oregon | ADT Range | Number of 1-Mile Sections | ADT | SDR | LA | SH | CDW | RDW | INT |
| Western | 2,000 - 2,999 | 190 | 0.186[a] | 0.130 | -0.053 | -0.167[a] | 0.231[a] | 0.084 | 0.191[a] |
| Western | 3,000 - 3,999 | 73 | 0.028[a] | 0.484 | -0.254[a] | -0.571[a] | 0.488[a] | 0.027 | 0.160[a] |
| Western | 4,000 - 4,999 | 57 | 0.206 | 0.430 | -0.161 | -0.549[a] | 0.530[a] | 0.428[a] | 0.589[a] |
| Western | 5,000 - 5,999 | 41 | 0.089 | 0.025 | 0.058 | -0.103 | 0.275[a] | 0.514[a] | 0.583[a] |
| Western | 6,000 - 7,999 | 42 | 0.329[a] | 0.107 | 0.022 | -0.170 | 0.451[a] | 0.536[a] | 0.354[a] |
| Eastern | 2,000 - 2,999 | 173 | 0.096 | -0.088 | 0.030 | -0.063 | 0.400[a] | 0.316[a] | 0.350[a] |
| Eastern | 3,000 and over | 51 | 0.568[a] | 0.266 | -0.126 | 0.142 | 0.781[a] | 0.573[a] | 0.616[a] |

[a] Factors employed in the regression equations described in the text.

TABLE 4

MULTIPLE CORRELATIONS BETWEEN ROADWAY ELEMENTS AND TOTAL ACCIDENTS

| Part of Oregon | ADT Range | Best Predictors [a] | Coefficient of Multiple Correlation | Standard Error of Estimate | Ratio of the Standard Error of Estimate to the Mean |
|---|---|---|---|---|---|
| Western | 2,000 - 2,999 | ADT-SH-CDW-INT | 0.362 | 4.57 | 0 49 |
| Western | 3,000 - 3,999 | SDR-LA-SH-CDW-INT-ADT | 0 684 | 5 82 | 0.44 |
| Western | 4,000 - 4,999 | SDR-SH-CDW-RDW-INT | 0.813 | 8 07 | 0 45 |
| Western | 5,000 - 5,999 | CDW-RDW-INT | 0.713 | 9 00 | 0 42 |
| Western | 6,000 - 7,999 | ADT-CDW-RDW-INT | 0 663 | 10 85 | 0 46 |
| Eastern | 2,000 - 2,999 | CDW-RDW-INT | 0 476 | 3.05 | 0.75 |
| Eastern | 3,000 and over | ADT-SDR-CDW-RDW-INT | 0 852 | 3 44 | 0.35 |

[a] These elements were used in the regression equations described in the text.

gression, the effect was so small that it is not included in the equations.

Lane width shows important relationships in some, but not all, ADT ranges. The higher correlations are negative, indicating that less accidents can be expected on roadways with wide lanes, but this relationship is not consistent in all ADT ranges. It will be recalled that lane width increased with increasing ADT's (Table 2), and also that the range in lane width is usually not more than 4 ft.

Shoulder width shows strong relationships in some ranges, and is negative in all but one. It too, was strongly related to ADT and pavement width. Commercial driveways show a strong positive relationship to accidents in all ADT ranges. The number of commercial driveways is also related to ADT (Table 2).

Residential driveways showed a positive relationship to accidents in all ADT ranges, but the strength of this relationship varies from one range to another. The number of residential driveways was not so closely related to ADT as was the number of commercial driveways.

Intersections showed a positive relationship to accidents in all ADT ranges. This relationship was not particularly strong in the low ADT ranges for western Oregon.

On the basis of the zero order correlations (Table 3) and on the basis of the intercorrelations between the various roadway elements, the coefficients of multiple correlation were calculated for the relationship between certain combinations of roadway elements and accidents. These multiple correlations, together with the standard errors of estimate and the ratios of the standard error of estimate to the mean number of accidents, are shown in Table 4. Also shown in this table are the roadway elements which were combined in the regression equations.

The regression equations developed from this analysis are as follows:

For highways in western Oregon:

1W when the ADT is between 2,000 and 2,999

$$A = 1.07 + 0.10\,ADT - 0.16\,SH + 0.11\,CDW + 0.24\,INT$$

2W when the ADT is between 3,000 and 3,999

$$A = -2.12 + 0.50\,LA - 0.58\,SH + 0.35\,CDW + 0.21\,INT + 0.12\,ADT$$

3W when the ADT is between 4,000 and 4,999

$$A = 7.32 + 0.01\,SDR - 0.61\,SH + 0.07\,CDW + 0.06\,RDW + 1.37\,INT$$

4W when the ADT is between 5,000 and 5,999

$$A = 3.67 + 0.01\,CDW + 0.28\,RDW + 1.17\,INT$$

5W when the ADT is between 6,000 and 7,999

$$A = -10.66 + 0.23\,ADT + 0.17\,CDW + 0.45\,RDW + 0.49\,INT$$

For highways in eastern Oregon:

1E when the ADT is between 2,000 and 2,999

$$A = 0.95 + 0.28\,CDW + 0.24\,INT + 0.04\,RDW$$

2E when the ADT is 3,000 or over

$$A = -0.26 + 0.34\,CDW + 0.33\,INT + 0.08\,RDW + 0.05\,ADT + 0.01\,SDR$$

in which

A = total accident experience for a 1-mile section in a 1-year period;
ADT = average daily traffic divided by 100;
CDW = number of commercial driveways per mile;
INT = number of intersections per mile;
LA = lane width in ft;
RDW = number of residential driveways per mile;
SDR = percent of the 1-mile section where sight distance is restricted expressed as a whole number, thus, 10 percent = 10.0; and
SH = shoulder width in feet.

It was arbitrarily decided that the standard error of estimate must be less than half the mean number of accidents before the equation would be acceptable. There was only one equation where this ratio could not be obtained, and that was for sections of roadway in the 2,000 and 2,999 ADT range in eastern Oregon. Since this ratio was not obtainable by any method, the regression equation is shown, but its reliability is debatable. The coefficient of multiple correlation for highways in western Oregon in the 2,000 to 2,999 ADT range was so low that predictions obtained by the regression equation are of doubtful value. The remainder of the equations yield accident predictions which have reasonable accuracy.

## COMPARISON OF PREDICTIONS WITH ACTUAL CASE HISTORIES

The regression equations were employed to predict the number of accidents which would be expected to occur during a 3-year period on 1-mile sections of highway in the various ADT ranges. Contiguous sections which could be combined to give sections 4 miles or more in length were used. A total of 70 percent of the sample with ADT of 3,000 or over was usable. These predictions for any given 1-mile section were then compared with the actual number of accidents which were observed for that section for the years 1952, 1953, and 1954. The percentage of error in accident predictions using these equations is presented in Figure 2. The percent error of prediction is plotted as a function of a number of contiguous miles in a section. The figure reveals a general trend for the percent of prediction errors to decrease as the length of the section increases. Unfortunately, there were not many of the longer sections (sections 8 miles or longer) so this trend was not very clear.

The average error of prediction was about 14.6 percent. It appeared that in about 50 percent of the cases it was possible to predict accidents with less than a 15 percent error. Since the predictions presented in Figure 2 were based upon the years 1952-1954 inclusive and the actual accidents are for those same years, it might be expected that the accuracy of these predictions would be somewhat exaggerated. To reduce this tendency, the regression equations based on 1952-1954 accident data were used to predict accident frequency over a 6-year period including the years 1950 through 1955. In this instance, the regression equations would be required to predict not only for the years upon which they were derived—namely 1952-1954—but also for 2 years prior to these years and 1 year following.

The percent of error in prediction is presented as a function of a number of contiguous miles in a section (Figure 3). Again, the error of prediction tends to decrease as the length of the section increases. The average absolute error of prediction for this 6-year period is 17.4 percent, and again the error of prediction is less than 15 percent in one-half of the cases. When only those sections are considered which are at least 6 miles in length, the average error of prediction

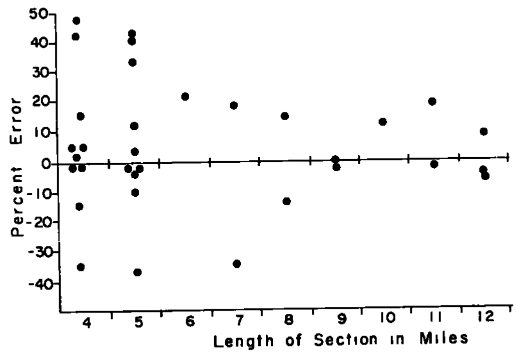



Figure 2. Percent error of total accident predictions for a 3-year period using 4 or more contiguous 1-mile sections.

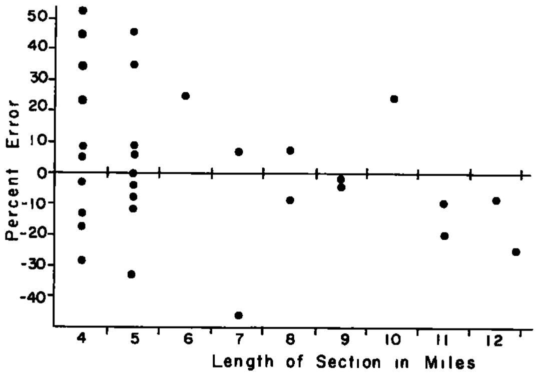



Figure 3. Percent error of total accident predictions for a 6-year period using 4 or more contiguous 1-mile sections.

for the data shown in Figure 2 is 11.6 percent, and the corresponding data for the 6-year period shown in Figure 3 is 15.2 percent. Thus, it seems that accident predictions shown in Figure 2 based on the same years for which the predictions are made are somewhat inflated with regard to accuracy, since a slightly greater order of errors in prediction was found over a 6-year period.

## ACCIDENT PREDICTION FOR LOW-VOLUME ROADS

Inasmuch as satisfactory predicting equations for highway sections in the 0-999 and 1,000-1,999 ADT ranges did not result from the analysis described above, these data were made the subject of more intensive study. The preliminary analysis resulted in very low zero order correlations between accidents and the various highway elements. The extreme variation in the accident data from year to year for the same 1-mile section, and the low number of accidents generally encountered, made it appear that more satisfactory results could be obtained by combining contiguous 1-mile sections. This was done for both ADT ranges, and new coefficients of correlation were computed. Contiguous sections with identical lane width, shoulder width, and ADT were added together to give 2-mile sections. The results did not yield high coefficients of correlation, and the ratios of the standard errors of estimate to the means were regarded as too low for satisfactory accuracy.

Congestion was the only one highway element which showed any relationship to accidents in the 0-999 ADT range. Congestion was defined as the ADT divided by the capacity. For this computation, capacity was not converted to an ADT basis as the information necessary to do so was not available. It is possible that conversion to an ADT basis would have improved the relationships but this would require knowledge of hourly variations on the highways studied. Further study of this matter is recommended.

In the 1,000-1,999 ADT range, shoulder width and sight distance restriction showed the best relationships, although these relationships were not particularly high. The data for the 1,000-1,999 ADT range were again re-organized to give 3-mile sections (contiguous sections with similar characteristics were combined in groups of three). The coefficient of correlation was somewhat improved, but the ratio of the standard error of estimate to the mean was only 0.61 which was still over the desired 0.50. The regression equations are not shown in this report as it is doubtful if predictions obtained from them would have accuracy sufficient for practical use. A summary of the results of these analyses is shown in Table 5.

TABLE 5

SUMMARY TABULATION OF RESULTS OF VARIOUS ANALYSES OF SECTIONS IN LOW ADT RANGES

| ADT Range | Number of Contiguous Sections | Predictors Used | Coefficient of Correlation[a] | Standard Error of Estimate | Ratio of the Standard Error of Estimate to the Mean |
|---|---|---|---|---|---|
| 0 - 999 | 2 | Congestion | 0 458 | 2 08 | 0 96 |
| 1,000 - 1,999 | 2 | SH - SDR | 0 413 | 5 38 | 0.58 |
| 1,000 - 1,999 | 3 | SH - SDR | 0 464 | 7 55 | 0.61 |

[a] Either zero order or multiple depending on the number of predictors used

## SUMMARY OF FINDINGS

1. Accident predictions are less subject to error for roadways with an ADT of 3,000 or more, than for sections with less than 3,000 ADT.

2. Personal injury accidents vary greatly by location and do not appear to be related to roadway features.

3. Accident predictions are more accurate when separate equations are used for eastern and western Oregon, thus taking into account the differences in climatic and geographic conditions which exist in the state.

4. On the rural 2-lane highways studied which perform "long-haul" functions, accidents appear to be closely related to access features (intersections and driveways); by contrast, on highways which have a primarily local service function, accidents are closely related to design features of the road itself.

5. The most important factor in the prediction of traffic accidents is the vehicle volumes on the highway. Points of access are second in importance, and design features, such as lane width, shoulder width, and sight restrictions, are third.

6. Traffic accidents on low volume roadways, particularly those on sections of highway with less than 2,000 ADT are not importantly related to any roadway element.

7. The equations presented can be used to predict total accidents on 1-mile sections of rural 2-lane highways with gravel shoulders in Oregon.

## CONCLUSIONS

1. Motor vehicle accidents are directly related to vehicle volumes and certain physical features of the highway. This relationship is strong enough in the higher ADT ranges to make it possible to predict accidents on the basis of known physical features.

2. Access to the highway through driveways or intersections is directly related to accidents at all ADT levels. The number of access points is a reasonably good indicator of the number of accidents within an ADT group.

3. Although the highway design elements such as lane width, shoulder width, and sight distance restriction are related to accidents, they do not ordinarily serve as good predictors of accidents. Generally speaking, wider lanes, wider shoulders, and unimpaired sight distance result in a safer highway.

4. An analysis of the data presented in this report confirms the theory that accidents are essentially chance occurrences resulting from errors in judgment. The number of accidents increases with the number of situations presenting a change in conditions, and therefore requiring a decision on the part of the motor vehicle operator. These data confirm this theory in the following ways. (a) Accidents on low volume roads do not appear to be related to any roadway feature. (b) Accidents increase when: (1) vehicle volumes increase; (2) access points increase; (3) sight distance is impaired; and (4) the cross-section is reduced.

## ACKNOWLEDGMENT

The author gratefully acknowledges the assistance rendered by Dr. Noel F. Kaestner, Statistician, Oregon State Highway Department, and Professor of Psychology, Willamette University, who provided the statistical control for the study described in this report.

# Appendix A

## SOURCE OF RAW DATA

The raw data employed in this investigation were derived from two major sources. The first source was obtained by three observers working in the field. The second source of data was available in the office. A detailed description of the field procedures, measurements, and recordings follows.

### Field Data

The observers' task was to record shoulder and lane widths, percent sight restriction, terrain description (that is, level, rolling, or mountainous), and other pertinent remarks for each 1-mile section along a prescribed route. The cars used were specially equipped with survey speedometers which permitted identification of the exact location at which measurements and other observations were made. The survey speedometers were readable to 0.01 mile. Previously, field sheets had been prepared which provided ample space for the convenient recording of all data. A sample field sheet

Highway No 7

| Terrain | ROADWAY CHARACTERISTICS | | | | | |
|---|---|---|---|---|---|---|
| | Width Measurement | | | Sight Restriction | | Other Characteristics |
| | Lane Feet | Shoulder Feet | Location M P | Location to the nearest one-tenth of a mile | % | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| | | | | B<br>M.P 2 05 | | |
| R<br>R<br>(R) | 10<br>11<br>(10) | 3<br>4<br>(3) | 2.05<br>2 61 | E<br>B<br>E<br>M P 3 05 | 85 | *1 Structure*<br>*Beg M P 2 32*<br>*L=* 01 *W=*26<br>*1 Culvert*<br>*M P 2 60*<br>**Beyond outer edge of shoulder** |
| R<br>L<br>(L) | 10<br>10<br>(10) | 3<br>3<br>(3) | 3.05<br>3 57 | B<br>M P 4 05 | 25 | |
| | | | | E<br>E<br>M.P 6 73 | — | *Speed Zone*<br>*40 MPH*<br>*Omit!* |
| L<br>L<br>(L) | 10<br>10<br>(10) | 5<br>4<br>(5) | 6.74<br>7.25 | 8<br>M P 7 33 | 20 | *Check Sharp Curves*<br>*2 Posted*<br>IIII |
| | | | | | | |

Figure 4. Shoulder and roadway elements accident study.

appears in Figure 4. The material in slant print in column 7 was placed on the field sheet by the accident analysis section prior to the observers' trip to the field. It included a designation of the observers' route by consecutive 1-mile sections (column 5 of the field sheet). The number and location of structures, the location of known speed zones and reminders to check sharp curves were written in column 7. The field data are presented on the sample field sheet in bold print and were obtained in the following way.

At the beginning of each 1-mile section (column 5), the field observer would record the terrain description. The abbreviations "L" for level, "R" for rolling, and "M" for mountainous (column 1) were employed throughout. At the same location in the field the observer would also measure the lane width and shoulder width to the nearest foot and record the same (columns 2 and 3). After making these measurements and recordings, the observer would proceed along the 1-mile section taking note of the terrain and any potential speed restriction factors in the 1-mile section. Somewhere further on, usually in the middle of the section, the driver again made shoulder and lane measurements and also recorded the abbreviated description of the terrain. In this manner at least two measurements were taken of the lane width and shoulder width within each mile. The mile post location of the first and second and any other points of measurement within the 1 mile were also recorded (column 4). Total pavement width (both lanes) and both left and right shoulders were measured at each stop. The shoulder width was taken as that area which was obviously safe or practical for shoulder use. Generally, the distance between the outer edge of the pavement and the inner edge of the ditch, or in some cases merely stable roadside surface, satisfied this criterion. Before leaving any 1-mile section, the driver used the above measurements to estimate a more representative index of lane width, shoulder width, and terrain for the section. These best estimates appear in circles in columns 1, 2, and 3 for each 1-mile section. Since the best estimates were based on the mile considered as a whole, no location measurement for them appears in column 4.

In addition to the above measurements and recordings, the driver kept a continuous record of the presence or absence of sight restriction. The 0.1-mile divisions appearing in column 5 were utilized in recording these data. As the observer proceeded through a section, special notations were made concerning the location of the beginning and end of unrestricted sight distance (1,500 ft of pavement visible). When the observer approached a section with restricted sight distance, he watched the road behind him to find the beginning point of unrestricted sight distance for vehicles traveling in the opposite direction. Upon reaching that point, its location was noted in column 5 on the field sheet. The letter "E" was used to designate this point. The beginning of sight distance restriction for the observer's direction of travel was 1,500 ft (0.3 mile) behind the point E. As he proceeded through the section with restricted sight distance, he selected a point which appeared to offer the beginning of unrestricted sight distance for his direction of travel and recorded a "B" (correct to the nearest 0.1 mile) in column 5. The end point of pavement visibility for vehicles traveling in the opposite direction was 1,500 ft ahead of the point designated by B.

Upon the field observer's return to the office, he blanked out (indicated by the vertical lines in column 5) any 0.1-mile sections in either direction of travel that did not have the required 1,500 ft sight clearance. In this manner, it was possible to determine in 5-percent steps the amount of sight restriction present for each 1-mile section, and these determinations appear in column 6.

Concurrently with the above measurements and estimates, the field observer measured the structures and checked the number of curves when these were indicated in column 7 (slant print). The length of the structures measured in hundredths of a mile and the width of structures measured to the nearest foot, were recorded below the indicated structure. In a similar way, the observer's tabulation of the number of sharp curves was recorded. In those cases where a culvert was indicated, the observer

| Hwy No | ADT in Hundreds | Beginning Mile Post | Width | | Terrain | Sight Restriction (Per Cent) | Structures | | | Number of Curves | DRVWY | | Number of Intersections | Capacity Index | Accidents | | | | | | Congestion Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | Non Intersectional | | | Intersectional | | | |
| | | | Lane | Shoulder | | | Length | Width | Number | | Commercial | Residental | | | Fatal | Non-fatal | Property Damage | Fatal | Non-fatal | Property Damage | |
| 35 | 35 | 00030 | 10 | 03 | 1 | 100 | 01 | 22 | 1 | 10 | 03 | 00 | 02 | 315 | 0 | 06 | 16 | 0 | 0 | 02 | 1100 |
| 35 | 31 | 00130 | 10 | 04 | 1 | 80 | 00 | 00 | 0 | 08 | 05 | 00 | 01 | 320 | 1 | 06 | 24 | 0 | 1 | 03 | 0970 |
| 35 | 31 | 00230 | 11 | 03 | 0 | 100 | 00 | 00 | 0 | 09 | 00 | 00 | 02 | 355 | 0 | 06 | 19 | 0 | 1 | 02 | 0870 |
| | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |

Figure 5. Roadway elements study.

would note whether the outer edge of the culvert infringed upon the natural shoulder width for that portion of the 1-mile section. If the culvert did restrict the shoulder width at that point, its length and width were also recorded.

The data on the field sheets were transcribed in the office onto code sheets (Figure 5). This field data appears on the sample code sheet in bold print. The terrain description presented on the field sheet in terms of single letter abbreviations was transformed into a numerical code wherein level, rolling, and mountainous were designated by 0, 1, and 2, respectively. The other data appearing in slant print on the code sheet were obtained in the office.

Office Data

An estimate of the ADT for each 1-mile section was developed from the data of traffic volume tables for 1953. No 1-mile section was included in this study which had more than a 10 percent difference in ADT throughout the mile. In addition to the ADT values, accident data and driveway data were available in the accident analysis section of the traffic engineering division. This section provided accident data for each 1-mile stretch in the sample of 1,374 sections.

The number of accidents per year in terms of personal injury, property damage, and their total were placed on the code sheets mentioned above. These included intersectional as well as non-intersectional accidents. The completed code sheet provided the following information for each 1-mile section: terrain, lane width, shoulder width, sight restriction, ADT, and personal injury, property damage, and total accidents for each year from 1952 to 1954.

# Appendix B

## ANALYSIS OF NON-INTERSECTIONAL ACCIDENTS

A considerable amount of time was spent in developing a method of analysis. Several efforts to derive useful predictive devices were made in this particular study prior to those finally employed. Some of the findings in the earlier analyses are of interest and, therefore, the history of the various analyses is presented here.

All of the analyses described in this appendix dealt with non-intersectional accidents. Preliminary studies had shown that the high variability of personal injury or fatal accidents precluded the possibility of predicting these accidents individually. They did not show strong relationships to individual highway elements and their occurrences were so random and so few that a sufficient body of data could not be developed to permit a thorough analysis. Therefore, personal injury and fatal accidents were combined with accidents which resulted in property damage only. This total was used in all of the following analyses. The distribution of non-intersectional accidents is shown in Figure 6.

In the first approach to the problem of accident prediction, the relationship between accidents and congestion was examined. The congestion of the roadway was expressed as the ratio of the highways ADT to its capacity (for the non-intersectional part of the section). Thus, congestion reflects the effect of the actual usage of a roadway relative to its theoretical traffic carrying ability.

In these original analyses, the highway sections were not grouped in ADT ranges. The relationship between congestion and accidents was reasonably strong (the coefficient of correlation was 0.725). However, the ratio of the standard error of estimate to the mean was 0.83. When commercial driveways were combined with congestion, the coefficient of correlation improved somewhat as did the ratio of the standard error of estimate to the mean. A similar slight improvement was realized when residential driveways were added. These findings are summarized in Table 6. None of the relationships showed a sufficiently low ratio of the standard error of estimate to the mean for accurate predictions.

Another analysis was undertaken which investigated the relationship between ADT and accidents. This relationship had been found to be very strong in the previous analysis, and it was thought that satisfactory prediction equations could be developed based on ADT plus commercial and residential driveways. This analysis was similar to that

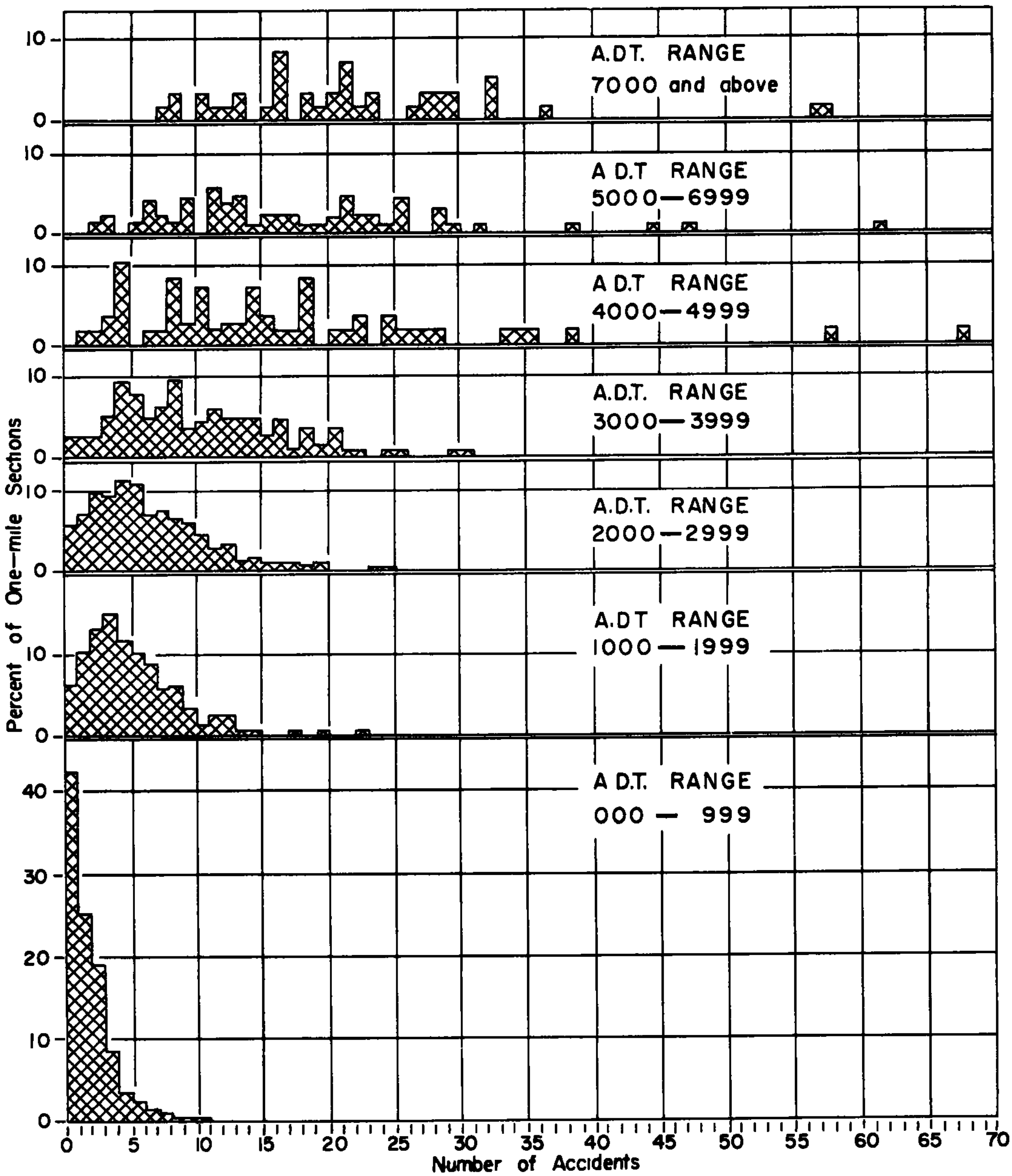



Figure 6. The percentage distribution of 1-mile sections by number of non-intersectional accidents for various ADT ranges.

TABLE 6

SUMMARY TABULATION OF RESULTS OBTAINED FROM ANALYSES USING UNGROUPED DATA FOR NON-INTERSECTIONAL ACCIDENTS WITH NO GEOGRAPHICAL BREAKDOWN

| Predictors Used | Coefficient of Correlation [a] | Standard Error of Estimate | Ratio of the Standard Error of Estimate to the Mean |
|---|---|---|---|
| ADT | 0 700 | 5.20 | 0.86 |
| ADT-CDW | 0.751 | 4.81 | 0.80 |
| ADT-CDW-RDW | 0.761 | 4.72 | 0.78 |
| Congestion | 0 725 | 5 02 | 0.83 |
| Congestion-CDW | 0 765 | 4.69 | 0.78 |
| Congestion-CDW-RDW | 0 774 | 4.61 | 0.76 |

[a] Either zero order or multiple depending on number of predictors

described above and is also summarized in Table 6. Once again, satisfactory predictions did not appear possible because of the high ratios of the standard errors of estimate to the means.

It appeared that it would not be possible to develop satisfactory predicting equations without grouping the data in ADT ranges. When this was done, the coefficients of correlation were somewhat less than those obtained in the earlier analyses, but the ratios of the standard errors to the means were considerably increased.

Originally congestion was used alone, then commercial and residential driveways were added. Ultimately the three or four best predictors observed in the zero order correlations were combined. These three or four individual elements frequently gave results as satisfactory as those obtained using congestion and driveways. Since congestion involves a fairly complicated computation requiring knowledge of each of five individual highway elements, it seemed advisable to use the three best predictors in the equations. This requires considerably less field investigation, and yields accuracy as great or greater than that resulting from the more complicated computations. The results of these analyses are summarized in Table 7.

When the final regression equations had been computed, accident predictions for various representative sections were computed and checked against actual accident history for these sections. While the results were generally encouraging and within reasonable limits of accuracy, there were several cases of extreme variance. An examination of the individual cases led to the conclusion that regression equations based on all the data were not satisfactory for sections of highway in all portions of the state. It was decided that the data should be further divided on an east-west basis.

These two sections of Oregon have great differences in climate and geography as well as in travel characteristics. Cities in eastern Oregon are smaller and farther apart than those in western Oregon, thus requiring longer travel distances between population centers with less commercial and residential development along the route. Most highways in eastern Oregon perform long haul functions, whereas many highways in western Oregon are used for farm-to-market trips or short trips between cities. When the data were divided geographically and analyzed for each ADT range in the two geographic divisions, better results were obtained when predictions were compared to actual case histories.

Therefore, this type of analysis was used for total accident predictions as described in the text.

TABLE 7

RESULTS OF ANALYSIS OF NON-INTERSECTIONAL ACCIDENTS WITH SECTIONS GROUPED IN ADT RANGES

| ADT Range | Section of Oregon | Predictors Used | Coefficient of Correlation [a] | Standard Error of Estimate | Ratio of the Standard Error of Estimate to the Mean |
|---|---|---|---|---|---|
| 3,000 - 3,999 | All | Congestion | 0 590 | 5 08 | 0 51 |
| | All | Cong -CDW-RDW | 0.668 | 4.67 | 0 47 |
| | All | SDR-CDW-SH | 0.664 | 4 70 | 0.47 |
| | Western | SDR-SH-CDW+LA | 0.913 [b] | 2.77 | 0.24 |
| 3,000 and over | Eastern | CDW-RDW-INT-SH | 0.711 [b] | 3.15 | 0.43 |
| 4,000 - 4,999 | All | Congestion | 0 427 | 10 97 | 0.70 |
| | All | Cong +CDW+RDW | 0.610 | 9.62 | 0 62 |
| | Western | CDW-RDW+SH | 0 670 [b] | 9.00 | 0.58 |
| 5,000 - 6,999 | All | Congestion | 0.142 | 10.75 | 0.63 |
| | All | Cong. +CDW+RDW | 0.665 | 8.11 | 0 47 |
| | Western | CDW+RDW+SH | 0 670 [b] | 8.06 | 0.47 |
| 7,000 and over | Western | Congestion | 0.313 | 10.24 | 0.47 |
| | Western | Cong. +CDW+RDW | 0.388 | 9.93 | 0.44 |
| | Western | ADT+RDW+SH | 0.501 [b] | 9.32 | 0.41 |

[a] Either zero order or multiple, depending on the number of predictors used.
[b] These combinations were used in the regression equations shown in the text.

The regression equations for non-intersectional accidents are as follows:

For highways in western Oregon:

1W when the ADT is between 3,000 and 3,999

$A = 7.69 + 0.03\ SDR - 0.21\ SH + 0.10\ CDW - 0.41\ LA$

2W when the ADT is between 4,000 and 4,999

$A = 8.51 - 0.58\ SH + 0.23\ CDW + 0.004\ RDW$

3W when the ADT is between 5,000 and 6,999

$A = 4.84 + 0.31\ RDW + 0.19\ CDW - 0.12\ SH$

4W when the ADT is 7,000 or more

$A = 3.75 - 0.24\ SH + 0.26\ RDW + 0.16\ ADT$

For highways in eastern Oregon:

1E when the ADT is between 3,000 and over

$A = 1.04 + 0.23\ CDW + 0.11\ RDW + 0.08\ INT + 0.12\ SH$

in which

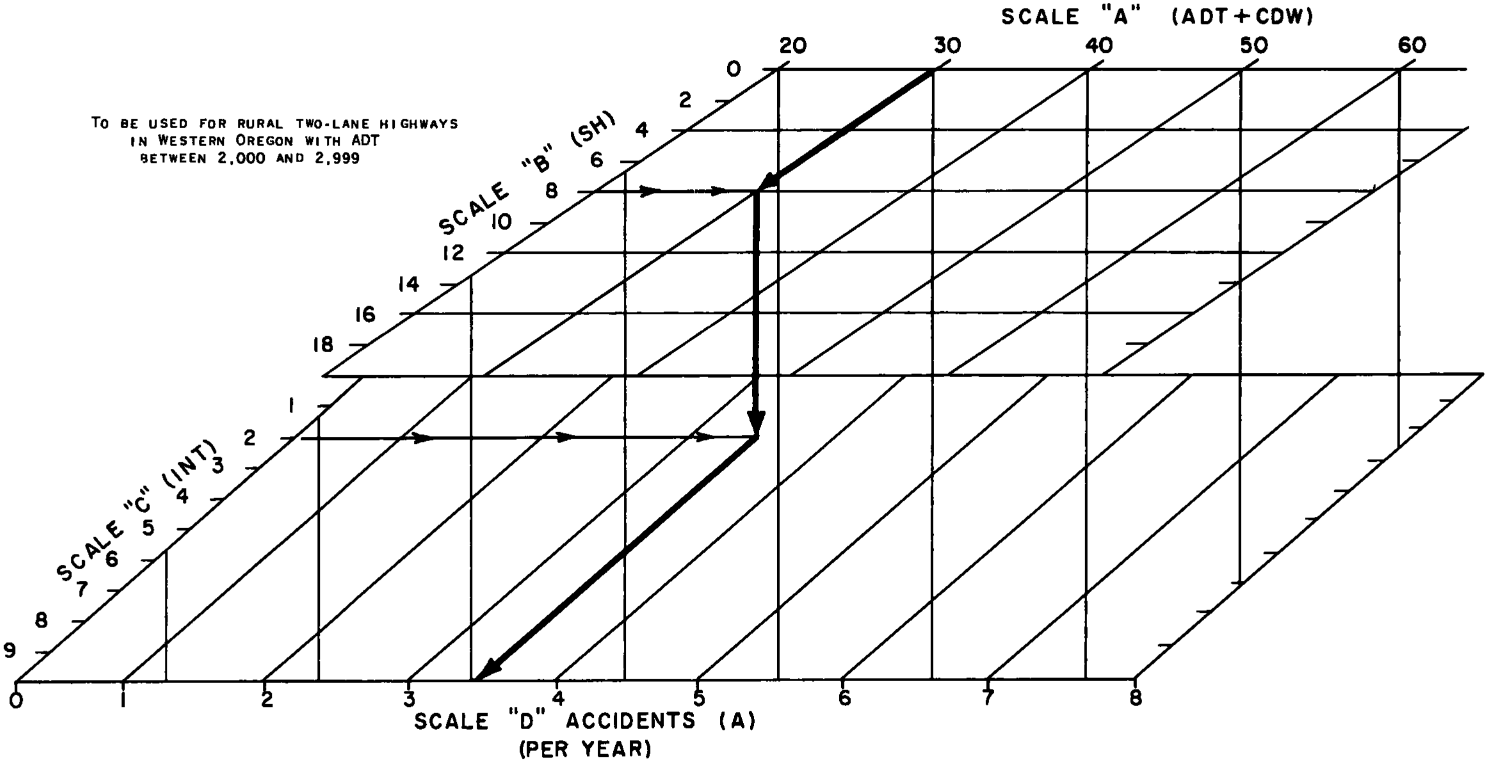
A = total non-intersectional accident experience for a 1-mile section during a 1-year period;
ADT = number of average daily traffic divided by 100;
CDW = number of commercial driveways per mile;
INT = number of intersections per mile;
LA = lane width in feet;
RDW = number of residential driveways per mile;
SDR = percent of the 1-mile section where sight distance is restricted. expressed as a whole number, thus 10 percent = 10.0; and
SH = shoulder width in feet.

# Appendix C

## NOMOGRAM SOLUTIONS

Calculation of accident predictions can be simplified considerably by the use of nomograms which have been prepared for each of the 7 equations. They permit rapid graphical solutions giving satisfactory accuracy. The equations were modified in some cases by combining elements with like coefficients or substituting averages for certain elements with very low coefficients. The loss of accuracy resulting from these modifications is negligible.

The nomograph solutions for the various equations are shown in Figures 7 through 14.




1 ENTER SCALE A WITH THE SUM OF ADT (IN HUNDREDS) AND COMMERCIAL DRIVEWAYS

2 FOLLOW PARALLEL TO SCALE B TO INTERSECTION WITH SHOULDER WIDTH

3 DROP VERTICAL FROM THIS POINT TO INTERSECTION WITH NUMBER OF INTERSECTIONS (SCALE C)

4 FOLLOW PARALLEL TO SCALE C TO INTERSECTION WITH SCALE D

5 READ ACCIDENTS DIRECT FROM SCALE D

EXAMPLE

| | |
|---|---|
| ADT | 2,500 |
| CDW | 5 |
| SH | 8 |
| INT | 2 |
| A | 3 5 |

EQUATION 1W, MODIFIED $A = 0\ 11\ (ADT\quad CDW) - 0\ 16SH + 0\ 28INT$

Figure 7. Nomogram for the solution of Equation 1W.

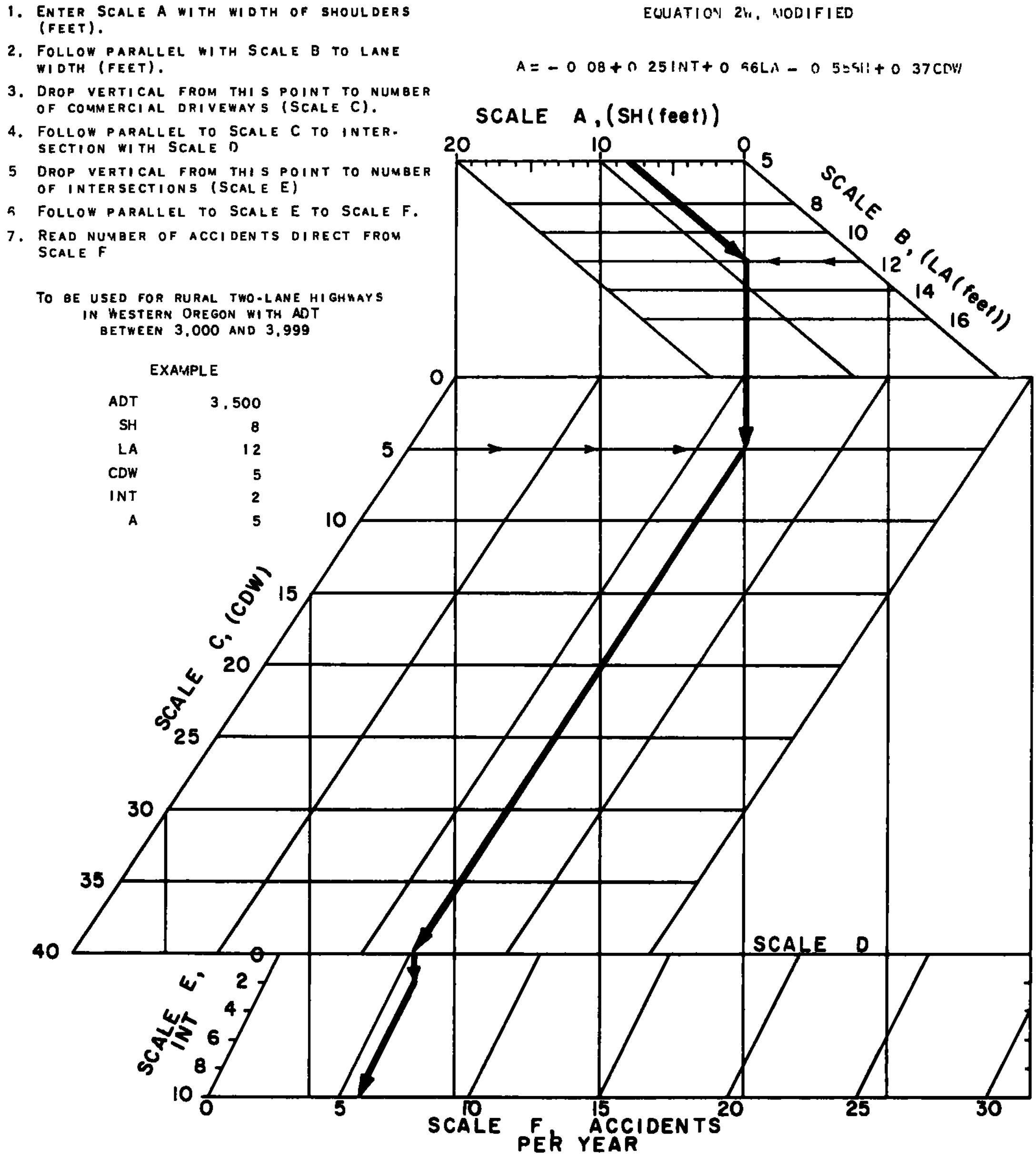



Figure 8. Nomogram for the solution of Equation 2W.

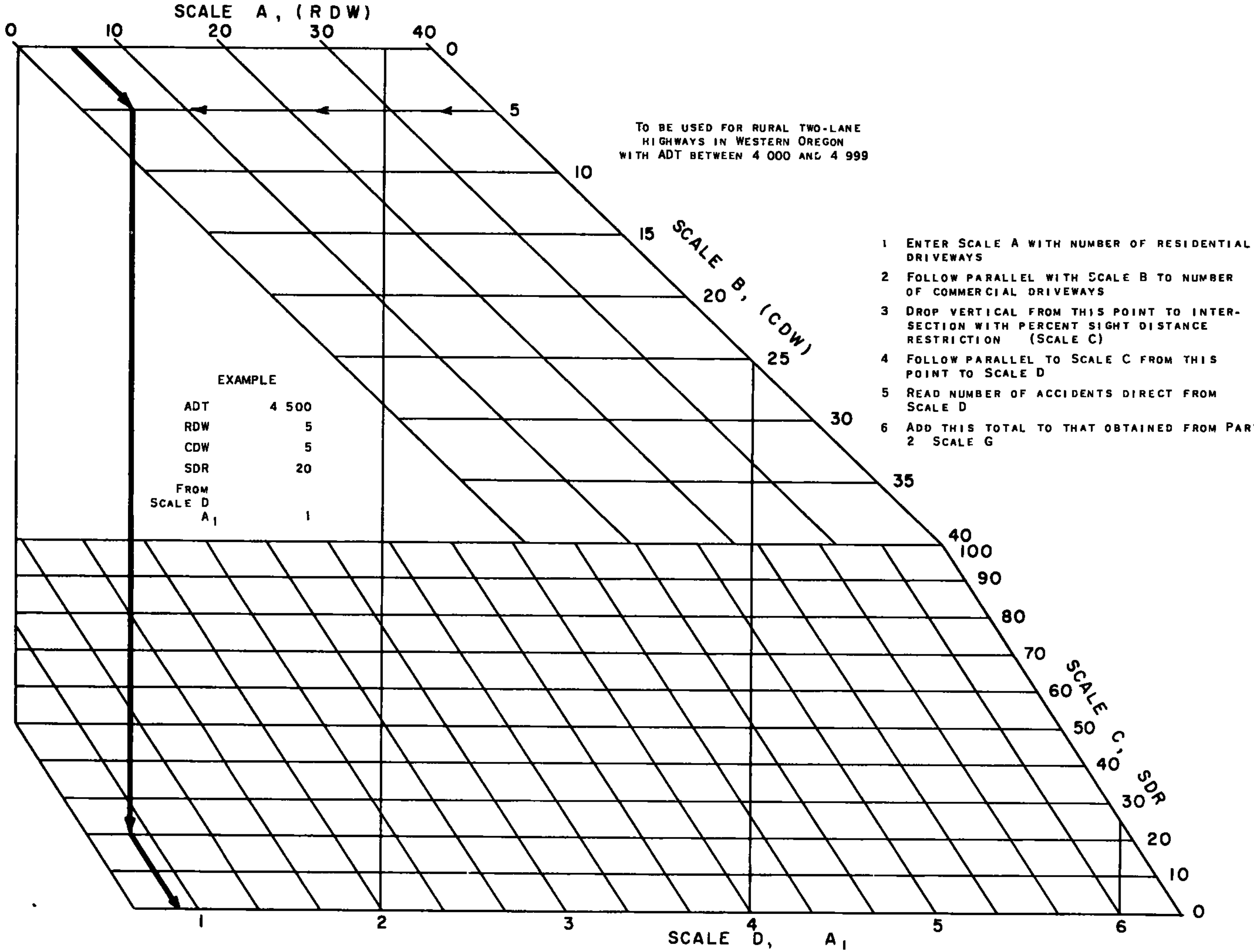



Figure 9. Nomogram for the sloution of Equation 3W, Part 1.

To be used for rural two-lane
highways in Western Oregon
with ADT between 4,000 and 4,999

1. Enter Scale E with number of intersections.
2. Follow parallel to Scale F to intersection with shoulder width
3. Drop vertical from this point to Scale G.
4 Read number of accidents direct from Scale G.
5. Add this total to that obtained from Part 1, Scale D.

EQUATION 3W, MODIFIED $A = A_1 + A_2$

$A_1 = 0\ 01SDR + 0.07CDW + 0.06RDW$

$A_2 = 7\ 33 - 0\ 61SH + 1\ 37INT$

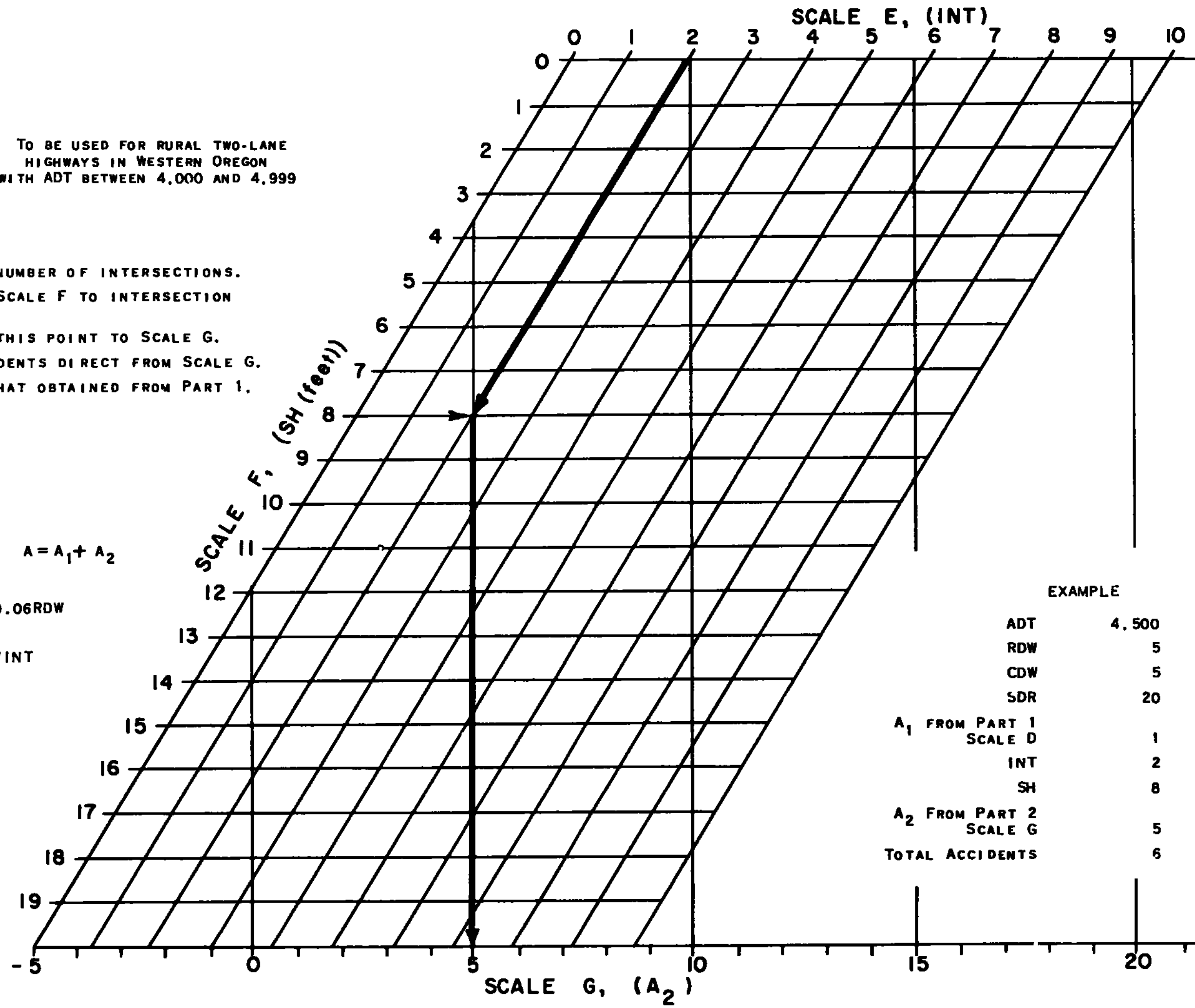



Figure 10. Nomogram for the solution of Equation 3W, Part 2.

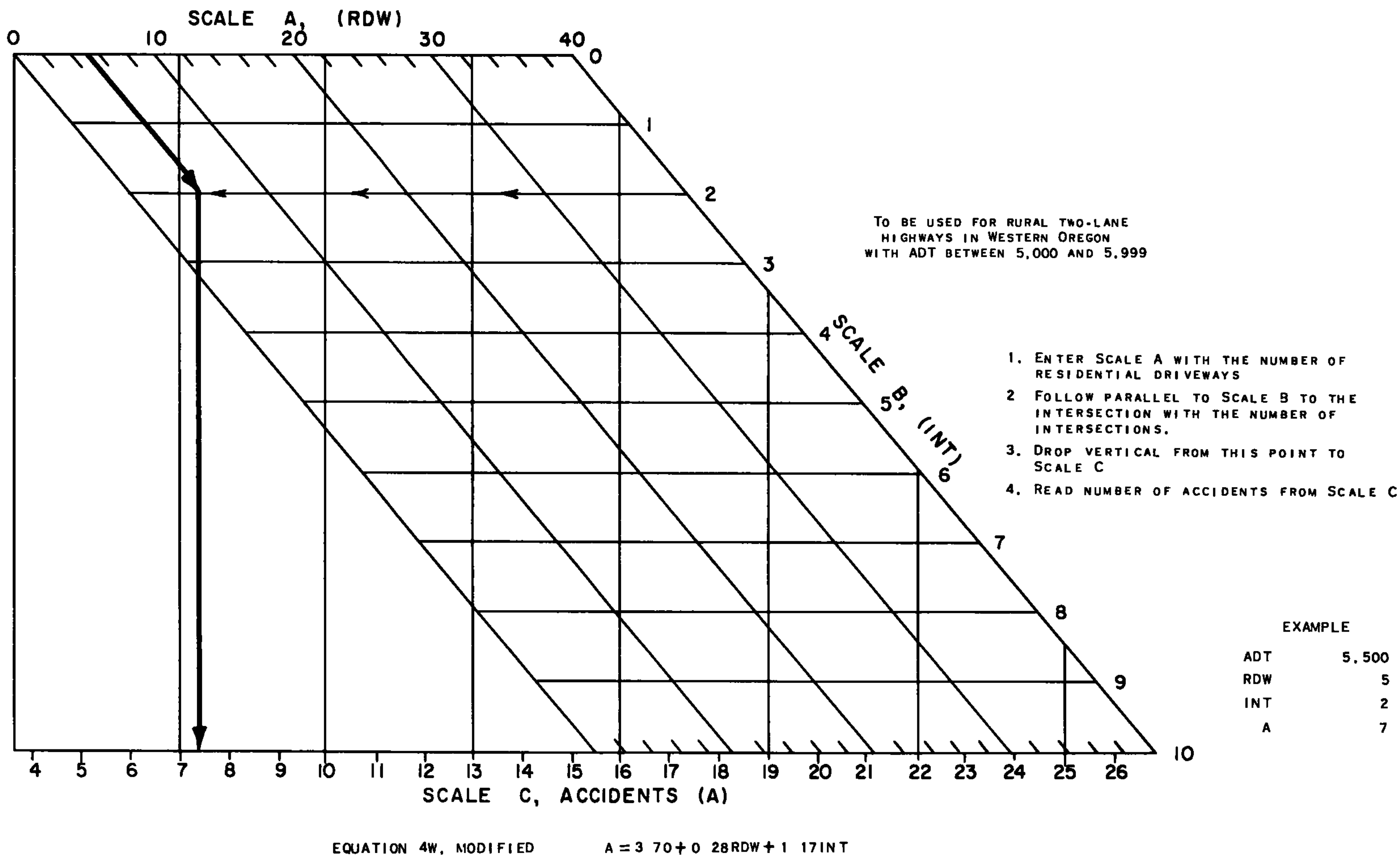



Figure 11. Nomogram for the solution of Equation 4W.

To be used for rural two-lane highways in western Oregon with ADT between 6 000 and 6 999

1 Enter Scale A with number of residential driveways
2 Follow parallel to Scale B to intersection with number of intersections
3 Drop vertical from this point to intersection with ADT (Scale C)
4 Follow parallel to Scale C to Scale D
5 Drop vertical from this point to intersection with number of commercial driveways (Scale E)
6 Follow parallel to Scale E from this point to Scale F
7 Read number of accidents from Scale F

EQUATION 5W, MODIFIED A = − 10 67 + 0 33ADT

+0 17CDW + 0 48RDW +, 0 49INT

EXAMPLE

| | |
|---|---|
| ADT | 7,000 |
| RDW | 5 |
| INT | 2 |
| CDW | 5 |
| A | 10 |

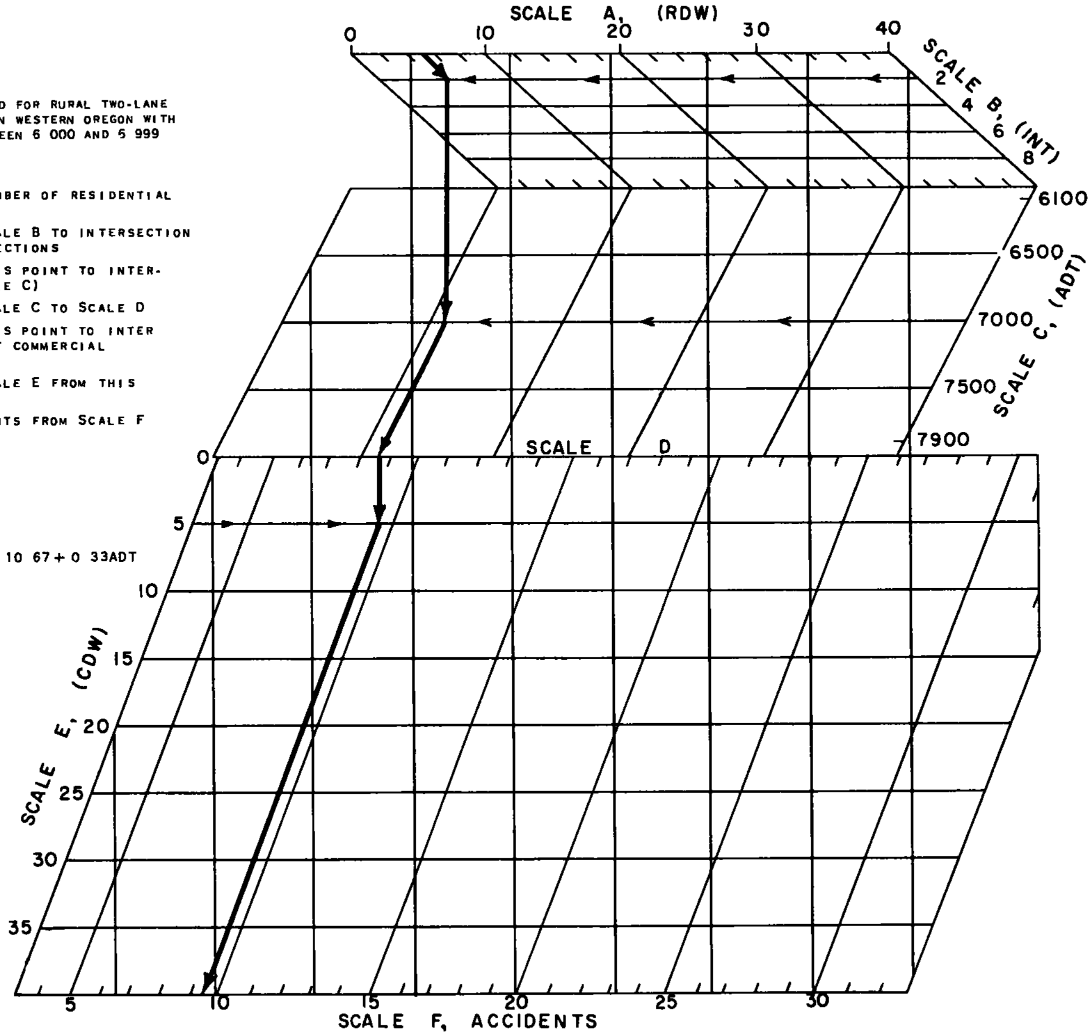
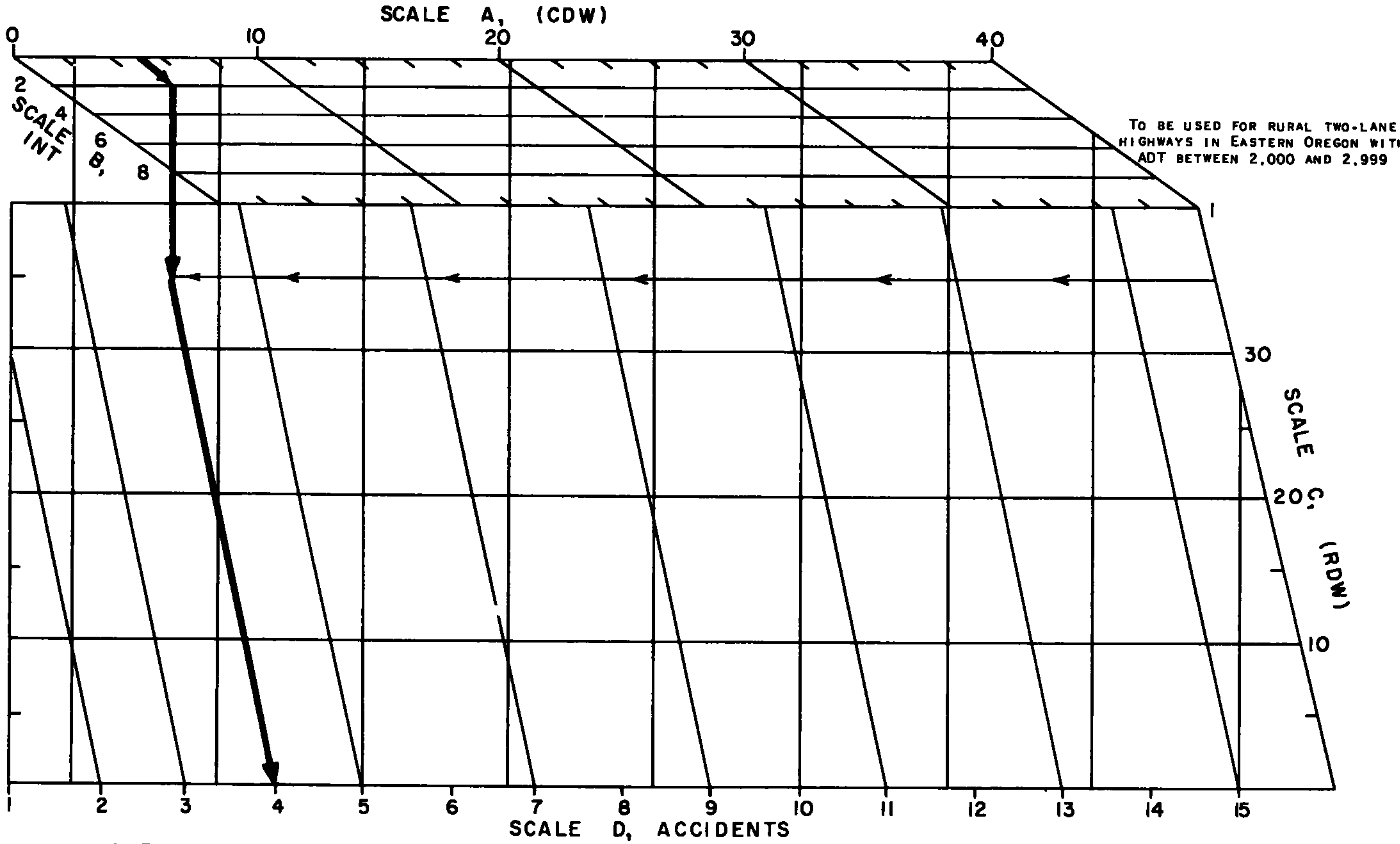



Figure 12. Nomogram for the solution of Equation 5W.




1 ENTER SCALE A WITH THE NUMBER OF COMMERCIAL DRIVEWAYS

2 FOLLOW PARALLEL TO SCALE B TO AN INTERSECTION WITH THE NUMBER OF INTERSECTIONS.

3 DROP VERTICAL FROM THIS POINT TO AN INTERSECTION WITH THE NUMBER OF RESIDENTIAL DRIVEWAYS (SCALE C)

4 FOLLOW PARALLEL TO SCALE C TO SCALE D

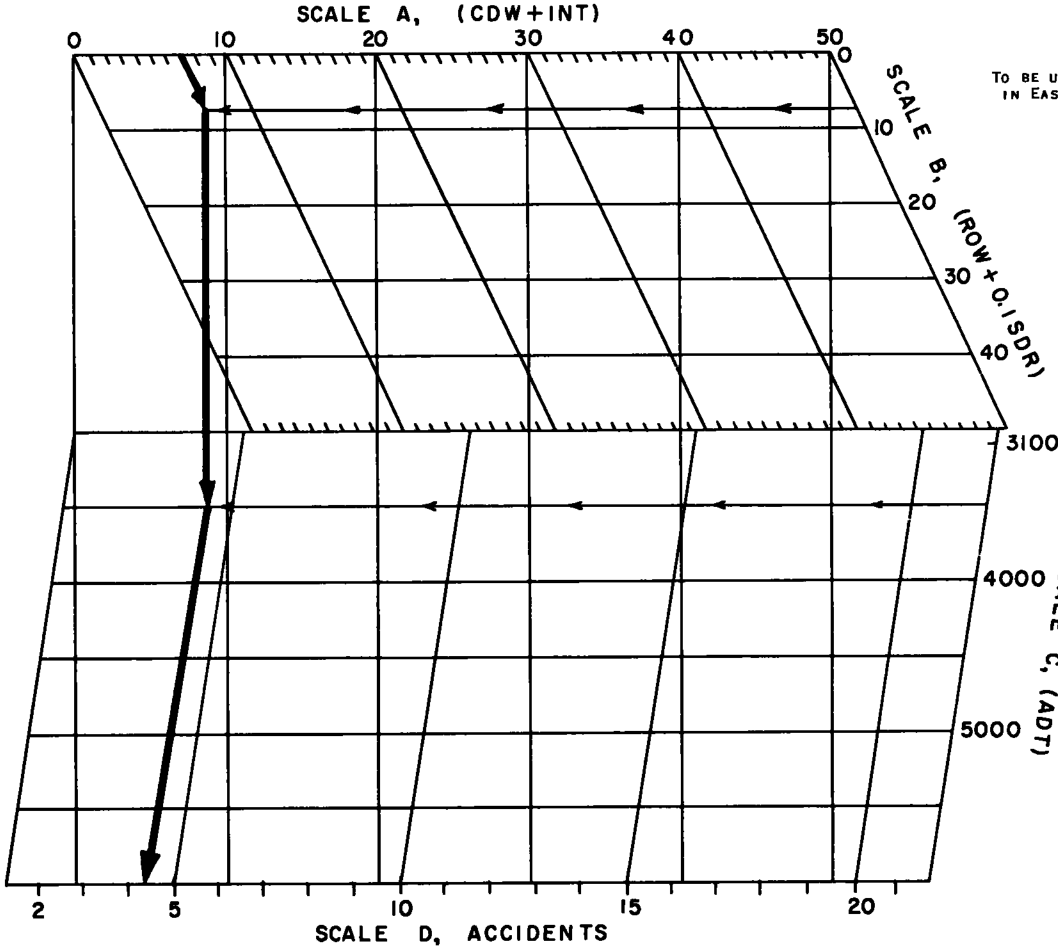
5 READ NUMBER OF ACCIDENTS FROM SCALE D

EXAMPLE

| | |
|---|---|
| ADT | 2,500 |
| CDW | 5 |
| INT | 2 |
| RDW | 5 |
| A | 4 |

EQUATION 1E MODIFIED   A =0 95+0 28CDW+0.24INT+0 04RDW

Figure 13. Nomogram for the solution of Equation 1E.




To be used for rural two-lane highways in Eastern Oregon with ADT above 3,000

1 Enter Scale A with sum of commercial driveways and intersections.
2. Follow parallel to Scale B to intersection with sum of residential driveways plus 0.1 times the percent of sight restriction (Scale B).
3. Drop vertical to intersection with ADT, Scale C.
4 Follow parallel to Scale C from this point to Scale D.
5. Read number of accidents direct from Scale D

EXAMPLE

| | |
|---|---|
| ADT | 3,500 |
| CDW | 5 |
| INT | 2 |
| RDW | 5 |
| SDR | 20 |
| A | 4 |

EQUATION 2E, MODIFIED

A = 0 26 + 0 05ADT + 0 33(CDW INT) + 0 08(RDW 0 1SDR)

Figure 14. Nomogram for the solution of Equation 2E.

# Two New Classification Techniques

P. E. WADE, R. B. TRUEMNER, and R. I. WOLFE
Ontario Department of Highways

●ONTARIO is a large province, extending approximately 1,000 miles in both the east-west and the north-south directions. By geology and climate it is divided into two distinct parts, which are disproportionate in area and economic development (See Fig. 1). In the cold northern part lies the vast Precambrian Shield, an ancient rock formation on which are located most of Ontario's forestry and mineral resources and recreational areas. Southern Ontario contains 88 percent of Ontario's 5,300,000 people living in only 7 percent of the area. Within the southern area virtually all of Ontario's agricultural and industrial activity is carried out. These two areas have different transportation needs and the techniques described below were put to greater use in the highly developed southern portion.

The highways of Ontario are classified into three major jurisdictions:

1. The King's highway system under the control of the province.
2. The county road system under the control of the organized counties.
3. The township road system under the control of the organized townships.

It was the purpose of a recent study conducted by the Department of Highways of Ontario to classify the King's highway system in conjunction with a comprehensive needs study of these roads. This classification had two objectives: to stabilize the extent of this system by defining a King's highway, and to establish sub-classes of King's highways for administrative purposes.

For the purposes of this study King's highways were defined as "Those collector roads that carry relatively large volumes of interregional traffic, offer the shortest routes between major points of traffic interest and can interconnect all such places with reasonable service to the more widely distributed population in rural areas."

Three main sub-classes of King's highways were established as a result of the classification study: freeway, trunkline and feeder highways. Freeway highways are major international and interprovincial routes connecting metropolitan centers and major regions. Trunkline highways are routes completing a network of highways that connect all other large cities and important areas in the province. This class is subdivided into major and minor trunklines. Feeder highways are routes that are not essential to the interconnection of the system but that maintain a desirable and consistent level of service to all areas of the province.

For the purpose of defining the limits of the system and to differentiate the sub-classes, criteria were sought as a measure of the service characteristics of each highway section. These include the familiar elements: traffic volume, population of urban centers, natural resources and land use characteristics, plus the integration of the highway network.

To indicate more precisely the function of each highway, two added measures of service were developed: Intercenter service and rural access service.

## INTERCENTER SERVICE

A major service performed by a provincial or state highway system is the interconnection of important population centers. The place a highway is given in an over-all classification depends to a large extent on the total intercenter service it thus provides, irrespective of any other considerations.

Accordingly some method was sought for defining and evaluating this aspect of highway service. The results of orgin-and-destination surveys were utilized for this purpose. These determine the amount of traffic wishing to travel between various population centers. A measure of highway intercenter service was obtained by relating this data to the different classes of population centers.

### Place Classification

Of the various characteristics indicating the importance of population centers, it was decided that population was the most significant, particularly from a traffic generation consideration. Therefore cities and towns in Ontario were classified by total population. A curve was drawn of the populations of the centers in diminishing order of size (Fig. 2). A guide in the selection of classes was the shape of this curve. Class limits were chosen at well-defined breaks in the curve slope. Six classes of population centers were selected and the members of each class were assumed to be of the same order of importance. For convenience, the classes were identified by the letters M (metropolitan), A, B, C, D and E. Population ranges were chosen for these place classes of southern Ontario and are shown in Table 1. Border-crossing towns were given a higher classification than their population warranted, since a great deal of international traffic must funnel through them.

Use of Origin-and-Destination Data

External origin-and-destination surveys have been made at most of the major cen-

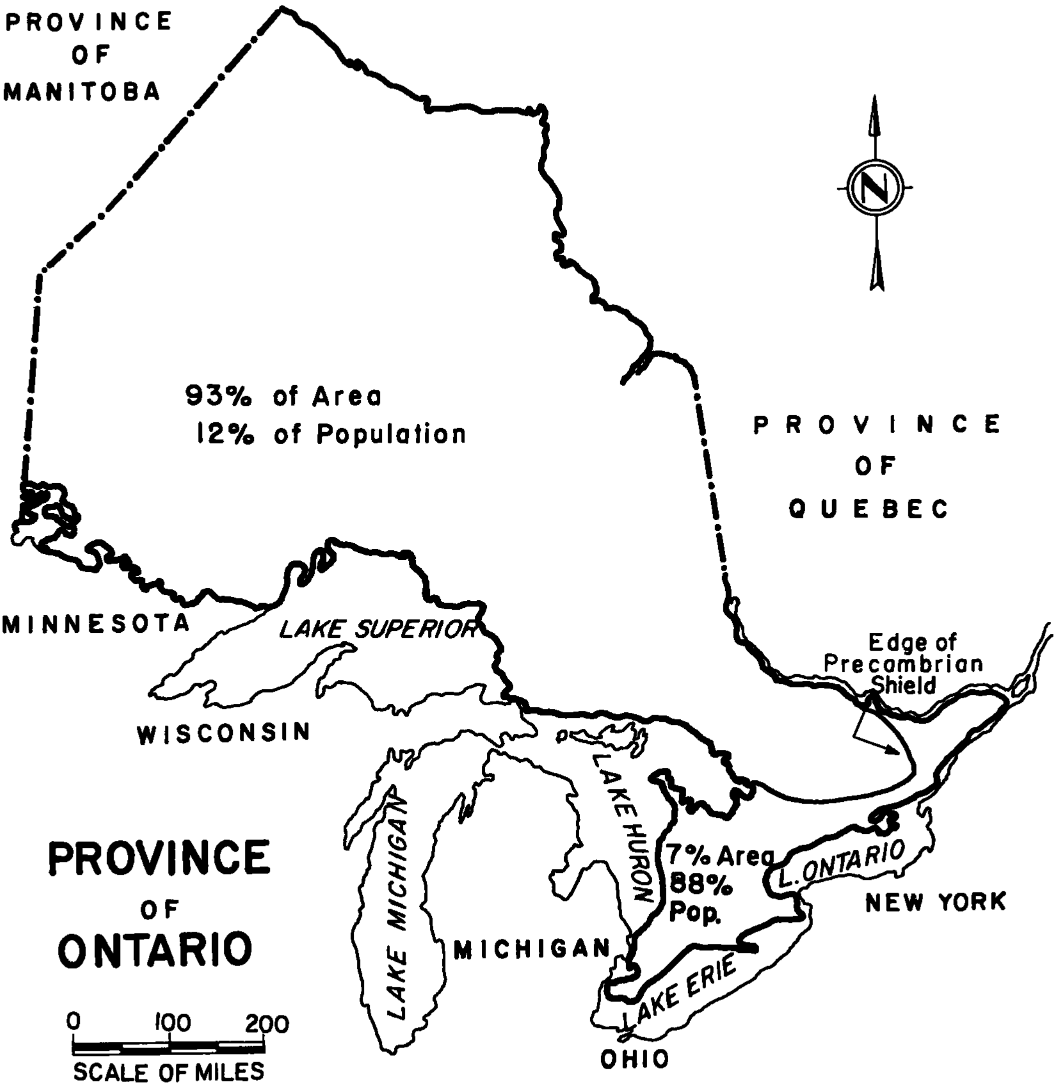



Figure 1.

ters in the province. The numbers of daily through trips between all surveyed centers of over 3,500 population (the minimum size of places classified), were tabulated from these O-D data, and the average number of daily through trips was computed for each type of place connection. M to M connections, for example, average 660 daily trips, M to A connections 620, and so on.

TABLE 1

| Class | Population Range | |
|---|---|---|
| M | over | 1,000,000 |
| A | 60,000 to | 300,000 |
| B | 30,000 to | 60,000 |
| C | 10,000 to | 30,000 |
| D | 7,500 to | 10,000 |
| E | 3,500 to | 7,500 |

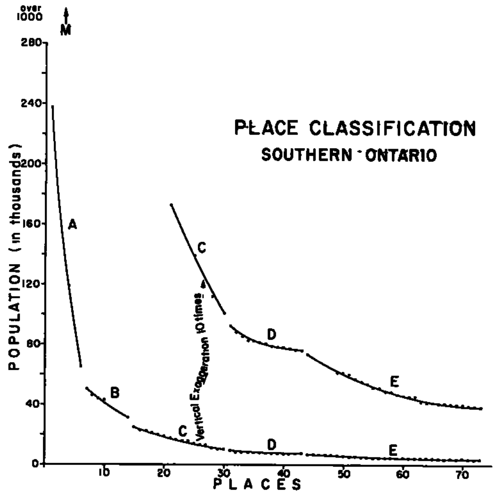



Figure 2. Place classification

It was found that average numbers of daily through trips approximated either 600, 300, or 100 for most intercenter connectors (Table 2). These approximate averages

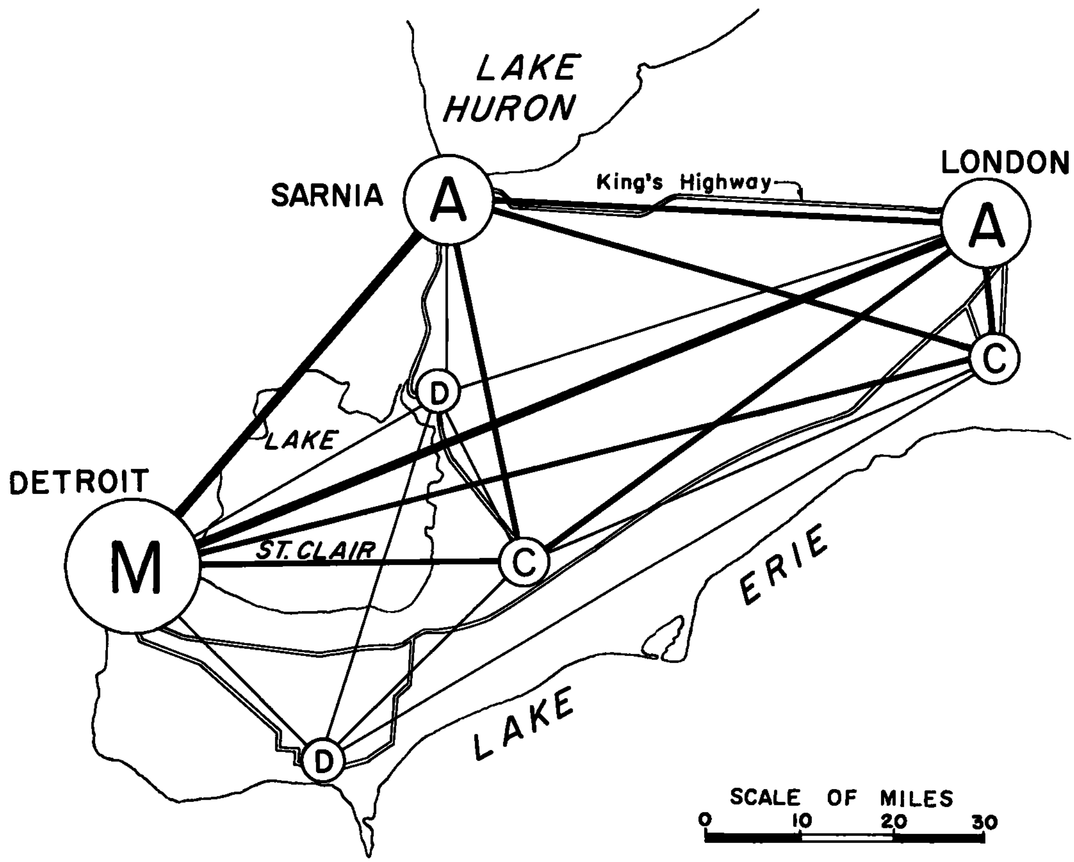



Figure 3. Intercenter connectors; the straight lines represent the various intercenter connectors between classified places; width of line indicates intercenter point rating; external connectors have been excluded.

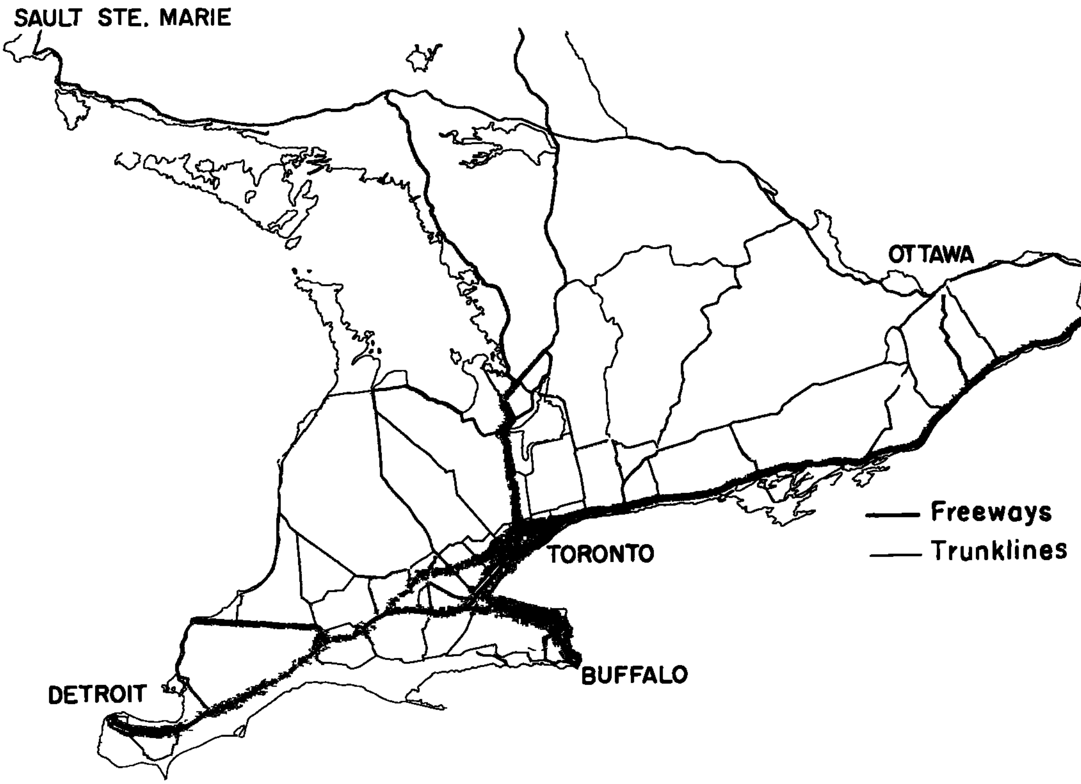



Figure 4. Intercenter point ratings of southern Ontario.

were used to construct a convenient point system, in which a conversion factor of one point was assigned to each 100 daily through trips. Accordingly, the various types of intercenter connectors were assigned either 6, 3 or 1 points with little distortion of the end results.

## Assignment of Point Ratings to Highway Sections

The determination of the total number of combinations of intercenter connectors for each highway section was carried out graphically. All connectors between the various classes of centers were geographically located on separate transparent overlays and in different widths of line (Fig. 3). By placing these transparent overlays upon map of existing highways, the intercenter connectors served by each highway section were determined and a total point rating was computed, by assigning either 6, 3, or 1 points for each connector (Fig. 4).

Where the distance between two centers was so great that any travel desire between them would be insignificant, then their connector was excluded. This usually was done when the number of daily trips for a given connector fell below 20 percent of the average for that type of connector. This was established by referring to the available O-D data and using judgment when this data was incomplete.

TABLE 2

CONVERSION OF INTERCENTER TRIPS TO POINT RATINGS

| Intercenter Connector | Average Daily Through Trips | Point Rating |
|---|---|---|
| | Year 1954 | |
| M to M | 660 | 6 |
| M to A | 620 | |
| M to B | 610 | |
| A to A | 360 | 3 |
| M to C | 340 | |
| A to B | 310 | |
| A to C | 280 | |
| A to D | 160 | 1 |
| M to E | 120 | |
| M to D | 110 | |
| B to C | 100 | |
| Others | 100± | |

TABLE 3

| Highway Class | | Intercenter Point Rating Average | Range |
|---|---|---|---|
| Southern Ontario | Freeway | 35 | over 20 |
| | Trunkline | 4 | |
| | Major | 8 | 6 to 20 |
| | Minor | 3 | 1 to 5 |
| Northern Ontario | Trunkline | 3 | |
| | Major | 4 | over 3 |
| | Minor | 3 | 1 to 3 |
| All of Ontario | Freeway | 35 | over 20 |
| | Trunkline | 4 | |
| | Major | 5 | 4 to 20 |
| | Minor | 3 | 1 to 5 |

## Application to Classification

Finally, these results were related to the highway classification. Ranges of point ratings for each highway class were selected, containing most highway sections in the class (Table 3). Each route falling outside of the range of intercenter point ratings for its class was studied further for assignment to another class.

In this way a numerical intercenter point rating was established and utilized as a separate factor in the functional classification of the King's highway system.

# RURAL ACCESS SERVICE

Besides providing connections between population centers, provincial highways also serve rural populations. To be adequate a system of King's highways must give persons living in rural areas the opportunity to travel beyond their own localities on conveniently located routes.

The existing King's highway system was found to be generally satisfactory in this respect. The objective therefore was to establish, with minimum of changes, a highway system providing consistent service. Accordingly the following principle was adhered to: that the inhabitants of any rural area should have a King's highway as close as have the inhabitants of other rural areas with similar development. To study this characteristic the accessibility of King's highways was related to the density of rural population.

## Rural Population

The objective was to establish minimum qualifications for King's highways in agricultural regions where uniformity of population density exists. The chief criterion selected to indicate the economic development in these areas was the density of rural population. To Compute population densities published data for the townships of Ontario were used. (Not including populations in centers of 1,000 or over, or in suburban areas.)

By inspection five ranges of population density were established (Table 4).

TABLE 4

| Class | Population Density (per square mile) |
|---|---|
| Very high | over 50 |
| High | 35 to 49 |
| Average | 25 to 34 |
| Low | 10 to 24 |
| Very low | under 10 |

Regions with very low population densities, that is, with fewer than 10 persons per square mile, were excluded from further study. These sparsely settled rural areas contain little agricultural development, and other considerations, for example recreational land use, have greater importance in the evaluation of highway service.

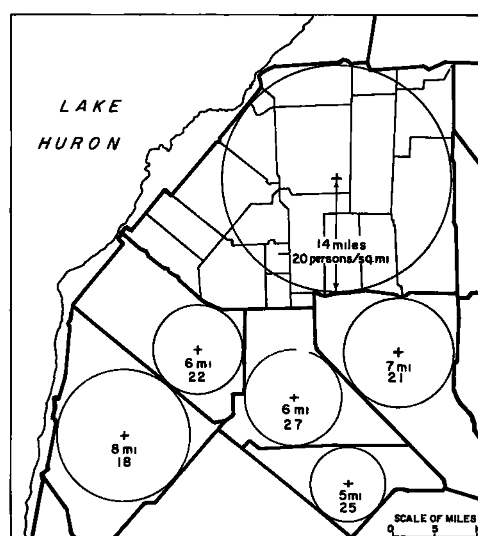



Figure 5. Rural access service; highway cells formed by King's highways are shown with rural population density and position of most remote point within them; county roads are shown in one cell.

## Highway Cells

The network of King's highways creates

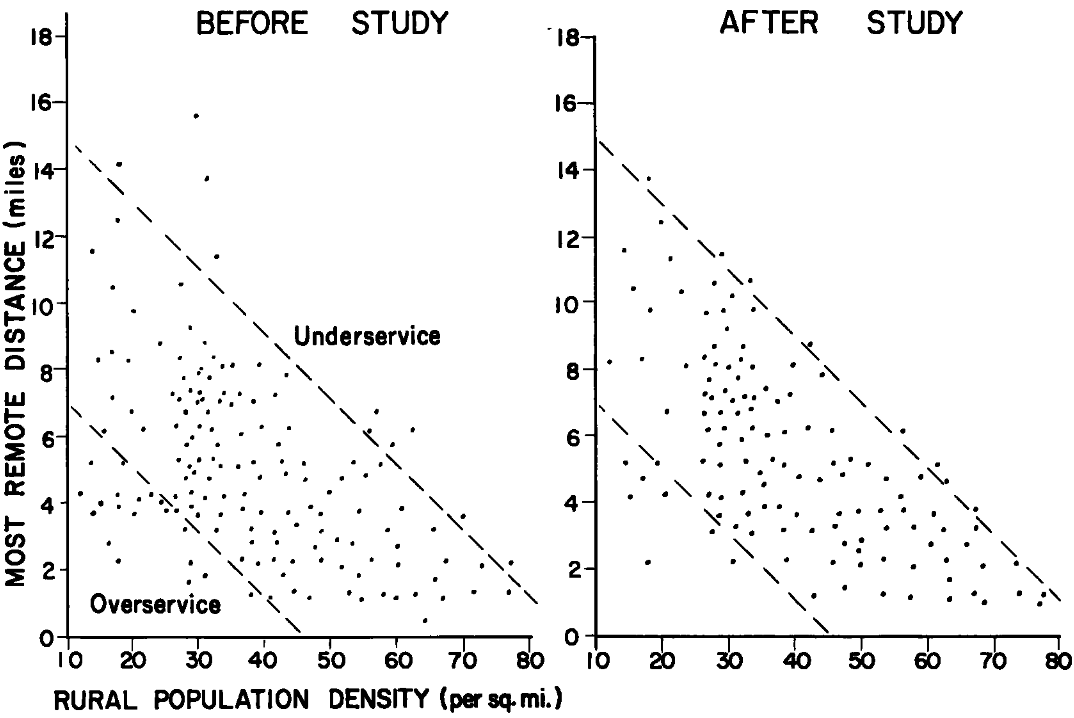



Figure 6. Relation of highway accessibility to population density.

what may be called highway cells, areas completely bounded either by highways alone or by highways and shorelines. Within each cell there may be any number of municipal roads, but no other King's highways. This highway cell was used as the unit of rural area (Fig. 5).

The chief measure of highway accessibility was taken as the distance in miles from the most remote point within each highway cell to the bounding highways. At the same time the effects were taken into account of such factors as the pattern of the internal network of municipal roads within each cell, and the locations of the nearest major market centers or traffic generators.

Finally, a useful tool in the classification process was prepared by plotting for each highway cell the most remote distance value against the population density. This may be referred to as the accessibility scatter diagram (Fig. 6).

## Application to Classification

The accessibility scatter diagram was useful in establishing minimum qualifications for King's highways in agricultural areas; that is, for setting the limits for feeder highways in these areas. It was utilized as a guide when making decisions concerning areas either overserviced or underserviced by King's highways.

## Overserviced Areas

In the route-by-route analysis of the King's highway system, when a particular highway rated relatively low for the usual service characteristics, such as traffic volume, intercenter service or otherwise, the scatter diagram was referred to. The accessibility of the adjoining areas was considered in relation to that of other areas of similar population density. If the accessibility distances indicated that the adjoining areas were overserviced, that is the accessibility distances were considerably shorter than for most similar areas, then the road was considered seriously for reversion or transfer to another system. If, on the other hand, removal of the route would cause the adjoining areas to have relatively large accessibility distances or become underserviced, then a strong argument existed for retaining the highway on the system.

TABLE 5

| Class | Population Density (per square mile) | Range of Remote Distances (mi.) |
|---|---|---|
| Very high | over 50 | under 5 |
| High | 35 to 49 | 4 to 7 |
| Average | 25 to 34 | 5 to 9 |
| Low | 10 to 24 | 7 to 11 |
| Very low | under 10 | over 10 |

## Underserviced Areas

To identify areas of relatively poor accessibility it was necessary to examine the scatter diagram and select the areas that had distances considerably larger than those for areas of similar population density. When these had been identified, each was studied in more detail and possible routes were considered for assumption in the highway system. When all factors pointed to the establishing of consistent service if one or more routes were assumed, then such assumptions were recommended. An important consideration was the desirability of keeping all changes to a minimum. Where a suggested change made similar changes necessary in other areas, then it was avoided if possible.

It was apparent that the ranges of remote distances varied by population density. That is, the lower the population density, the greater were the distances to the nearest highways. Upon inspection of prevailing service conditions in Ontario a series of ranges of prevailing remote distances for the different population density classes were selected (Table 5).

TABLE 6

| Highway Class | Miles | % | Traffic Volume[a] | Intercenter Point Rat'g. | Travel, % |
|---|---|---|---|---|---|
| **Southern Ontario** | | | | | |
| Freeway | 820 | 17 | 6,100 | 35 | 39 |
| Trunkline | 2,230 | 46 | 2,500 | 4 | 43 |
| Major | 600 | 12 | 3,800 | 8 | 18 |
| Minor | 1,630 | 34 | 2,000 | 3 | 25 |
| Feeder | 1,790 | 37 | 1,200 | -- | 18 |
| **Northern Ontario** | | | | | |
| Trunkline | 2,790 | 72 | 700 | 3 | 80 |
| Major | 1,470 | 38 | 800 | 4 | 48 |
| Minor | 1,320 | 34 | 600 | 3 | 32 |
| Feeder | 1,080 | 28 | 450 | -- | 20 |
| **All of Ontario** | | | | | |
| Freeway | 820 | 9 | 6,100 | 35 | 32 |
| Trunkline | 5,010 | 58 | 1,500 | 4 | 50 |
| Major | 2,060 | 24 | 1,670 | 5 | 23 |
| Minor | 2,950 | 34 | 1,370 | 3 | 27 |
| Feeder | 2,870 | 33 | 900 | -- | 18 |
| | 8,700 | | | | |

[a]1954 average daily traffic.

Since factors other than rural land access strongly affect the location of King's highways, such ranges were not analyzed statistically nor rigidly adhered to, and served only as a guide. However, comparison of the scatter diagrams for conditions before and after the study was completed show how a greater consistency of service was obtained for the areas having large remote distances. Those areas having small remote distances do not display the same conformity. This is expected since in many cases the highways in these areas must be retained for valid service reasons.

## FINAL CLASSIFICATION

With the aid of the above simple quantitative guides and of service criteria previously mentioned, a final King's highway classification was established (Table 6).

# Administrative Application of a Method of Road and Street Classification

JOHN D. CRUISE, Michigan State Highway Department

A method of rural road classification founded on the functional concept of highway service and operation has been used for classification purposes for more than ten years. It was found that all the populated places in the state could be put into five classes of different importance and that the relative importance of the connecting roads depended on the classified importance of the principal places connected.

In 1951 the method was adopted for the administration of Michigan's new highway legislation. County primary road and city and village major street systems were established in each county, city, and village. The mileage of these systems is one of the principal elements in the allocation to and use by local governments of state motor vehicle funds. Some local governments believe that there are considerable advantages to an extended system.

The extent of the principal road and street systems has been limited through the application of basic principles, guiding factors, and good intergovernmental relations.

● A METHOD founded on the functional concept of highway service and operation was discussed in "A Method of Rural Road Classification" (1). The idea of classifying roads and streets on the basis of relative traffic attraction was presented. The basic theory was stated in the paper:

1. Highways exist to serve the economic and social organization which consists of individual dwelling, farm, business, industrial, service, government, and other units, and successive accumulative groupings of these units into communities of increasing extent and function.

2. The organization functions by means of a constant movement of people and goods between and to the units and within and between the communities. The highways carrying these movements are classified by their predominant usage as determined by the character of the places they principally connect.

(a) Highways used predominantly for traffic movement between and to the various land-use units, are local highways.

(b) Highways used predominantly for traffic movement within communities, are community highways.

(c) Highways used predominantly for traffic movement between communities, are transportation highways.

3. The relative importance of a transportation highway is indicated by the degree and range of the traffic attraction exerted by the communities it principally connects; this traffic attraction, in turn, is governed by the magnitude of the communities' operations and resources, and by the extent to which these operations and resources integrated with those of other communities.

The paper described how, with the fundamental concept, various types of economic and traffic data were used to establish the relative traffic attraction of some 1,300 populated places in Michigan. It then described how the classification of places was used to classify the state's primary and secondary roads.

The research described in the paper was carried out (1) to classify all the places in the state on the basis of traffic attraction for road and street classification, and (2) to identify readily available social economic data and analytical procedures that will produce comparable classification of places—the latter to be used in other states and to reclassify Michigan places in an expanding and shifting economy.

It was found that all of the places in Michigan from Detroit to the least important neighborhood center could be classified in groups of similar importance by the intensity of their traffic attraction. Ten place groups were identified. They were combined to form 5 classes with two place groups in each class:

Class I, metropolitan centers;
Class II, regional centers;
Class III, intermediate market centers;
Class IV, minor market centers; and
Class V, neighborhood centers.

It was found that the populated groups can be classified and placed in five classes of relative importance using one or more of the following indices: (1) population of the immediate retail trade area; (2) assessed valuation; (3) a measure of banking resources; (4) newspaper circulation; and (5) retail trade of the place.

With minor exceptions due to inconsistencies in the indices the populated places fell in the same groups as with using the traffic attraction index.

The study in highway classification concluded that place Classes I, II, and III are of sufficient statewide importance to be served by the state trunkline system. Class IV and Class V are locally important and can be served by county primary roads. Studies in Illinois (2) and Maine (3) following similar principles have reached the same conclusion.

A minimum mileage highway transportation system can be laid out for each place group by connecting the places with desire lines and the selection of routes to serve the connecting desire lines. This task done in order of diminishing importance provides the basic framework to guide system selection and to judge the merits of each route designated in an integrated system.

The principles of that study in road and street classification were adopted and used in 1947 by the Highway Study Committee of the Michigan Good Roads Federation for the classification of roads and streets. The results were incorporated as a fundamental part of the 1948 report "Highway Needs in Michigan."

The work performed and the leadership exercised by the 1947-1948 Highway Study Committee, resulted in the 1951 Michigan Legislature enacting Act 51 of the Public Acts of 1951—an act to: Provide for the classification of all roads, streets and highways; establish a motor vehicle highway fund; provide for the allocation of money therefrom and the administration thereof for highway purposes. The act stipulated an annual progress report to the governor and the state legislature. The administrative features of this act are considered among the most progressive.

The state highway commissioner designated his special assignment engineer to administer for him, all clauses of the act pertaining to counties and incorporated cities and villages. A local government section was organized in the executive division to do the work.

This paper describes the results of that work in the area of road and street classification. The Michigan procedures are founded on the premise that the agency, group, or individual jurisdictionally responsible for a system of roads or streets should initiate all actions pertaining to their administration, operation and improvement. The administration requires that the local government section give guidance and review and approve specific actions. The local officials are expected to justify each action where approval is sought.

To conform with the requirements of the act and provide system mileage figures for allocation purposes, it was necessary to classify by July 1, 1952, all of the public roads and streets in the 83 counties and the 488 incorporated cities and villages.

In nine months, the local officials designated, certified and submitted their road and street systems and mileages. The systems and mileages were reviewed by the staff of the local government section. Adjustments of differences were made with local officials and the mutually agreed upon systems were approved for the state highway commissioner so that the mileage figures could be used for all purposes of the act after July 1, 1952.

Further adjustments have been made in subsequent annual recertifications and approvals when reconsideration is given to each road ans street system.

The mileages of the road and street systems are used in the formulas to allocate the motor vehicle highway funds to the counties and to the cities and villages. The funds are restricted to use on the respective road and street systems for consturction and maintenance. Each county, city, and village is required to submit for approval each year a biennial construction program for each system based on a long range development plan. They are required to report the progress made each year in the development of the respective systems and the mileage and condition of each system. Furthermore, they are required to submit an annual report of all receipts and disbursements for highway purposes for each system. The road and street systems are the means of administrating the local government phases of the act.

County Primary Road Systems

The county road officials had experience with highway classification. The original county road act of 1893 had generated many model county primary road systems. There had been several selections of federal aid secondary systems. They had selected a system of county primary roads for the 1946 highway study. They had been furnished all the information available: (1) a classification of all the populated places in the county; (2) a map of a possible minimum highway transportation system in the county; (3) available traffic information on the transportation, roads; and (4) an explanation of highway classification and its objectives with qualifying criteria including reasonable spacing.

They were familiar with the principles. They had selected a county primary road system for the highway study. They certified these systems with additions, some of which were not justified. Where these were identified they were reviewed with local officials and many deletions were made before the systems were approved. Some of the road commissions felt they should be conservative in the selection and certification of primary roads taking additional roads into the system as they could be improved. Other commissions felt that they could better satisfy their constituents by expansion of the primary road system.

The results of some 15 years of rural road classification are given in Table I. Comparisons are made of county primary road mileages for each county in county groups of similar economy.

The greatest variations occur between administrative mileages for 1956 and the general purpose highway formula. The latter is a formula using available social-economic data. It was adopted to limit the mileages of federal secondary routes in any county. The least variation occurs between the 1955 highway study mileages and the 1956 administrative mileages. The latter is evidence that there is very close agreement of transportation highways identified for highway study purposes and for the administration of the county primary road systems. The two sets of mileage figures were formulated with the same basic principles and were designated by engineers and administrators with similar backgrounds. The comparison between the administrative system figures and the historic figures are evidence that land area and population are the principal factors contributing to the need for rural roads. They provide excellent indices to guide system selection and for other phases of county road administration.

The following excerpt from the Michigan administrative procedure serves to define the transportation routes that comprise the 83 county primary road systems. Section 2, Public Acts of 1951, as amended, provides that the primary roads shall be selected on the basis of their greatest general importance to the county. Roads which meet these qualifications and promote the general over-all economy of the county conform to the following definitions.

Primary roads connect the centers of traffic interest (such as cities, villages, unincorporated communities or trade centers, rural industries, consolidated schools and other public institutions, and large auction centers) with each other, with other more important regional trading centers, with other important primary roads and with state trunklines

In rural agricultural areas the centers of traffic interest should be connected by extending the roads in the four cardinal directions from these centers. In sparsely populated areas, the routes may follow existing diagonal roads but should be so located as to provide a minimum of mileage and still serve the existing and potential uses of the land.

TABLE 1

MICHIGAN RURAL COUNTY PRIMARY ROAD SYSTEM MILEAGE IN 1952 AND 1956 COMPARED WITH FORMULA AND HIGHWAY STUDY MILEAGES BY COUNTIES IN GROUPS OF SIMILAR ECONOMY

| Group and County | Total County Rural Road Mileage | 1956 Actual | | 1952 Actual | Formula Based on Highway Needs Study | | | | Inverse Ratio of Actual 1956 County Primary Road Mileage | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 1952 | Formula Based on Highway Study | | | |
| | | % Total | Miles | Miles | Averages | Social Economic | 1947 | 1955 | Actual | Averages | Social Economic | 1947 | 1955 |
| (a) UPPER PENINSULA COUNTIES | | | | | | | | | | | | | |
| Alger | 450 | 31 | 141 | 161 | 142 | 157 | 142 | 142 | 1 14 | 1 01 | 1 11 | 1 01 | 1 01 |
| Baraga | 455 | 27 | 123 | 108 | 121 | 68 | 62 | 119 | 88 | 98 | 55 | 50 | 97 |
| Chippewa | 1,230 | 25 | 307 | 320 | 320 | 433 | 433 | 303 | 1 04 | 1 04 | 1 41 | 1 41 | 99 |
| Delta | 838 | 41 | 341 | 340 | 326 | 330 | 323 | 318 | 1 00 | 96 | 97 | 95 | 93 |
| Dickinson | 534 | 31 | 167 | 157 | 164 | 186 | 185 | 166 | 94 | 98 | 1 11 | 1 11 | 99 |
| Gogebic | 497 | 41 | 204 | 195 | 193 | 213 | 200 | 209 | 96 | 95 | 1 04 | 98 | 1 02 |
| Houghton | 911 | 33 | 303 | 306 | 311 | 263 | 251 | 312 | 1 01 | 1 03 | 87 | 83 | 1 03 |
| Iron | 598 | 40 | 240 | 235 | 238 | 239 | 141 | 239 | 98 | 99 | 99 | 59 | 1 00 |
| Keweenaw | 154 | 55 | 84 | 81 | 82 | 92 | 91 | 116 | 96 | 98 | 1 10 | 1 08 | 1 38 |
| Luce | 354 | 36 | 128 | 121 | 129 | 149 | 123 | 128 | 95 | 1 01 | 1 16 | 96 | 1 00 |
| Mackinac | 613 | 28 | 171 | 171 | 172 | 187 | 121 | 164 | 1 00 | 1 01 | 1 09 | 71 | 96 |
| Marquette | 1,263 | 22 | 275 | 270 | 275 | 270 | 275 | 276 | 98 | 1 00 | 98 | 1 00 | 1 00 |
| Menominee | 1,199 | 36 | 432 | 424 | 431 | 388 | 388 | 419 | 98 | 1 00 | 90 | 90 | 97 |
| Ontonagon | 533 | 44 | 235 | 184 | 193 | 195 | 198 | 214 | 78 | 82 | 83 | 84 | 91 |
| Schoolcraft | 377 | 42 | 160 | 180 | 157 | 174 | 186 | 161 | 1 13 | 98 | 1 09 | 1 16 | 1 01 |
| Total | 10,006 | 33 | 3,311 | 3,253 | 3,254 | 3,344 | 3,119 | 3,286 | 98 | 98 | 1 01 | 94 | 99 |
| (b) NORTHERN MICHIGAN COUNTIES | | | | | | | | | | | | | |
| Alcona | 685 | 19 | 133 | 132 | 168 | 179 | 159 | 123 | 99 | 1 26 | 1 35 | 1 20 | 92 |
| Alpena | 615 | 29 | 181 | 165 | 227 | 172 | 176 | 168 | 91 | 1 25 | 95 | 97 | 93 |
| Antrim | 817 | 24 | 194 | 191 | 157 | 179 | 179 | 195 | 98 | 81 | 92 | 92 | 1 01 |
| Arenac | 585 | 23 | 133 | 132 | 154 | 133 | 134 | 130 | 99 | 1 16 | 1 00 | 1 01 | 98 |
| Benzie | 592 | 27 | 161 | 148 | 118 | 162 | 160 | 153 | 92 | 73 | 1 01 | 99 | 95 |
| Charlevoix | 726 | 22 | 162 | 161 | 166 | 208 | 204 | 162 | 99 | 1 02 | 1 28 | 1 26 | 1 00 |
| Cheboygan | 1,026 | 18 | 188 | 223 | 214 | 229 | 234 | 189 | 1 19 | 1 14 | 1 22 | 1 25 | 1 01 |
| Clare | 888 | 24 | 210 | 200 | 188 | 182 | 179 | 199 | 95 | 90 | 87 | 85 | 95 |
| Crawford | 647 | 20 | 131 | 155 | 115 | 144 | 136 | 152 | 1 18 | 88 | 1 10 | 1 04 | 1 16 |
| Emmet | 805 | 25 | 198 | 197 | 182 | 184 | 176 | 199 | 99 | 92 | 93 | 89 | 1 01 |
| Gladwin | 739 | 25 | 184 | 160 | 183 | 151 | 152 | 170 | 87 | 99 | 82 | 83 | 92 |
| Grand Traverse | 834 | 25 | 211 | 197 | 194 | 201 | 197 | 201 | 93 | 92 | 95 | 93 | 95 |
| Iosco | 813 | 20 | 160 | 132 | 190 | 196 | 198 | 139 | 83 | 1 19 | 1 23 | 1 24 | 87 |
| Isabella | 1 138 | 28 | 320 | 317 | 302 | 315 | 286 | 312 | 99 | 94 | 98 | 89 | 98 |
| Kalkaska | 885 | 24 | 215 | 220 | 163 | 216 | 222 | 189 | 1 02 | 76 | 1 00 | 1 03 | 88 |
| Lake | 921 | 24 | 225 | 211 | 176 | 236 | 237 | 217 | 94 | 78 | 1 05 | 1 05 | 96 |
| Leel nau | 615 | 26 | 162 | 142 | 126 | 150 | 145 | 138 | 88 | 78 | 93 | 90 | 85 |
| Manistee | 1,067 | 21 | 222 | 221 | 204 | 225 | 231 | 226 | 1 00 | 92 | 1 01 | 1 04 | 1 02 |
| Mason | 917 | 19 | 177 | 173 | 229 | 207 | 210 | 176 | 98 | 1 29 | 1 17 | 1 19 | 99 |
| Mecosta | 1,157 | 23 | 270 | 262 | 243 | 270 | 271 | 273 | 97 | 90 | 1 00 | 1 00 | 1 01 |
| Midland | 790 | 32 | 253 | 264 | 284 | 237 | 222 | 255 | 1 04 | 1 12 | 94 | 88 | 1 01 |
| Missaukee | 972 | 19 | 188 | 189 | 210 | 215 | 217 | 189 | 1 01 | 1 12 | 1 14 | 1 15 | 1 01 |
| Montcalm | 1,491 | 23 | 336 | 325 | 303 | 340 | 340 | 338 | 97 | 90 | 1 01 | 1 01 | 1 01 |
| Montmorency | 648 | 23 | 148 | 144 | 174 | 155 | 157 | 150 | 97 | 1 18 | 1 05 | 1 06 | 1 01 |
| Newaygo | 1,589 | 17 | 267 | 261 | 327 | 344 | 325 | 263 | 98 | 1 23 | 1 29 | 1 22 | 99 |
| Oceana | 1,118 | 21 | 232 | 227 | 252 | 250 | 237 | 217 | 98 | 1 09 | 1 08 | 1 02 | 94 |
| Ogemaw | 765 | 30 | 227 | 223 | 203 | 236 | 217 | 226 | 98 | 89 | 1 04 | 96 | 1 00 |
| Osceola | 920 | 19 | 179 | 172 | 188 | 180 | 181 | 173 | 96 | 1 05 | 1 00 | 1 01 | 97 |
| Oscoda | 659 | 19 | 124 | 118 | 160 | 141 | 134 | 119 | 95 | 1 29 | 1 14 | 1 08 | 96 |
| Otsego | 742 | 23 | 172 | 172 | 176 | 171 | 158 | 171 | 1 00 | 1 02 | 99 | 92 | 99 |
| Presque Isle | 712 | 25 | 178 | 177 | 185 | 192 | 221 | 178 | 99 | 1 04 | 1 08 | 1 24 | 1 00 |
| Roscommon | 804 | 15 | 118 | 123 | 133 | 134 | 112 | 105 | 1 04 | 1 13 | 1 14 | 99 | 89 |
| Wexford | 944 | 17 | 162 | 153 | 190 | 141 | 142 | 158 | 94 | 1 17 | 87 | 88 | 98 |
| Total | 28,626 | 22 | 6,421 | 6,287 | 6,484 | 6,675 | 6,549 | 6,253 | 98 | 1 01 | 1 04 | 1 02 | 97 |
| (c) SOUTHERN MICHIGAN AGRICULTURAL COUNTIES | | | | | | | | | | | | | |
| Allegan | 1,814 | 24 | 443 | 415 | 415 | 424 | 411 | 419 | 94 | 94 | 96 | 93 | 95 |
| Barry | 1,066 | 27 | 286 | 269 | 245 | 290 | 280 | 275 | 94 | 86 | 1 01 | 98 | 96 |
| Branch | 947 | 31 | 298 | 297 | 262 | 284 | 279 | 294 | 1 00 | 88 | 95 | 94 | 99 |
| Cass | 969 | 25 | 245 | 234 | 225 | 300 | 199 | 233 | 96 | 92 | 1 22 | 81 | 95 |
| Clinton | 1,107 | 27 | 297 | 288 | 321 | 262 | 268 | 299 | 97 | 1 08 | 88 | 90 | 1 01 |
| Eaton | 1,043 | 29 | 304 | 293 | 257 | 297 | 316 | 300 | 96 | 85 | 98 | 1 04 | 99 |
| Gratiot | 1,194 | 29 | 351 | 349 | 287 | 289 | 293 | 351 | 99 | 82 | 82 | 83 | 1 00 |
| Hillsdale | 1,117 | 26 | 292 | 290 | 253 | 312 | 313 | 290 | 99 | 87 | 1 07 | 1 07 | 99 |
| Huron | 1,594 | 17 | 269 | 269 | 309 | 333 | 329 | 268 | 1 00 | 1 15 | 1 24 | 1 22 | 1 00 |
| Ionia | 1,086 | 30 | 328 | 310 | 263 | 301 | 284 | 320 | 95 | 80 | 92 | 87 | 98 |
| Lapeer | 1,231 | 24 | 301 | 298 | 314 | 288 | 279 | 298 | 99 | 1 04 | 96 | 93 | 99 |
| Lenawee | 1,497 | 30 | 448 | 435 | 348 | 406 | 389 | 450 | 97 | 78 | 91 | 87 | 1 00 |
| Livingston | 1,061 | 28 | 296 | 294 | 278 | 303 | 280 | 297 | 99 | 94 | 1 02 | 95 | 1 00 |
| Sanilac | 1,776 | 14 | 251 | 253 | 315 | 384 | 374 | 251 | 1 01 | 1 26 | 1 53 | 1 49 | 1 00 |
| Shiawassee | 1,043 | 28 | 295 | 305 | 287 | 238 | 249 | 299 | 1 03 | 97 | 81 | 84 | 1 01 |
| St Joseph | 972 | 33 | 317 | 363 | 217 | 247 | 249 | 298 | 1 15 | 69 | 78 | 79 | 94 |
| Tuscola | 1,593 | 18 | 279 | 266 | 340 | 333 | 318 | 269 | 95 | 1 22 | 1 19 | 1 14 | 96 |
| Van Buren | 1,254 | 25 | 313 | 312 | 289 | 320 | 283 | 327 | 1 00 | 92 | 1 02 | 90 | 1 04 |
| Total | 22,364 | 25 | 5,613 | 5,540 | 5,225 | 5,611 | 5,393 | 5,538 | 99 | 93 | 1 00 | 96 | 99 |
| (d) SOUTHERN MICHIGAN INDUSTRIAL COUNTIES | | | | | | | | | | | | | |
| Bay | 996 | 29 | 291 | 294 | 299 | 224 | 221 | 288 | 1 01 | 1 03 | 77 | 76 | 99 |
| Berrien | 1,298 | 34 | 439 | 410 | 382 | 271 | 278 | 389 | 93 | 87 | 62 | 63 | 89 |
| Calhoun | 1,326 | 34 | 452 | 458 | 435 | 417 | 484 | 446 | 1 01 | 96 | 92 | 1 07 | 99 |
| Jackson | 1,412 | 35 | 493 | 459 | 413 | 445 | 438 | 488 | 93 | 84 | 90 | 89 | 99 |
| Kalamazoo | 1,210 | 34 | 407 | 414 | 435 | 331 | 330 | 417 | 1 01 | 1 07 | 81 | 81 | 1 02 |
| Monroe | 1,197 | 30 | 356 | 320 | 356 | 265 | 247 | 335 | 90 | 1 00 | 74 | 69 | 94 |
| Muskegon | 1,203 | 31 | 369 | 335 | 359 | 280 | 285 | 367 | 91 | 97 | 76 | 77 | 99 |
| Ottawa | 1,399 | 26 | 360 | 340 | 377 | 356 | 353 | 361 | 94 | 1 05 | 99 | 98 | 1 00 |
| St Clair | 1,499 | 28 | 415 | 411 | 381 | 395 | 346 | 422 | 99 | 92 | 95 | 83 | 1 02 |
| Washtenaw | 1,350 | 32 | 434 | 428 | 433 | 463 | 498 | 433 | 99 | 1 00 | 1 07 | 1 15 | 1 00 |
| Total | 12,890 | 31 | 4,016 | 3,869 | 3,870 | 3,447 | 3,480 | 3,946 | 96 | 96 | 86 | 87 | 98 |
| Genesee | 1,402 | 30 | 415 | 374 | 494 | 370 | 350 | 397 | 90 | 1 19 | 89 | 84 | 96 |
| Ingham | 1,154 | 31 | 362 | 333 | 401 | 300 | 286 | 348 | 92 | 1 11 | 83 | 79 | 96 |
| Kent | 2,010 | 30 | 599 | 590 | 533 | 548 | 546 | 592 | 98 | 89 | 91 | 91 | 99 |
| Macomb | 1,270 | 27 | 341 | 317 | 441 | 281 | 287 | 311 | 93 | 1 29 | 82 | 84 | 91 |
| Oakland | 2,391 | 25 | 595 | 602 | 678 | 524 | 503 | 676 | 1 01 | 1 14 | 88 | 85 | 1 14 |
| Saginaw | 1,647 | 24 | 393 | 383 | 427 | 353 | 362 | 371 | 97 | 1 09 | 90 | 92 | 94 |
| Total | 9 874 | 27 | 2,705 | 2,599 | 2,974 | 2,376 | 2,334 | 2,695 | 96 | 1 10 | 88 | 86 | 1 00 |
| (e) MISCELLANEOUS | | | | | | | | | | | | | |
| Wayne | 1,557 | 30 | 463 | 448 | 577 | 468 | 459 | 495 | 97 | 1 25 | 1 01 | 99 | 1 07 |
| Grand Total | 85,317 | 26 | 22,529 | 21,996 | 22,384 | 21,921 | 21,334 | 22,213 | 98 | 99 | 97 | 95 | 99 |

Also of primary road importance are the collector-distributor routes which supplement the basic grid network to provide complete access to centers of traffic interest and to provide adequate intra-county and inter-county mobility. These roads should be laid out on a rectangular grid pattern. Although traffic volumes should serve as a guide in the selection of a route, they are not necessarily a controlling factor.

In the rural agricultural areas, the routes should be spaced from three to four miles apart. In the highly developed residential areas surrounding metropolitan centers, routes spaced one mile apart may be justified. In the sparsely settled areas, the uses made of the land should be the controlling factor in establishing the need for collector-distributor routes.

Topographical conditions must be considered in the location analysis of each roadway section. In general, large developed lakes may require additional primary routes around their shores and wide rivers may require routes along both sides. The location of large industries, auction centers, public institutions, parks, etc., may also increase the need for additional routes.

## City and Village Major Street Systems

Most of this paper is devoted to the principles of rural road classification, related studies and a 5-year experience with the administration of 83 county primary road systems. In general, the same principles can be applied to the task of identifying and segregating the city and village streets that are the more important for transportation service.

In 1951 the city officials, governing bodies, mayors, directors of public work, city engineers, and village clerks had little background in the field of street classification. There was very little information available and few cities had traffic information or city plans to guide them.

The city officials were given instructions and criteria for selecting their major street systems and establishing their street mileage. They were obliged to furnish their own maps and establish new mileage records. They were requested to designate, certify and submit a system of major streets with the mileage of the certified major streets and the local streets along with all supporting data available.

TABLE 2

COMPARISON OF MAJOR STREET MILEAGE ON JULY 1, 1952 AND ON JULY 1, 1956 BY POPULATION GROUPS

| Population Group | Number of Places | | Major St Mileage | | Total St Mileage | | Percent Major St | | Difference |
|---|---|---|---|---|---|---|---|---|---|
| | 1952 | 1956 | 1952 | 1956 | 1952 | 1956 | 1952 | 1956 | |
| State Totals | 488 | 501 | 3,329 74 | 3,734 05 | 12,252 15 | 13,514 39 | 27 2 | 27 6 | 0 4 |
| 1,000,000 and over | 1 | 1 | 574 98 | 608 04 | 2,447 53 | 2,630 10 | 23 5 | 23 1 | 0 4 |
| 100,000-250,000 | 2 | 2 | 229 99 | 238 55 | 858 56 | 871 75 | 26 8 | 27 4 | 0 6 |
| Group Average | | | 115 00 | 119 28 | 429 29 | 435 88 | 26 8 | 27 4 | |
| 50,000-100,000 | 7 | 7 | 364 93 | 399 94 | 1,392 46 | 1,451 58 | 26 2 | 27 6 | 1 4 |
| Group Average | | | 52 13 | 57 13 | 198 92 | 207 38 | 26 2 | 27 6 | |
| 25,000-50,000 | 10 | 10 | 289 56 | 313 64 | 1,055 09 | 1,105 06 | 27 4 | 28 4 | 1 0 |
| Group Average | | | 28 96 | 31 36 | 105 51 | 110 51 | 27 4 | 28 4 | |
| 20,000-25,000 | 4 | 5 | 47 11 | 62 05 | 183 84 | 268 52 | 25 6 | 23 1 | -2 5 |
| Group Average | | | 11 78 | 12 41 | 45 96 | 53 70 | 25 6 | 23 1 | |
| 15,000-20,000 | 19 | 20 | 331 96 | 380 84 | 1,268 60 | 1,517 77 | 26 2 | 25 1 | -1 1 |
| Group Average | | | 17 47 | 19 04 | 66 77 | 75 89 | 26 2 | 25 1 | |
| 10,000-15,000 | 13 | 13 | 175 48 | 193 44 | 615 48 | 709 12 | 28 5 | 27 3 | -1 2 |
| Group Average | | | 13 50 | 14 88 | 47.35 | 54 55 | 28 5 | 27 3 | |
| 5,000-10,000 | 37 | 37 | 344 00 | 384 01 | 1,197 77 | 1,365 39 | 28 7 | 28 1 | -0 6 |
| Group Average | | | 9 30 | 10 38 | 32 37 | 36 90 | 28 7 | 28 1 | |
| 2,500-5,000 | 47 | 50 | 255 14 | 308 16 | 869 70 | 976 22 | 29 3 | 31 6 | 2 3 |
| Group Average | | | 5 43 | 6 16 | 18 51 | 19 52 | 29 3 | 31 6 | |
| 2,000-2,500 | 29 | 30 | 107 66 | 122 88 | 374 05 | 426 06 | 28 8 | 28 8 | -- |
| Group Average | | | 3 71 | 4 10 | 12 90 | 14 20 | 28 8 | 28 8 | |
| 1,500-2,000 | 41 | 43 | 125 10 | 152 98 | 448 73 | 502 79 | 27 9 | 30 4 | 2 5 |
| Group Average | | | 3 05 | 3 56 | 10 94 | 11 69 | 27 9 | 30 4 | |
| 1,000-1,500 | 57 | 58 | 128 86 | 153 16 | 452 32 | 500 51 | 28 5 | 30 6 | 2 1 |
| Group Average | | | 2 26 | 2 64 | 7 94 | 8 63 | 28 5 | 30 6 | |
| 500-1,000 | 101 | 104 | 188 34 | 230 80 | 599 80 | 682 22 | 31 4 | 33 8 | 2 4 |
| Group Average | | | 1 86 | 2 22 | 5 93 | 6 56 | 31 4 | 33 8 | |
| 0-500 | 120 | 121 | 166 63 | 185 56 | 488 22 | 507 30 | 34 1 | 36 6 | 2 5 |
| Group Average | | | 1 39 | 1 53 | 4 07 | 4 19 | 34 1 | 36 6 | |

The initially submitted street systems were reviewed in the office by the staff. It was found desirable to check each major street system in the field and where necessary make adjustments with the local officials. Upon the return to the office, each adjusted major street system was reviewed by the section head with the field representative. These reviews supplemented with staff conferences accomplished a consistent treatment of large cities, small cities, and villages.

The field work included a general inventory of principal land uses. These were recorded on a map of the village with supplemental notes. This information was background and the justification for the designation of major streets. This information in files has been useful in judging the merits of proposed changes in and additions to the major street system. In many instances proposed changes can be approved without a field investigation.

Table 2 is a comparison by population groups of the average major street mileage, approved in 1956. The figures show the expansion of cities and the evidence that the extent of major street systems can be limited through good administrative procedures using sound basic principles. From 1952 to 1956 the major street systems have only increased by 0.4 percent. The detail of the figures shows that this increase occurred in the smaller places.

In the initial submission in 1951, the smaller cities and villages had difficulty in dividing their streets into major and local street systems. This resulted in over emphasis of the importance of many local streets and submission of nearly 100 percent major street systems. To accomplish the tasks of completing the review of 488 city and village street systems required the services of additional personnel who had to be trained in the classification procedures. These field representatives were instructed to hold the percentage of major streets to a minimum. In many instances these instructions were over applied and resulted in some inequities which have been gradually corrected.

Table 3 is a comparison of arterial street mileage by population groups, July 1, 1952 and July 1, 1956 and shows more clearly the changes that have occurred in the 5-year period. Arterial street mileage is the combined mileage of state trunklines, county primary roads, and major streets. When all the arterial streets are taken into account, it appears that the percentage has decreased by 0.2 since 1952.

TABLE 3

COMPARISON OF ARTERIAL STREET MILEAGE ON JULY 1, 1952 AND ON JULY 1, 1956 BY POPULATION GROUPS

| Population Group | Number of Places | | Arterial St Mileage | | Total St Mileage | | Percent Arterial St | | Difference |
|---|---|---|---|---|---|---|---|---|---|
| | 1952 | 1956 | 1952 | 1956 | 1952 | 1956 | 1952 | 1956 | |
| State Totals | 488 | 501 | 4,855 25 | 5,274 10 | 13,798 34 | 15,085 28 | 35 2 | 35 0 | -0 2 |
| 1,000,000 and over | 1 | 1 | 743 47 | 779 30 | 2,616 02 | 2,802 59 | 28 4 | 27 8 | -0 6 |
| 100,000-250,000 | 2 | 2 | 276 59 | 280 27 | 905 16 | 913 47 | 30 6 | 30 7 | 0 1 |
| Group Average | | | 138 30 | 140 14 | 452 59 | 456 74 | 30 6 | 30.7 | |
| 50,000-100,000 | 7 | 7 | 509 35 | 533 39 | 1,536 88 | 1,586 45 | 33 1 | 33 6 | 0 5 |
| Group Average | | | 72 76 | 76 20 | 219 55 | 226 63 | ---- | 33 6 | |
| 25,000-50,000 | 10 | 10 | 389 91 | 410 75 | 1,155 44 | 1,203 65 | 33 7 | 34 1 | 0 4 |
| Group Average | | | 38 99 | 41 08 | 115 55 | 120 36 | 33 7 | 34 1 | |
| 20,000-25,000 | 4 | 5 | 67 27 | 92 93 | 204 00 | 300 30 | 33 0 | 30 9 | -2 1 |
| Group Average | | | 16 83 | 18 59 | 51 01 | 60 06 | 33 0 | 30 9 | |
| 15,000-20,000 | 19 | 20 | 510 86 | 570 31 | 1,447 80 | 1,712 44 | 35 3 | 33 3 | -2 0 |
| Group Average | | | 26 89 | 28 52 | 76 19 | 85 62 | 35 3 | 33 3 | |
| 10,000-15,000 | 13 | 13 | 252 05 | 306 27 | 692 15 | 822 47 | 36 4 | 37 2 | 0 8 |
| Group Average | | | 19 39 | 23 56 | 53 24 | 63 27 | 36.4 | 37 2 | |
| 5,000-10,000 | 37 | 37 | 512 59 | 545 41 | 1,375 56 | 1,536 78 | 37 3 | 35 5 | -1.8 |
| Group Average | | | 13 85 | 14.74 | 37 17 | 41 54 | 37 3 | 35 5 | |
| 2,500-5,000 | 47 | 50 | 395 26 | 448 40 | 1,010 12 | 1,117 46 | 39.1 | 40 1 | 1 0 |
| Group Average | | | 8 41 | 9 87 | 21 49 | 22 35 | 39 1 | 40 1 | |
| 2,000-2,500 | 29 | 30 | 171 67 | 186 21 | 438 66 | 489 61 | 39 1 | 38 0 | -1 1 |
| Group Average | | | 5 92 | 6 21 | 15 13 | 16 32 | 39 1 | 38 0 | |
| 1,500-2,000 | 41 | 43 | 198 00 | 224.22 | 522 03 | 575 74 | 37 9 | 38 9 | 1 0 |
| Group Average | | | 4 83 | 5 21 | 12 73 | 13 39 | 37 9 | 38 9 | |
| 1,000-1,500 | 57 | 58 | 288 73 | 253 93 | 554 19 | 604 50 | 41 3 | 42 0 | 0 7 |
| Group Average | | | 4 01 | 4 48 | 9 72 | 10 42 | 41 3 | 42 0 | |
| 500-1,000 | 101 | 104 | 325 56 | 358 33 | 742 12 | 812 23 | 43 9 | 44 1 | 0 2 |
| Group Average | | | 3 22 | 3 45 | 7 35 | 7.81 | 43 9 | 44 1 | |
| 0-500 | 120 | 121 | 273 94 | 284 38 | 598.21 | 607 59 | 45 8 | 46 8 | 1 0 |
| Group Average | | | 2 28 | 2 35 | 4 98 | 5 02 | 45 8 | 46 8 | |

The table presented here is a summary. It shows the averaged changes. The detail table giving the mileage values and ratios for each city and village is useful as a guide in controlling the mileage of major streets. Should the percentage of major streets for the place be low, the group figure indicates a liberal attitude can be applied. Should the percentage of major streets be high, a thorough review of the qualifications of all streets in the system should be made.

The following excerpt from the Michigan administrative procedures defines the transportation streets that comprise the 501 major street systems: "Major streets are the streets of greatest general importance in each city and village. They are the streets that serve relatively high traffic volumes and lead to or connect with other streets that lead to areas where people go and congregate for commercial, occupational, industrial, medical, social, recreational and educational activities. These major city and village streets integrate with the state trunkline routes and county primary roads to form in each city and village a system of streets that serve the traffic generating centers and the principal requirements of motor vehicle highway transportation. They are the streets serving the following requirements of motor vehicle highway transportation:

"1. Extensions of rural state trunklines and county primary roads leading directly to the central business district and to other important traffic generating centers.

"2. Streets connecting the industrial centers with other major streets and with other related industries and transportation terminal facilities.

"3. Streets that connect the principal transportation terminals and warehouse areas with other major streets, state trunklines and county primary roads.

"4. Streets that are designated as truck routes for through traffic and between important traffic centers within the municipality.

"5. Streets that are operated for a considerable distance as one-way traffic.

"Streets serving the following requirements of motor vehicle highway transportation may be major streets when warranted by the kind and quantity of traffic served:

"1. Streets that provide direct connections between other major streets and large educational institutions which attract considerable passenger car or school bus traffic.

"2. Streets that are used by traffic and are closely parallel to traffic congested major streets.

"3. Streets that provide for the circulation of traffic in and around the central business district.

"4. Streets providing direct connections between other major streets and hospitals, parking lots, industries, parks and other centers of comparable activity.

"5. Streets that are judged to be desirable for development as major streets."

## Summary and Conclusion

This discussion has covered a few points in a 15-year experience in the area of road and street classification. The experience began in an effort to find a formula using social economic factors to guide the limitation of federal aid secondary mileage in each county. It was followed by the arbitrary designation of federal aid secondary systems. The initial systems were established without the knowledge or sanction of the jurisdictionally responsible county officials. When the extent and character of the systems became known to the county authorities their protests were so great that approval of the system had to be cancelled.

This pointed to the need for the development of a practical method of road and street classification with principles and criteria that would be accepted and used by county road officials. The method described in this paper was adopted and put into use in the selection of a partial federal aid secondary system in 1945. (4) With the principles, criteria, and visual data the counties selected the FAS systems in cooperation with the department representative. The department representative was a person of outstanding background, highway engineering and administration experience with an excellent ability in the field of government relations. Within a year the county officials reversed their attitude and they became well satisfied with the results. They selected the road systems with their knowledge of local condition subject to the principles, criteria and guidance furnished by the state.

The basic principles, criteria and methods have been followed in all subsequent selections, reviews and approvals of road and street systems both official and unofficial.

Five years of experience with the administration of principal county road and city and village street systems have demonstrated that the extent of these systems can be controlled and kept with reasonable limits. They can be limited to a reasonable extent in a local environment of pressure to improve local roads and streets and the incentive to increase income through higher street classification.

The interpretation of Table 1 is that a formula is necessary to guide the selection, determination and administration of county primary road systems. It also can be interpreted that in a state of varied economy like Michigan, the local controlling factors are numerous and have not been formulized. When the local controlling factors are not identified and formulized one must resort to knowledge of local conditions. The actual county primary road systems that have proved satisfactory for highway administration have been brought into existence by the application of formula guides, criteria, mapped experiences, and data with a knowledge of local conditions.

In developing and using formulas there is a chance that the factors in the formula are subject to variations that may be as great as the variation with the actual. County boundaries and the subdivision of the included factors are arbitrary rather than natural.

For these and other reasons experience and comprehensive data along with knowledge of local conditions are essential tools to be used for judging the qualifications of routes and extent of county primary road systems.

Cities and villages have arbitrary boundaries originally established for a variety of objectives that are not associated with the social economic base. There are cities within cities, bedroom towns, industrial towns, great variations in population density, etc. It is impractical to identify all of the factors, give them proper weight, and formulize.

The comparisons in Tables 2 and 3 are evidence that accumulated data and a knowledge of local conditions is currently adequate for the selection, determination and administration of major street systems. However, a great deal more should be known about the highway transportation requirements of cities and how the street patterns can be adapted to the transportation requirements.

## REFERENCES

1. Carl J. Mc Monagle, "A Method of Rural Road Classification." Michigan State Highway Department (1950).

2. Report of the Department of Public Works, and Buildings on the Classification of Illinois Highways, March, 1951.

3. A Plan for Highway Classification in Maine, 1952.

4. Federal Aid Secondary Highways in Michigan, Partial Selection. Michigan State Highway Department November 1945.

# Factors Influencing Rural Road Mileage

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●ROAD DATA available in governmental publications will be examined to see if the road needs of the population follow a definite pattern. Rural road mileage requirements are the primary interest.

The method used is statistical; that is, the rural road mileages in the various states or the counties of Michigan are accepted as they are recorded in authoritative sources. These data are then analyzed in order to find out how the rural road mileage depends upon population, area, and other factors which cause roads to exist.

There is no question involved as to whether the average behavior of the group is right or those deviating from the average are wrong. The attempt is to show the patterns of rural road distribution in states or counties as they actually exist.

Initially, the hypothesis that roads result from the transportation needs of the people is used. Two equal populations living in two separate regions varying in land area will require the same number of roads, but the roads will be longer in the region of the larger area.

The next step is to test the hypothesis by arranging a given set of governmental data in accordance with the hypothesis and then to see whether the data fall into a recognizable pattern. In accorance with the above hypothesis, a road in Texas is 513 miles long (the square root of 263,500 sq mi) while a road in Rhode Island is only 33.2 mi long (Figure 1). If the rural population were the same then there would be the same number of roads in each but the Texas roads would be about 16 times as long.

From the data shown in Figure 2, the rural populations are nearly equal (Figure 2). The rural population of Oregon is 702,000; the rural population of Massachusetts, 731,000. The number of roads in Oregon (174 roads, 310 mi long) is approximately the same as the number of roads in Massachusetts (190 roads, 89 mi long).

In other words, in order to arrive at the number of roads in a political subdivision, the road mileage in any class of roads is divided by the square root of the land area in the subdivision. Thus a specialized concept of "a road" is reached. A road in this sense, has a length equal to the side of the county, state or nation, and its length is defined as the square root of the land area of the state.

If the road mileages in all the states are treated similarly a tabulation is obtained which shows the number of roads in each state, the length of each being proportional to the size of the state.

The rural populations of each state are tabulated and the number of roads in each state is plotted against its population on logarithmic paper (Figure 3). The definitions of the terms used in this paper are given in Appendix A.

The resulting plot is fitted by a regression line having the equation:

$$Y = \frac{X^{0.495}}{14}$$

A close approximation is:

$$Y = \frac{\sqrt{X}}{15.4}$$

The resulting curve indicates that the number of rural roads in any state should approximate an average which is proportional to the square root of the rural population.

The data representing the four states showing large deviations above the line are for North Dakota, South Dakota, Nebraska and Kansas. The causes for the peculiarities of this group have not been investigated although it is evident that they form a closed group geographically.

Present studies have shown that aligning this previous data to form a distribution curve results in a certain amount of skewness from a normal distribution curve so it is evident that there are some other factors which have not yet been considered. These are believed to be land use and farm size.

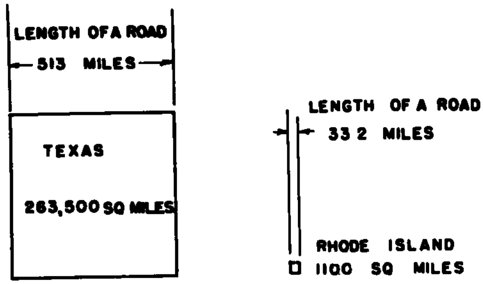



Figure 1.

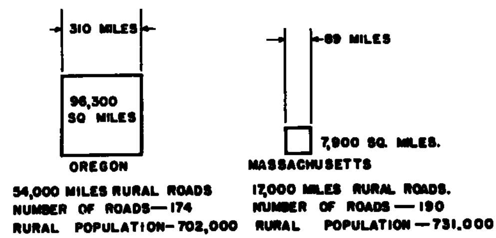



Figure 2.

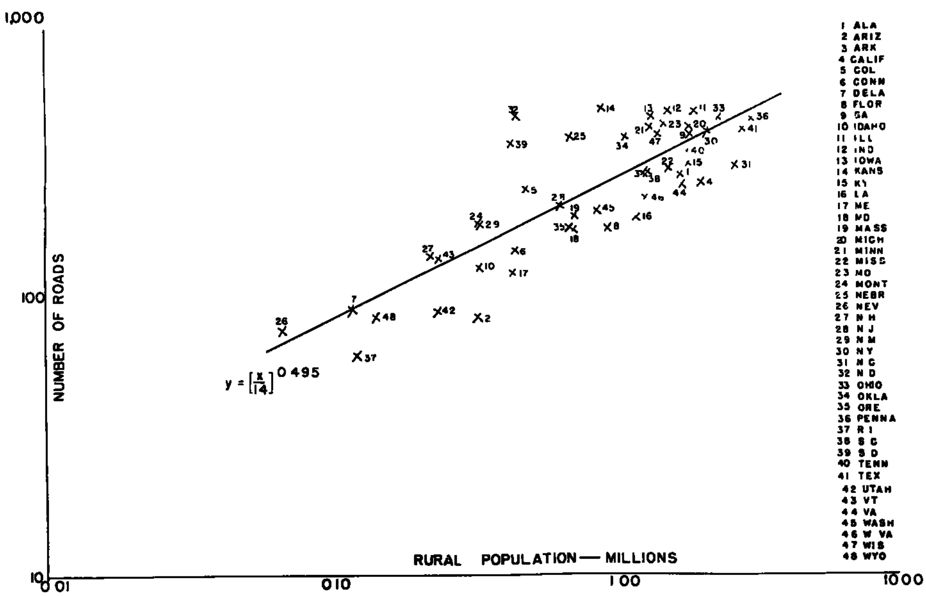



Figure 3. Rural road distribution by states.

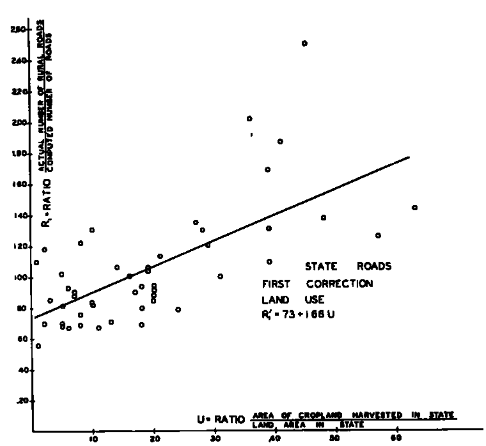



Figure 4.

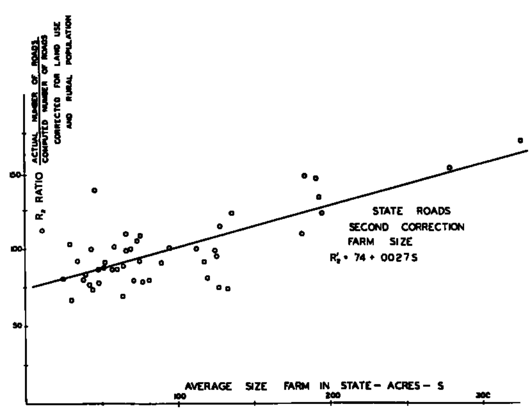



Figure 5.

To determine the effectiveness of the correction factors of land use and farm size, it is necessary to examine the distribution of the data for the various states about the regression or averaging lines.

For instance, taking the data from Figure 4, if the ratio of the actual number of roads in each state (Ya) to the computed number of roads (Yc) as shown by the averaging line in Figure 3 is used to show the distribution of these ratios on Figure 6 a highly skewed distribution results—11 spaces wide with a maximum of 14 states in 1 unit. These dimensions indicate that

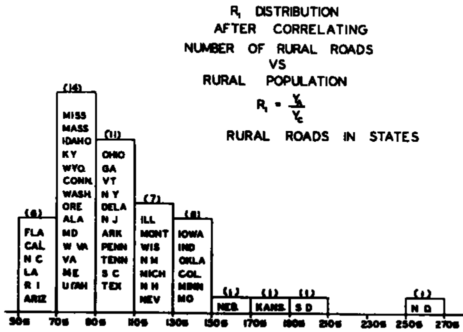



Figure 6.

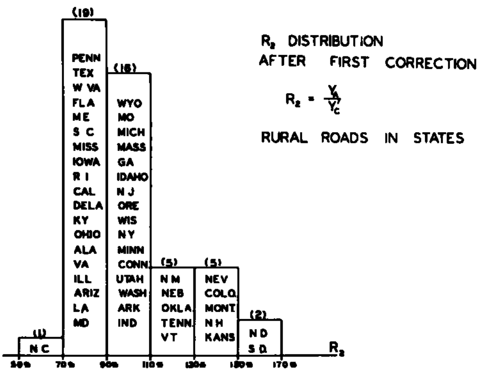



Figure 7.

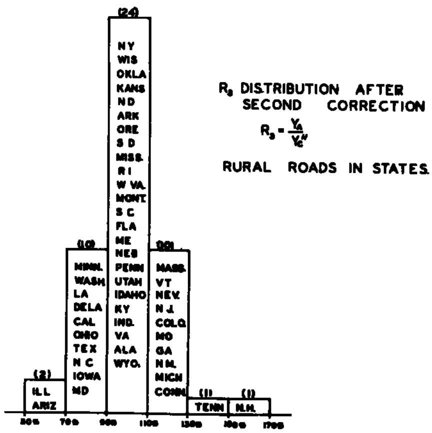



Figure 8.

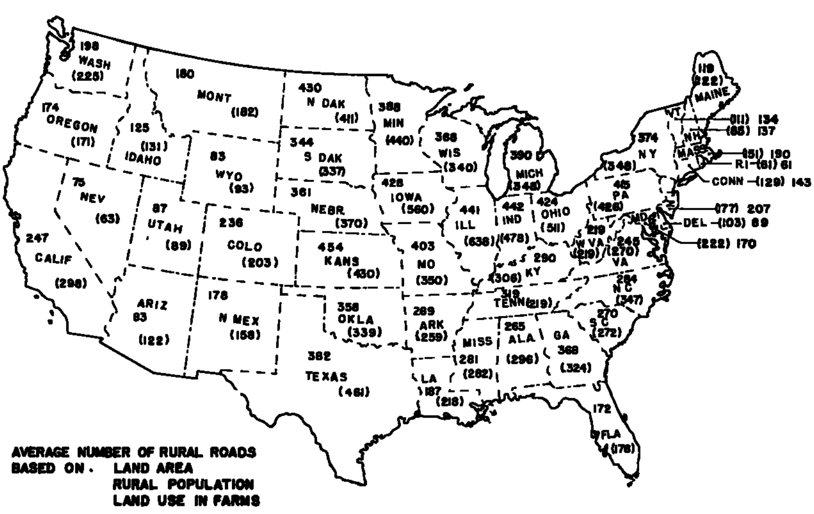



Figure 9. Actual and average number of rural roads in the United States.

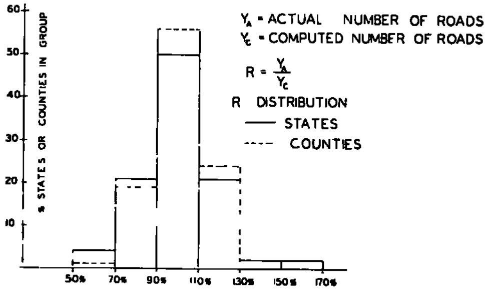



Figure 10.

there are some underlying factors, affecting the number of roads in a state, which are neglected when considering rural population alone.

Then if the ratios from Figure 4 are replotted, after applying the first correction for land use, the distribution of Figure 7 results. The improvement in distribution is apparent although considerable skewness remains. This indicates the presence of another variable, believed to be farm size (Figure 5).

Finally, the ratios are replotted with both corrections effective; Figure 8 results. This chart shows an almost normal distribution of the number of state roads about the average. Therefore, the principal factors determining rural road mileage in a state of the union are rural population, land area, land use, and farm size.

Random local conditions are a fifth factor, but it is uncontrollable and lies outside the pattern of behavior of the 48 states as a whole.

The figure showing the average number of rural roads in the states (Figure 9) was computed using the methods described in the above paragraphs.

If a similar pattern of numbers of roads and rural populations exists in the Michigan counties, it is probable that the hypothesis is correct.

As in the case of the states, it is necessary to find whether there are variables other than rural population and land area which determine rural mileage in the counties.

Figure 10 super-imposes the distribution curve for the counties in the lower peninsula of Michigan (based on rural population and land area only) on the distribution curve for the states (based on rural population and land area but corrected for land use and farm size.)

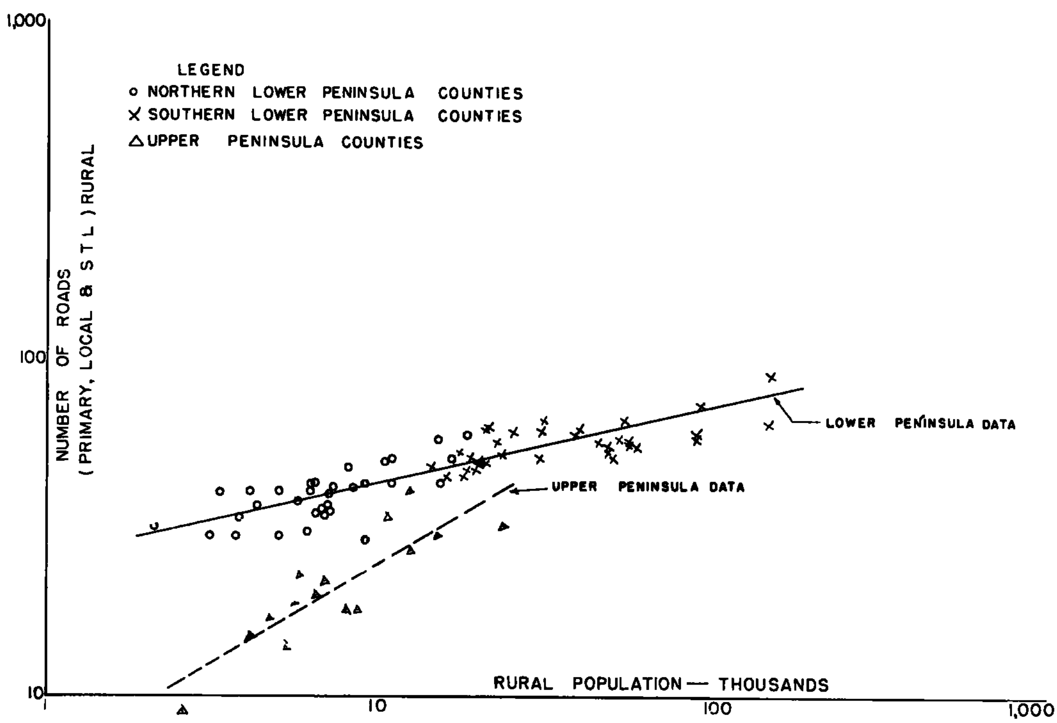



Figure 11. Distribution of rural roads by counties in Michigan.

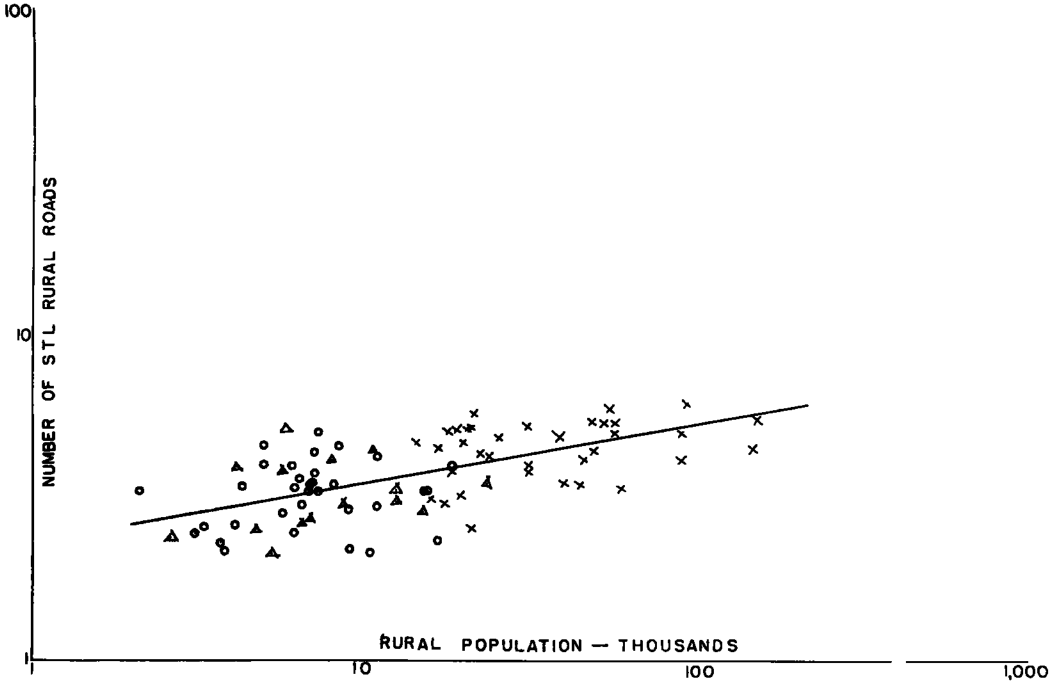



Figure 12. Distribution of rural S.T.L. roads by counties in Michigan.

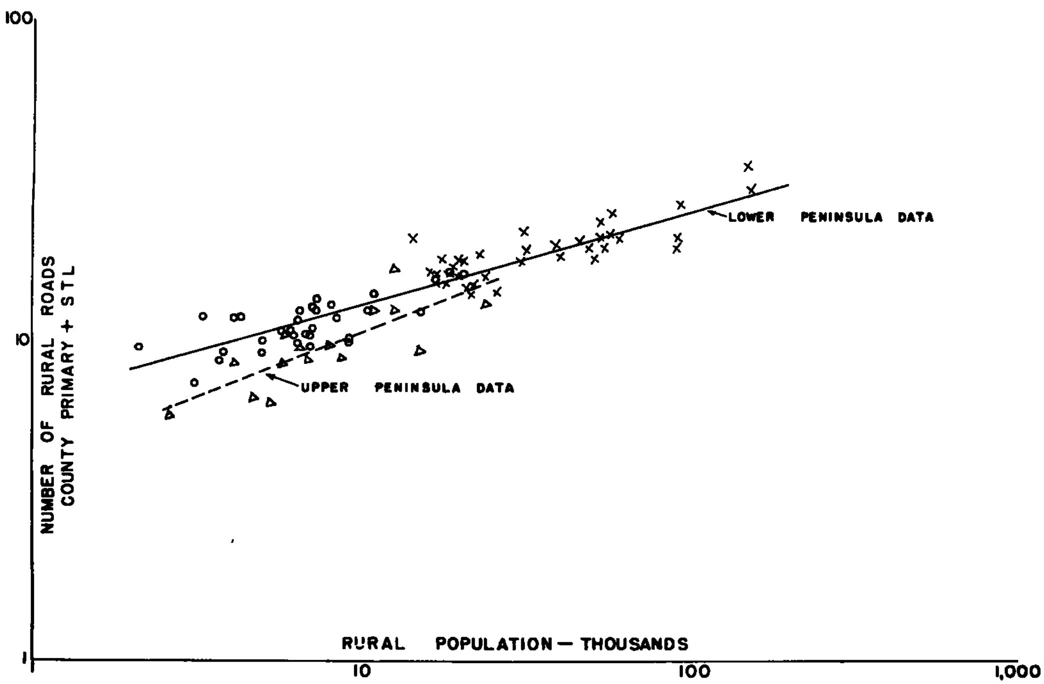



Figure 13. County primary roads in Michigan.

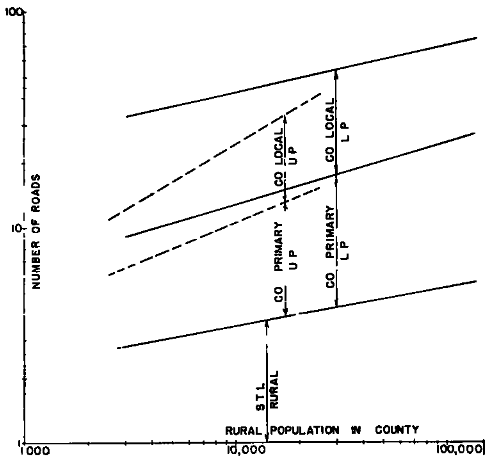



Figure 14. Road distribution in Michigan.

For the counties in the lower peninsula of Michigan, the distribution formula for rural roads funds should be based on rural population and land area only. The further corrections are unnecessary.

Figure 11 plots the numbers of rural roads against rural populations in the counties of Michigan. The data breaks up into two groups, the solid line showing a very close pattern for the 68 counties in the lower peninsula and the dotted line showing a similar pattern with different constants for the 15 upper peninsula counties.

The upper and lower peninsula counties of Michigan form two different economic units because they are isolated from each other by water. The new Straits of Mackinac bridge should show whether this is true in a matter of one or two decades.

Figure 12 shows the relation between rural state trunklines and population. This plot shows the same correlation for both upper and lower peninsula counties which reflects an over-all state highway department policy with respect to the building of trunklines.

Figure 13 shows the correlation of county primary roads with population. There are similar patterns with differing constants in the habits of the two peninsulas with respect to road needs.

Figure 14 combines the lines of Figures 11, 12, and 13, and indicates that there are approximately three times as many county primary roads as state trunkline rural roads, and that there are three times as many county local roads as county primary roads.

## CONCLUSIONS

The value of the knowledge of patterns in road mileage lies in its use for the equitable distribution of road supporting moneys. It is valuable also for making calculations of road needs because local abnormalities are easily recognized and equitable allowances made.

For instance, if the actual certified mileage in a county exceeds the average as set by the state pattern, then it is evident that enjoyment of this excess accrues locally and should be treated accordingly.

Another use of the data is to arrive at an equitable formula for supporting rural primary mileages from taxation. Furthermore, it will provide over-all data for estimates of financial requirements of the road systems.

By isolating the effect of the primary variable (population) from the statistical data of road mileage it is possible to uncover lesser variables which affect mileage and, thus, arrive at a scientific basis for writing road tax formulas.

Using the statistical methods, it is possible to compile average road mileage data. A county road commission can then compare their actual certified road mileage with the average road mileage for a county of the same population and area and having similar characteristics. If they find their actual mileage exceeds the average they have a valid basis to resist demands for increasing the mileage as any increased mileage might be beyond income with respect to proper maintenance of the increased mileage. If the tabulation shows that their actual road mileage is below the average then they can, with confidence, construct more roads and be confident of their ability to maintain them properly.

In order to calculate the average county primary mileage in a county of Michigan, the following steps are taken:

1. From Figure 13 find the number of rural roads, county primary plus S. T. L., given the rural population in the county.

2. Multiply the number of roads by the square root of the land area in the county in order to find the average county primary plus rural S. T. L. mileage for the county.

3. Subtract the actual S. T. L. rural from the average mileage found; the result will be the average county primary miles that should be in a county to approach the state average for the lower or upper peninsula.

Figure 14 shows the average number of county primary roads to be the remainder after subtracting the average number of S. T. L. in contract and actual S. T. L. as previously determined.

The average local mileage in a county is calculated by subtracting the actual primary and S. T. L. from the average total rural mileage.

# Appendix A

## DEFINITIONS

$M_a$ = Total actual miles of rural road in state.

A = Land area in state.

$Y_a = \frac{M_a}{\sqrt{A}}$ = actual number of rural roads in state.

X = Rural population in state.

$Y_c$ = Computed number of roads = $0.272\ x^{0.495}$ ; Figure 3.

$Y_{sl}$ = Number of roads if a road were on every section line.

$Y_{sl} = \frac{2A}{\sqrt{A}} = 2\sqrt{A}$.

D = Population density = $\frac{X}{A}$.

$\frac{Y_c}{Y_{sl}} = \frac{0.272\ x^{0.495}}{2\sqrt{A}} = 0.136\sqrt{D}$.

$R_1 = \frac{Y_a}{Y_c}$ ; Figure 6.

U = Land use in state = ratio $\frac{\text{cropland harvested in state}}{\text{land area in state}}$.

$R'_1$ = First correction factor = $(0.73 + 1.66\ U)$; Figure 4.

$Y'_c$ = Computed number of roads after first correction for land use.

$Y'_c = (0.272\ x^{0.495})\ (0.73 + 1.66\ U) = Y_c R'_1$.

$R_2 = \frac{Y_a}{Y'_c}$ ; Figure 7.

S = Average size of farms in state, acres.

$S = \frac{\text{area of cropland in state}}{\text{number of farms}}$.

$R'_2 = (0.74 + 0.0027\ S)$; Figure 5.

$Y''_c = Y'_c R'_2 = Y_c R'_2 R'_1 = (0.272\ x^{0.495})\ (0.73 + 1.66\ U)\ (0.74 + 0.0027\ S)$.

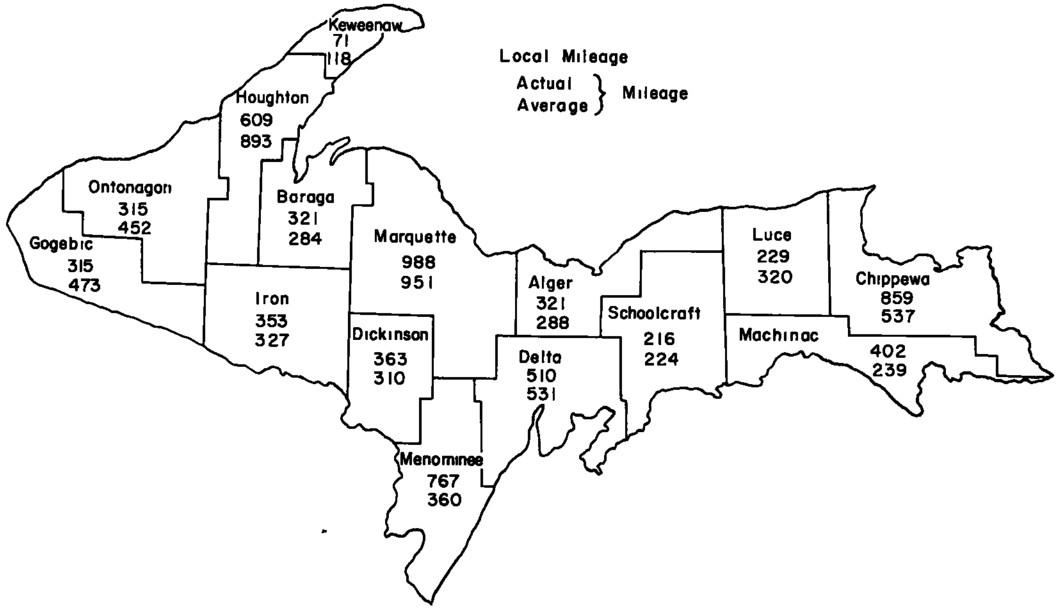
$Y''_c$ = Computed number of roads based on rural population, land use and farm size.

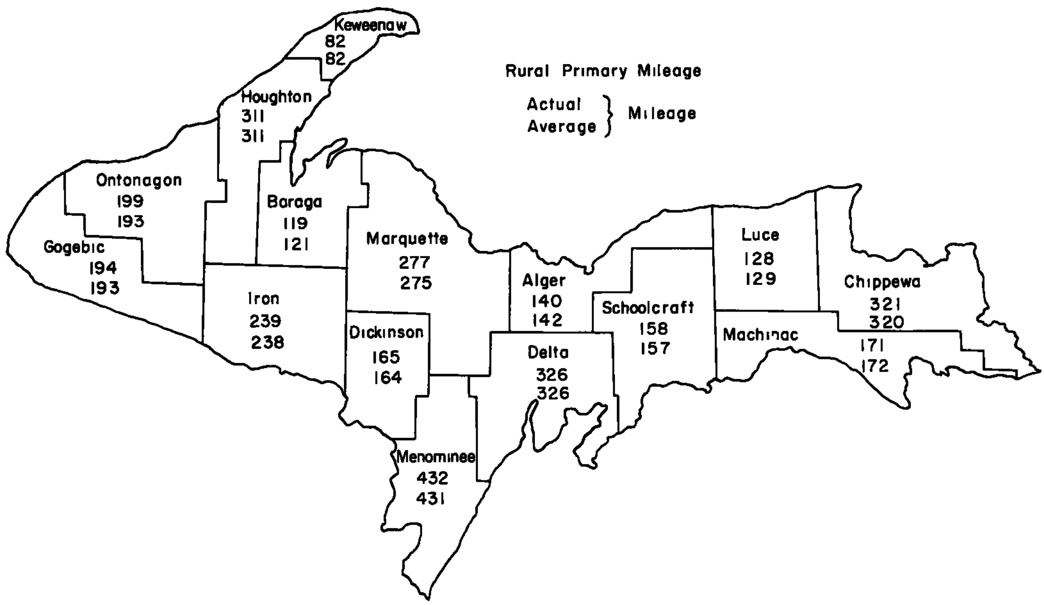
$R_3 = \frac{Y_a}{Y''_c}$ ; Figure 8.

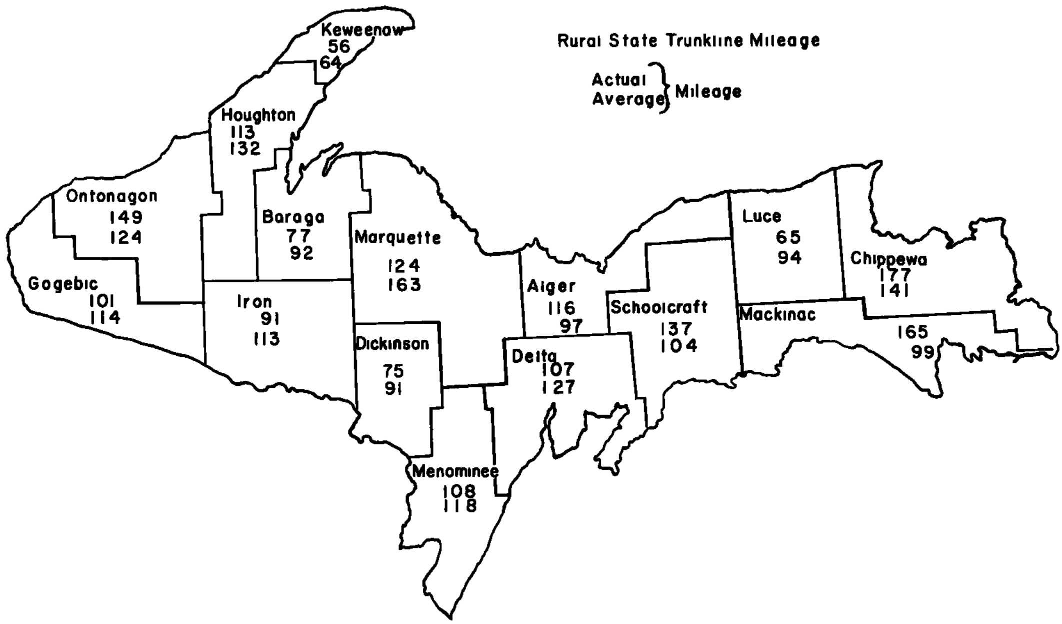
# Appendix B

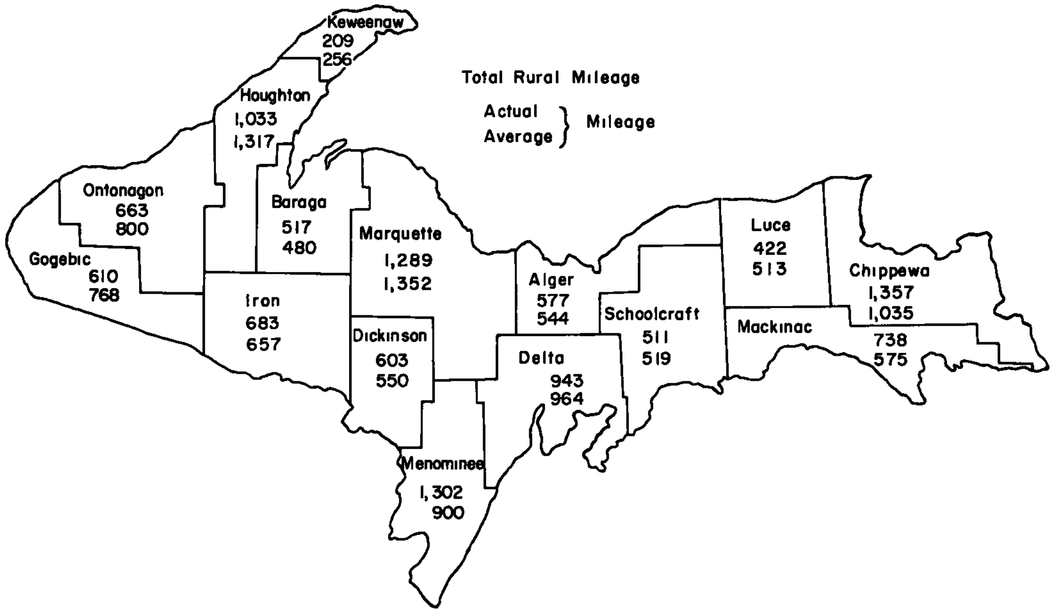
COUNTIES OF MICHIGAN
RURAL PRIMARY MILEAGE

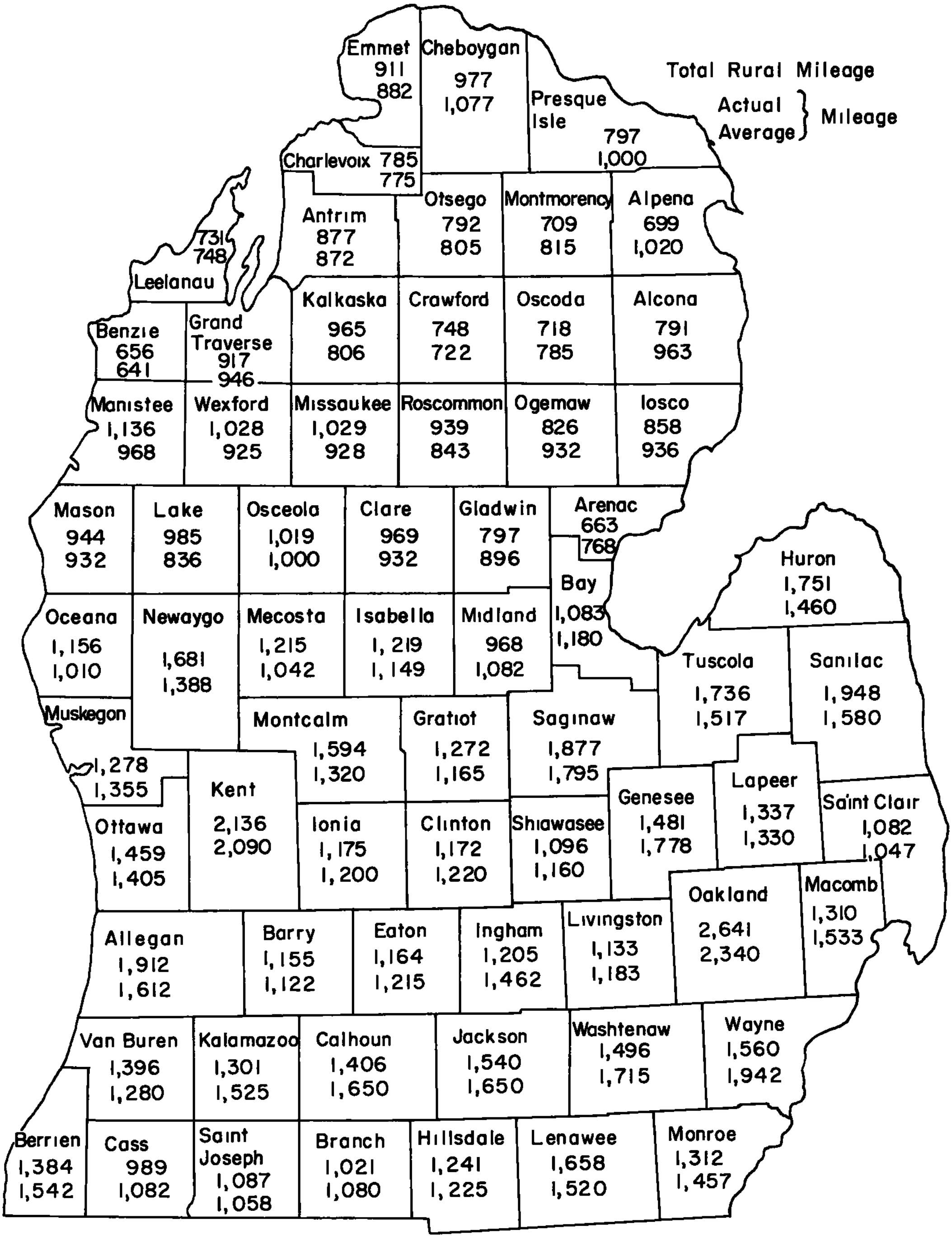
| | Actual | Average | % | | Actual | Average | % |
|---|---|---|---|---|---|---|---|
| Alcona | 134 | 168 | 125 | Lake | 221 | 176 | 80 |
| Alger | 140 | 142 | 101 | Lapeer | 299 | 314 | 105 |
| Allegan | 438 | 415 | 95 | Leelanau | 161 | 126 | 78 |
| Alpena | 164 | 227 | 138 | Lenawee | 451 | 348 | 77 |
| Antrim | 183 | 157 | 86 | Livingston | 295 | 278 | 94 |
| Arenac | 132 | 154 | 117 | Luce | 128 | 129 | 101 |
| Baraga | 119 | 121 | 102 | Mackinac | 171 | 172 | 101 |
| Barry | 273 | 245 | 90 | Macomb | 338 | 441 | 130 |
| Bay | 295 | 299 | 101 | Manistee | 226 | 204 | 90 |
| Benzie | 153 | 118 | 77 | Marquette | 277 | 275 | 99 |
| Berrien | 470 | 382 | 81 | Mason | 174 | 229 | 132 |
| Branch | 298 | 262 | 88 | Mecosta | 260 | 243 | 93 |
| Calhoun | 441 | 435 | 99 | Menominee | 432 | 431 | 99 |
| Cass | 218 | 225 | 103 | Midland | 295 | 284 | 96 |
| Charlevoix | 162 | 166 | 102 | Missaukee | 188 | 210 | 112 |
| Cheboygan | 197 | 214 | 109 | Monroe | 329 | 356 | 108 |
| Chippewa | 321 | 320 | 99 | Montcalm | 333 | 303 | 91 |
| Clare | 198 | 188 | 95 | Montmorency | 149 | 174 | 168 |
| Clinton | 294 | 321 | 109 | Muskegon | 369 | 359 | 97 |
| Crawford | 149 | 115 | 77 | Newaygo | 264 | 327 | 124 |
| Delta | 171 | 172 | 101 | Oakland | 651 | 678 | 104 |
| Dickinson | 165 | 164 | 99 | Oceana | 240 | 252 | 105 |
| Eaton | 297 | 257 | 87 | Ogemaw | 228 | 203 | 89 |
| Emmet | 199 | 182 | 91 | Ontonagon | 199 | 193 | 97 |
| Genesee | 406 | 494 | 122 | Osceola | 173 | 188 | 109 |
| Gladwin | 161 | 183 | 114 | Oscoda | 118 | 160 | 135 |
| Gogebic | 194 | 193 | 99 | Otsego | 172 | 176 | 102 |
| Grand Traverse | 206 | 194 | 94 | Ottawa | 352 | 377 | 107 |
| Gratiot | 353 | 287 | 81 | Presque Isle | 178 | 185 | 104 |
| Hillsdale | 291 | 253 | 87 | Roscommon | 123 | 133 | 108 |
| Houghton | 311 | 311 | 100 | Saginaw | 384 | 427 | 111 |
| Huron | 271 | 309 | 114 | Sanilac | 252 | 315 | 125 |
| Ingham | 342 | 401 | 117 | Schoolcraft | 158 | 157 | 99 |
| Ionia | 313 | 263 | 84 | Shiawassee | 298 | 287 | 96 |
| Iosco | 139 | 190 | 137 | St. Clair | 409 | 381 | 93 |
| Iron | 239 | 238 | 99 | St. Joseph | 363 | 217 | 60 |
| Isabella | 318 | 302 | 95 | Tuscola | 265 | 340 | 128 |
| Jackson | 483 | 413 | 86 | VanBuren | 337 | 289 | 86 |
| Kalamazoo | 414 | 435 | 105 | Washtenaw | 436 | 433 | 99 |
| Kalkaska | 223 | 163 | 73 | Wayne | 450 | 577 | 128 |
| Kent | 597 | 533 | 89 | Wexford | 153 | 190 | 124 |
| Keweenaw | 82 | 82 | 100 | | | | |

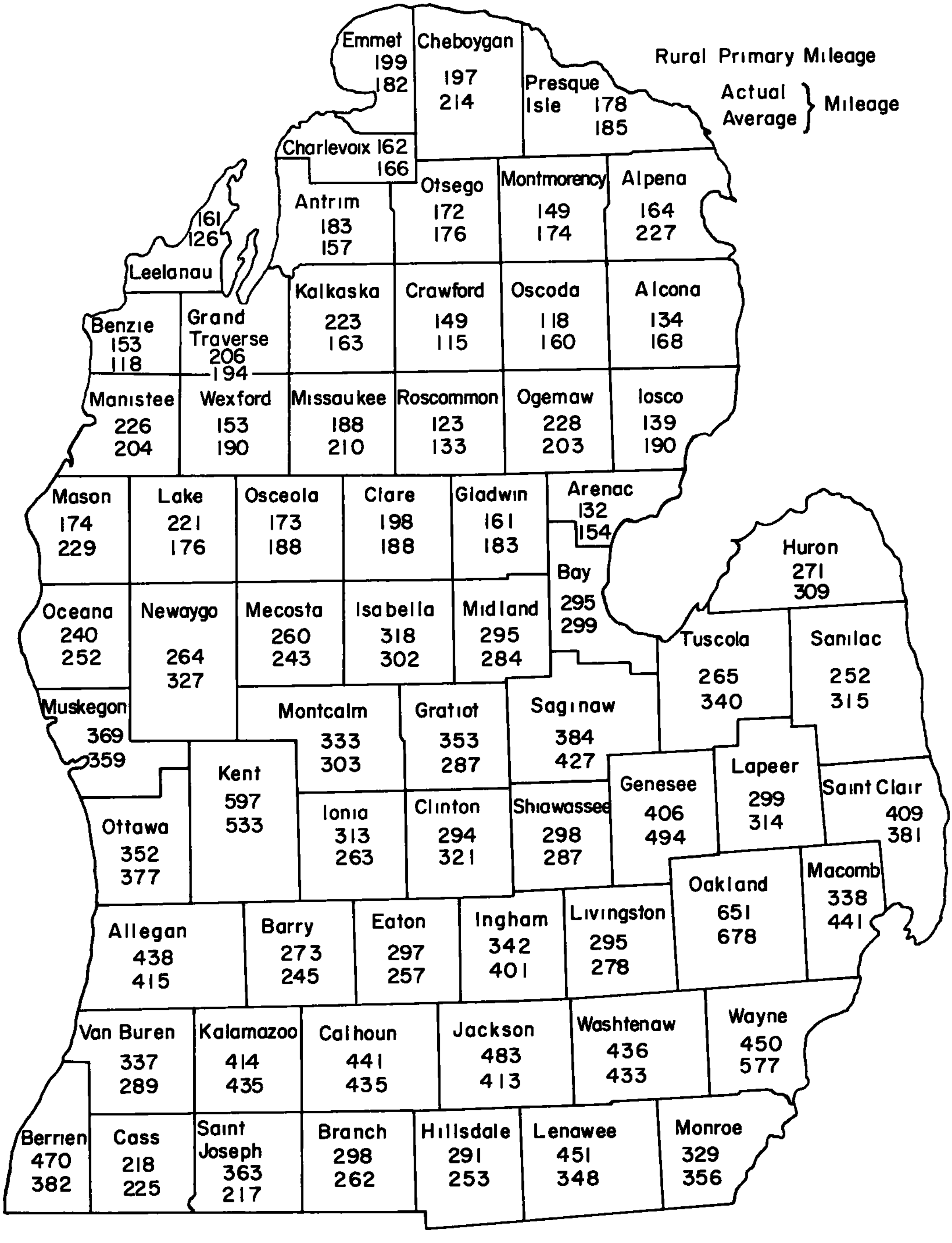

Local Mileage
Actual
Average
Mileage
Keweenaw 71 118
Houghton 609 893
Ontonagon 315 452
Baraga 321 284
Gogebic 315 473
Marquette 988 951
Iron 353 327
Dickinson 363 310
Alger 321 288
Schoolcraft 216 224
Luce 229 320
Chippewa 859 537
Machinac 402 239
Delta 510 531
Menominee 767 360

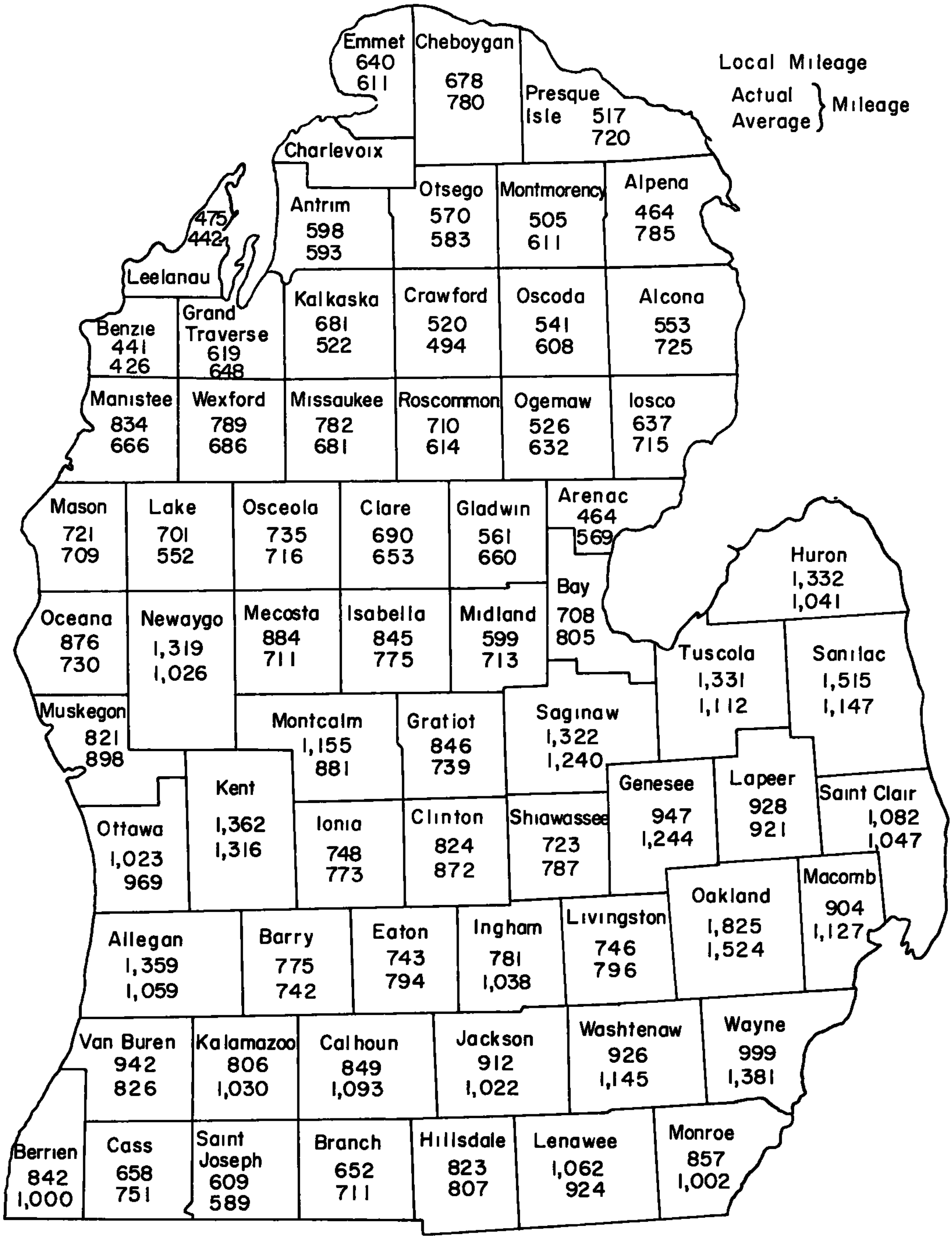

Rural Primary Mileage
Actual
Average
Mileage
Keweenaw 82 82
Houghton 311 311
Ontonagon 199 193
Baraga 119 121
Gogebic 194 193
Marquette 277 275
Iron 239 238
Dickinson 165 164
Alger 140 142
Schoolcraft 158 157
Luce 128 129
Chippewa 321 320
Machinac 171 172
Delta 326 326
Menominee 432 431

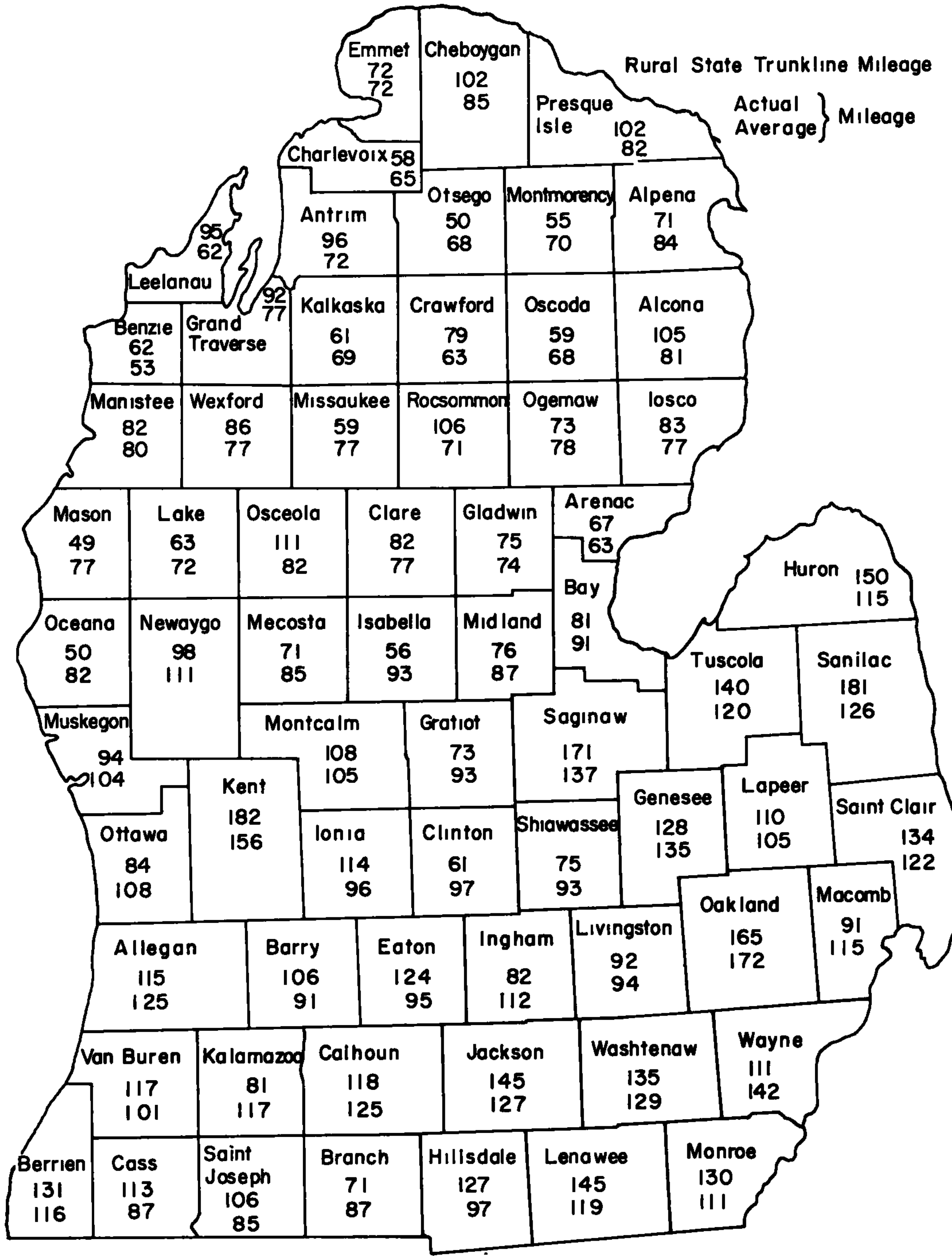

Rural State Trunkline Mileage
Actual
Average
Mileage
Keweenaw
56
64
Houghton
113
132
Ontonagon
149
124
Baraga
77
92
Marquette
124
163
Gogebic
101
114
Iron
91
113
Dickinson
75
91
Alger
116
97
Delta
107
127
Menominee
108
118
Schoolcraft
137
104
Luce
65
94
Chippewa
177
141
Mackinac
165
99


Total Rural Mileage
Actual
Average
Mileage
Keweenaw
209
256
Houghton
1,033
1,317
Ontonagon
663
800
Baraga
517
480
Marquette
1,289
1,352
Gogebic
610
768
Iron
683
657
Dickinson
603
550
Alger
577
544
Delta
943
964
Menominee
1,302
900
Schoolcraft
511
519
Luce
422
513
Chippewa
1,357
1,035
Mackinac
738
575


Total Rural Mileage
Actual
Average
Mileage
Emmet 911 882
Cheboygan 977 1,077
Presque Isle 797 1,000
Charlevoix 785 775
731 748
Leelanau
Antrim 877 872
Otsego 792 805
Montmorency 709 815
Alpena 699 1,020
Benzie 656 641
Grand Traverse 917 946
Kalkaska 965 806
Crawford 748 722
Oscoda 718 785
Alcona 791 963
Manistee 1,136 968
Wexford 1,028 925
Missaukee 1,029 928
Roscommon 939 843
Ogemaw 826 932
Iosco 858 936
Mason 944 932
Lake 985 836
Osceola 1,019 1,000
Clare 969 932
Gladwin 797 896
Arenac 663 768
Huron 1,751 1,460
Bay 1,083 1,180
Oceana 1,156 1,010
Newaygo 1,681 1,388
Mecosta 1,215 1,042
Isabella 1,219 1,149
Midland 968 1,082
Tuscola 1,736 1,517
Sanilac 1,948 1,580
Muskegon 1,278 1,355
Montcalm 1,594 1,320
Gratiot 1,272 1,165
Saginaw 1,877 1,795
Genesee 1,481 1,778
Lapeer 1,337 1,330
Saint Clair 1,082 1,047
Ottawa 1,459 1,405
Kent 2,136 2,090
Ionia 1,175 1,200
Clinton 1,172 1,220
Shiawassee 1,096 1,160
Oakland 2,641 2,340
Macomb 1,310 1,533
Allegan 1,912 1,612
Barry 1,155 1,122
Eaton 1,164 1,215
Ingham 1,205 1,462
Livingston 1,133 1,183
Van Buren 1,396 1,280
Kalamazoo 1,301 1,525
Calhoun 1,406 1,650
Jackson 1,540 1,650
Washtenaw 1,496 1,715
Wayne 1,560 1,942
Berrien 1,384 1,542
Cass 989 1,082
Saint Joseph 1,087 1,058
Branch 1,021 1,080
Hillsdale 1,241 1,225
Lenawee 1,658 1,520
Monroe 1,312 1,457


Rural Primary Mileage
Actual
Average
Mileage
Emmet 199 182
Cheboygan 197 214
Presque Isle 178 185
Charlevoix 162 166
161 126
Leelanau
Antrim 183 157
Otsego 172 176
Montmorency 149 174
Alpena 164 227
Benzie 153 118
Grand Traverse 206 194
Kalkaska 223 163
Crawford 149 115
Oscoda 118 160
Alcona 134 168
Manistee 226 204
Wexford 153 190
Missaukee 188 210
Roscommon 123 133
Ogemaw 228 203
Iosco 139 190
Mason 174 229
Lake 221 176
Osceola 173 188
Clare 198 188
Gladwin 161 183
Arenac 132 154
Bay 295 299
Huron 271 309
Oceana 240 252
Newaygo 264 327
Mecosta 260 243
Isabella 318 302
Midland 295 284
Tuscola 265 340
Sanilac 252 315
Muskegon 369 359
Montcalm 333 303
Gratiot 353 287
Saginaw 384 427
Genesee 406 494
Lapeer 299 314
Saint Clair 409 381
Kent 597 533
Ottawa 352 377
Ionia 313 263
Clinton 294 321
Shiawassee 298 287
Oakland 651 678
Macomb 338 441
Allegan 438 415
Barry 273 245
Eaton 297 257
Ingham 342 401
Livingston 295 278
Van Buren 337 289
Kalamazoo 414 435
Calhoun 441 435
Jackson 483 413
Washtenaw 436 433
Wayne 450 577
Berrien 470 382
Cass 218 225
Saint Joseph 363 217
Branch 298 262
Hillsdale 291 253
Lenawee 451 348
Monroe 329 356


Local Mileage
Actual
Average
Mileage
Emmet 640 611
Cheboygan 678 780
Presque Isle 517 720
Charlevoix
Leelanau 475 442
Antrim 598 593
Otsego 570 583
Montmorency 505 611
Alpena 464 785
Benzie 441 426
Grand Traverse 619 648
Kalkaska 681 522
Crawford 520 494
Oscoda 541 608
Alcona 553 725
Manistee 834 666
Wexford 789 686
Missaukee 782 681
Roscommon 710 614
Ogemaw 526 632
Iosco 637 715
Mason 721 709
Lake 701 552
Osceola 735 716
Clare 690 653
Gladwin 561 660
Arenac 464 569
Huron 1,332 1,041
Oceana 876 730
Newaygo 1,319 1,026
Mecosta 884 711
Isabella 845 775
Midland 599 713
Bay 708 805
Tuscola 1,331 1,112
Sanilac 1,515 1,147
Muskegon 821 898
Montcalm 1,155 881
Gratiot 846 739
Saginaw 1,322 1,240
Genesee 947 1,244
Lapeer 928 921
Saint Clair 1,082 1,047
Ottawa 1,023 969
Kent 1,362 1,316
Ionia 748 773
Clinton 824 872
Shiawassee 723 787
Oakland 1,825 1,524
Macomb 904 1,127
Allegan 1,359 1,059
Barry 775 742
Eaton 743 794
Ingham 781 1,038
Livingston 746 796
Van Buren 942 826
Kalamazoo 806 1,030
Calhoun 849 1,093
Jackson 912 1,022
Washtenaw 926 1,145
Wayne 999 1,381
Berrien 842 1,000
Cass 658 751
Saint Joseph 609 589
Branch 652 711
Hillsdale 823 807
Lenawee 1,062 924
Monroe 857 1,002


Rural State Trunkline Mileage
Actual
Average
Mileage
Emmet 72 72
Cheboygan 102 85
Presque Isle 102 82
Charlevoix 58 65
Otsego 50 68
Montmorency 55 70
Alpena 71 84
Antrim 96 72
95 62
Leelanau
92 77
Benzie 62 53
Grand Traverse
Kalkaska 61 69
Crawford 79 63
Oscoda 59 68
Alcona 105 81
Manistee 82 80
Wexford 86 77
Missaukee 59 77
Rocsommon 106 71
Ogemaw 73 78
Iosco 83 77
Mason 49 77
Lake 63 72
Osceola 111 82
Clare 82 77
Gladwin 75 74
Arenac 67 63
Bay 81 91
Huron 150 115
Oceana 50 82
Newaygo 98 111
Mecosta 71 85
Isabella 56 93
Midland 76 87
Tuscola 140 120
Sanilac 181 126
Muskegon 94 104
Montcalm 108 105
Gratiot 73 93
Saginaw 171 137
Kent 182 156
Genesee 128 135
Lapeer 110 105
Saint Clair 134 122
Ottawa 84 108
Ionia 114 96
Clinton 61 97
Shiawassee 75 93
Oakland 165 172
Macomb 91 115
Allegan 115 125
Barry 106 91
Eaton 124 95
Ingham 82 112
Livingston 92 94
Van Buren 117 101
Kalamazoo 81 117
Calhoun 118 125
Jackson 145 127
Washtenaw 135 129
Wayne 111 142
Berrien 131 116
Cass 113 87
Saint Joseph 106 85
Branch 71 87
Hillsdale 127 97
Lenawee 145 119
Monroe 130 111

# Estimating Maintenance Needs

The amounts allotted for highway and street maintenance in preparing annual programs is a substantial amount of the total annual highway program for states, cities, counties, and other local jurisdictions. If accuracy for the total annual program is to be attained, the same careful approach to maintenance needs must be used as the approach in appraisal of the improvement needs. Because of existing defects in definitions and accounting and lack of standards, existing maintenance records are usually insufficient for development of maintenance amounts for study programs. To supplement existing records and provide information where no records exist, several methods have been used to develop maintenance costs for annual programs. These methods are examined and discussed for state, city, and county jurisdictions.

## Part 1: Rural State Highways

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● HIGHWAY AND STREET MAINTENANCE is a substantial part of the total highway program. In 1956, the outlay for highway and street maintenance approached the $2 billion level. If accuracy of the total annual program is to be attained, maintenance needs must be determined as accurately as improvement needs. If excessive amounts are expended on maintenance, the improvement program is deprived of usable revenues. If maintenance allotments are inadequate, improvement needs are greatly accelerated.

Several factors make it difficult to obtain accurate maintenance costs. A prime factor is the lack of a definite and uniform definition of maintenance itself. Items of maintenance are generally not uniformly defined between the several states or between the several jurisdictions within a state. The inclusion of small capital improvements and betterments as maintenance cost items, without proper identification, is a real handicap. It precludes the use of historical cost data which otherwise would be of considerable assistance in projecting future maintenance needs.

Nonuniformity in accounting procedures also makes it difficult to arrive at the total outlay for annual maintenance. In addition, if the accounting procedure does not provide for the distribution of costs to the various operations, there can be no thorough appraisal of the efficiency of such operations.

Definite standards of maintenance adequacy are also necessary. Without such standards, it is difficult to judge whether reported expenditures are an accurate measure of what should have been spent to provide proper maintenance service. Where there are no standards of adequacy, the sufficiency of maintenance expenditures is usually judged by past expenditure levels without considering the adequacy or economy of the maintenance performance.

Because of this lack of exact definitions, uniform accounting practices, and standards of adequacy, existing records of maintenance are usually not suitable for use in the development of maintenance requirements. To supplement existing records and to provide information where records do not exist, several methods have been used to develop maintenance costs for annual road and street programs. An examination of these methods, together with comments on their advantages and limitations, may aid in the determination of the best method or methods.

Of all the jurisdictions engaged in highway or street maintenance, the state highway departments have the greatest amount of usable background information to assist in developing representative maintenance costs for program purposes. Many states have been following the proposed cost accounting breakdown of the American Association of State Highway Officials for a number of years. Usually, however, the available maintenance cost data of state highway departments cannot be used without some modification or amplification. It is necessary to know the volume of work performed, the adequacy of the maintenance performance, the economy of the manpower and equipment combinations used, and many other pertinent factors that affect the over-all maintenance costs.

The work of the Committee on Maintenance Costs of the Highway Research Board has been most beneficial. They have obtained average annual maintenance costs on a substantial mileage of the nation's highways, published a maintenance cost index, developed unit costs for various maintenance operations, and are promoting efficient operations on a national scale through proper mechanization and progressive methods and practices.

The "performance budget" is one of the best methods of estimating annual maintenance expenditures. Under this plan, the maintenance workload is developed in appropriate quantitative terms. Knowing the frequency and unit cost of each operation, it is possible to develop an annual maintenance cost for each functional activity. This workload method may also be used to good advantage in alloting operating funds to work subdivisions in the field.

Experience in conducting maintenance analyses, however, has shown that the complete maintenance workload is seldom available. As a rule considerable care is exercised in keeping current data on the type, width, and thickness of pavements but little or no effort is expended in keeping up-to-date records of the other highway improvements. Rural state highway pavement maintenance costs on the average comprise only about half of the total outlay for highway maintenance. On urban extensions and expressways, the cost of pavement maintenance is usually a very small portion of the total cost of providing highway service. No criticism is offered for the accuracy with which pavement data is kept. However, it is equally important to know such quantities as the acreage of right-of-way that must be mowed, the tons of steel that must be painted, the number of signs, and the amount of pavement marking.

As new facilities are added to the system, the maintenance engineer should be able to estimate their net effect on the annual maintenance budget. This can only be done by considering all of the physical and operational requirements of the new improvement. For example, the placing of a new interchange in operation may have little or no effect on pavement maintenance expenditures but may require substantial amounts for lighting and for structural upkeep.

The unit costs which are applied to the various work quantities should provide for an acceptable standard of work and reflect reasonable efficiency of operations. To illustrate, a durable reflectorized pavement marking should be applied at a rate of not less than one gallon of paint for 330 ft of 4-in. line. If proper equipment is used, it should be possible to paint such markings at a cost of 1.2 to 1.6 cents per linear foot. This unit cost, however, cannot be used unless the actual amount of line is known. One southeastern state which keeps an accurate record of pavement marking requirements has found that on the average it takes the equivalent of 5,000 ft of single solid line per mile of highway for the prevailing sight conditions. The amount varied from 4,000 to 6,000 ft per mile between the districts.

As a general rule, unit maintenance costs will vary between states. It should be possible, however, to develop representative unit costs in regions having comparable maintenance problems if proper weights are given to the variables.

In maintenance needs studies conducted to date, some rather broad guides have been developed for judging the adequacy and justification for reported maintenance expenditures. Traffic volumes affect both the upkeep of the physical elements of the highway and the extent to which operation services must be furnished. Studies show that the average annual cost per daily vehicle (365 vehicle miles per year) for high-traffic highways is about half of that experienced in the low traffic group. The range is from $0.82 per daily vehicle for highways carrying 6,000 vpd to $1.68 per daily vehicle for highways carrying an average of 500 vpd. The cost per daily vehicle provides a yardstick by which it is possible to determine within broad limits if the summation of the maintenance costs developed by the work unit-performance methods are reasonable.

Although some progress has been achieved in developing techniques for determining highway maintenance needs at state levels, much remains to be done to simplify procedures in the future. Action along the following lines would facilitate the determination of highway maintenance needs in the future and would also assist materially in the over-all administration of the nation's primary highway plant:

1. Adoption of uniform definitions for maintenance, traffic services and minor capital additions.
2. Completion of maintenance manuals (four chapters of AASHO Maintenance Manual have been completed to date).
3. Full adoption of proposed AASHO accounting system with such additions and revisions as are required for modern maintenance activities.
4. The compilation of complete records of the maintenance workload in suitable quantitative units.
5. Development of the most efficient labor and equipment combinations for various maintenance functions.

# Part 2: City Streets

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● PREVIOUS STUDIES have not developed city street maintenance costs with adequate consideration to the many factors that make up the total city street maintenance needs. It has not been possible to assemble comparative costs from various cities according to pavement types and widths, because of variations in the organizational structures of cities. In some cities, as many as six different departments perform street maintenance functions. Another serious obstacle is the variation in accounting procedures among departments and among cities. A further complication is the considerable confusion in opinions as to what are maintenance operations vs capital improvements. Frequently, street maintenance, water works, sewers, parks and recreation operate out of the maintenance budget with no clear-cut accounting of expenditures between them.

Obviously the daily production per man and per truck will have a profound effect on maintenance costs. In most needs studies time has not permitted a city by city evaluation of personnel and equipment efficiency.

In some cases where reasonably reliable accounting was available the maintenance costs were adjusted to compensate for the difference between the desirable and the present level of maintenance. These figures were then applied to all streets involved in the study. This method assumes a continuation of the existing degree of efficiency.

In the absence of reliable accounting it is usually necessary to discuss the maintenance activities in relation to the maintenance budget. Non-maintenance activities are estimated and deducted from the budget. The resulting figure is then adjusted to provide for an adequate level of maintenance. The adjusted figure is then readjusted according to surface types and traffic volume so that the total cost for all streets equals the adjusted maintenance total. Although the average cost may be fairly determined, it is doubtful that the costs assigned to different surface types and traffic volume groups carry the same degree of accuracy.

Both of the procedures have existing costs or budget for their basis. When applied to other cities in the state the costs may be wide of actual requirements because of variations in the frequency of flushing and sweeping, general age and condition of pavements, differing policies on snow removal and ice control, varying degrees of drainage adequacy, lighting costs, and efficiency of operation.

The cost for performing various maintenance functions should be developed and segregated in broad categories. For example, the cost of maintaining the pavement should be in one category while sweeping, drainage, lighting, and snow removal would be in other categories. In this way appropriate elements can be added together to arrive at the cost of performing needed activities. The development of these costs is, of course, the difficult part of any analysis.

The subcommittee has circulated a street maintenance questionnaire to six cities. Its purpose is to test the format and instructions of the questionnaire through these cities. As soon as its adequacy can be tested, the questionnaire will be sent to some 200 cities for their participation. The National Committee for Urban Transportation, the American Public Works Association, the American Municipal Association and the

United States Conference of Mayors have joined this effort.

The questionnaire has been simplified to the greatest extent possible. More detailed information would be desirable but the introduction of such detail would greatly narrow the response from the cities. Although the questionnaire is concise, past experience makes a satisfactory response doubtful. If a satisfactory response is not received, even a negative result may be of value. Knowledge that cities generally do not know the cost of maintaining their streets will be a strong argument for acceptance of the National Committee for Urban Transportation's maintenance accounting procedures now being developed.

# Part 3: County and Local Roads

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● IN COUNTY AND LOCAL road areas, yearly maintenance costs consume a large share of the total road budget. The reported national maintenance expenditure is about one-half the total road budget for all local road purposes.

If valid maintenance accounting were widely practiced, these records would provide basic information on which future maintenance expenditures could be projected. In some states a few counties have maintenance records but these may not reflect statewide amounts. In other states there are no records of maintenance costs available and, further, in many states, there is no distinction or record made between funds expended for maintenance and construction.

Even in the partial or complete absence of valid maintenance records, estimates must be established to reflect the maintenance needs in the annual programs. Four methods of estimating have been used. The choice of method is dependent on a general appraisal of the maintenance activity, including an examination of existing records and their accuracy.

## Present Maintenance Expenditures Method

A source of factual information in each state is the highway planning division, with its tabulation of reported expenditures by agencies and the breakdown of these expenditures for construction and maintenance. In some states the counties record total expenditures broken into these two divisions. A study of the information available will determine what material can best be utilized.

Where possible, even though a limited sample must be used, reported costs are tabulated by surface type and by systems so that differences in maintenance costs between types and systems can be reflected. Different kinds of maintenance with different costs can be expected on bituminous and gravel surfaces, and larger maintenance costs can be expected on county primary roads than on local access roads.

The expenditures are scrutinized to determine if items such as betterments, improvements, or special maintenance are included. If so, it becomes necessary to eliminate them because these specific items will be covered in the improvement programs. The accounting method may allow extraction of these items; if this is not possible, they should be removed on a percentage basis. The percentage of these items to the total maintenance budget will be determined by examination of records and estimates of engineers, or a combination of both.

The adequacy of the present operation must be appraised to evaluate the service provided and to determine its efficiency. Observation of results and consultation with maintenance employees aid in this evaluation. During this portion of the appraisal, the organization of maintenance management should be studied and evaluated.

In the development of needs programs the existing inventory by surface types is gradually changed by the improvements resulting in a changed inventory at the end of the program. If the reported yearly expenditure is not recorded by surface type it can be determined by assuming a cost-per-mile for each surface type and adjusting until the cost for total miles by surface types is equal to the total expenditure. Once this is done, the accuracy can be decided and future projections more readily made.

The determination of what items of maintenance are deficient and what costs are too high is now necessary. The cost per mile for each surface type is adjusted to represent this appraisal. These final estimated costs must represent a true picture of maintenance necessary over the program length and should reflect what should be, rather than what is now being done.

This method can be used only in states where existing records can furnish the necessary information with reasonable accuracy. A disadvantage is that it uses existing costs with only a general appraisal to determine operational efficiency and the necessity of the present operation according to established standards for traffic and service.

## Use of Detailed Maintenance Studies

These studies have been made in states where existing maintenance records were non-existent or inaccurate, and they arrive at program costs by building up costs by systems, based upon the frequency of each operation necessary for the upkeep of each surface type and other features. Known values of labor and equipment rental are applied to the operation to arrive at field costs. A 10 percent overhead allowance is usually added to these field costs.

This method approaches maintenance costs not on the basis of what is being done, but rather what should be done to provide maintenance service. It assumes a certain amount of efficiency of operation, including proper organization and mechanization, creates some standard of performance, and furnishes limits of time of these operations. For this reason, this method has the advantage of encouraging a new look at maintenance in general and operations in particular.

This type of study is useful when conducted by a specialist in this field, who is able to obtain data and interpret their implications. It requires considerable time, effort and talent. Funds may or may not be available when this information is needed. In county studies, where costs by regions are advisable, much time would be necessary for a special maintenance study. Even if representative unit costs can be developed, it is impossible to apply them if the physical and operational work loads are unknown.

## Sample Method of Estimating Maintenance

Scientific samples and statistical methods for their selection are the basis for this procedure. Maintenance estimates, for the selected samples, are compiled in the same manner as in the detailed maintenance studies. Each sample is appraised to estimate the cost resulting from each operation and its annual frequency. The detail work of estimating sample costs is performed by a member of the staff with the aid of each district maintenance engineer.

The sample size is dependent upon the statistical approach to the problem; variations of terrain, road mileage, and degree of accuracy are controlling factors. In one state, 10 percent of the state trunk system and 4 percent of the county primary system were sampled. Generally, sampling to determine estimates by surface types within the different systems is desirable.

Estimated costs for the samples are expanded by surface types for each system to give the estimated state totals. These totals over a program period should be adjusted to reflect changes which will occur through improved surfaces and also those required by increased traffic demands.

This type of appraisal approaches the problem in light of what should be done and what it should cost. It should stimulate operations to obtain performance at the estimated costs.

This method requires a skilled statistician and enough factual information must be assembled to determine a basis of sample selection. The detail work of estimating operations, their frequency and cost also requires skill by employees with practical experience in maintenance operations. The time required is considerable, and in state studies this often is an important factor.

## Consultation Method

Special maintenance committees composed of engineers estimate maintenance amounts. Starting with a system, an estimated annual cost per mile for each maintenance item is made for roads of various ADT and for each surface type. This is carried out for regions into which counties are grouped to reflect similar conditions.

The costs per mile of each function are added together, resulting in a total estimated cost per mile for each system and by surface type. Snow removal costs, if available, can be added for each system or they must be estimated. The amounts computed for each system are compared to existing expenditures and adjusted to provide for traffic increases with resulting maintenance demands during the program period.

This system is rapid, but it does lack factual background since the costs are largely a matter of judgment. It would not be practical to use consultation unless engineers or superintendents were competent or qualified to make these decisions.

Counties in some states have realized the value of reliable records in estimating maintenance needs for programming and are revising their accounting methods to obtain better facts. These revisions include:

1. Definite distribution between construction and maintenance functions by the use of uniform definitions;
2. Reporting and accounting to provide costs by surface types; and
3. Evaluation of maintenance operations to establish standards of maintenance.

Such counties are providing a sound basis for future maintenance estimates by a planned method of providing maintenance facts. This will allow maintenance estimates to be made with the same accuracy as construction estimates.

# Priorities Determination and Programming In Tennessee

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● A COMPREHENSIVE STUDY of highway needs in Tennessee was completed in November 1955, under the direction of the Automotive Safety Foundation. The report, "Highway Transportation in Tennessee," presented alternative long range programs for the several systems of roads and streets.

The Tennessee Department of Highways and Public Works decided that the first step in putting into operation the study's proposals relative to the state highway system, was the formulation of an initial 5-year short-range program to remedy the system's most critical deficiencies. A second step should be the formulation of criteria, techniques, and procedures necessary to establish a continuing construction program to meet future deficiencies as they accrue. Pursuant to this decision, the department and the Automotive Safety Foundation entered into a cooperative research project to accomplish these two tasks.

Work on the first of these tasks has been completed and this paper describes the development of the priority rating method and procedures found to be best adapted for the formulation of the initial 5-year program.

## ORGANIZATION OF THE FIELD OF STUDY

It was agreed that the initial program would be based upon data collected and developed during the highway needs study with attention concentrated on the sections found critically deficient. Such sections accounted for about one-half of the rural state highway mileage and about one-third of the system mileage on city streets. It was clear that correction of these deficiencies (estimated to cost $505 million on the rural highways and $268 million on their urban extensions) would utilize more than the estimated income of the department for the projected 5-year program period.

The problem of formulating improvement programs was complicated by the mass and variety of the conditions involved. Not only was there a great volume of the "needed-now" situations, but different sections of road were judged critically deficient for many reasons. On rural state highways alone, there were 3,284 miles which had serious structural defects, 3,000 odd miles were appraised deficient with respect to geometric design or alignment, 554 miles lacked sufficient capacity, and many sections had a combination of these deficiencies. In addition, some sections were "accident prone" while others, even though they have serious physical deficiencies, did not seem to produce accidents. Finally, some deficient roads penalized thousands of vehicles a day and others, only a few hundred.

There were different degrees of urgency among these sections even though they were all critically deficient. If the sections were to be examined and tested individually to establish the relative urgency of their condition, the first requirement was to develop a procedure for dividing them into comparable groups to narrow the field of judgment. Moreover, a practical construction program must provide an adequate amount of work on the state highway system throughout the state and on the several subdivisions of the system with due consideration for the various types of federal aid and state funds applicable to their improvement.

To accomplish area distribution, the various funds available were apportioned among the department's four field divisions in proportion to the total needs in each division as determined by the needs study. To provide distribution to the several parts of the state system, it was determined that within each field division a rating procedure would be applied separately to the critical needs of the rural and urban portions of the federal aid primary system and of the rural and urban state highways not included in that system. Programs were then developed for each of these highway subdivisions providing for an equal rate of improvement throughout the system.

## INTERSTATE SYSTEM

In the early stages of this study, the rural and urban sections of the National System of Interstate and Defense Highways on the existing state system were also considered as subdivisions of the state highway system and deficiencies on them were determined in relation to the high standards prescribed for interstate routes and then were apportioned and rated in the same manner as deficiencies on other federal aid and state highway sections. However, after the programming study had been under way for some time, the Federal Aid Highway Act of 1956 was passed and soon thereafter the state and the Bureau of Public Roads agreed upon routes for interstate highways which, with few exceptions, were on new locations, generally some distance from the existing routes.

It was evident that a sensible and logical program for interstate projects on these new locations could not be formulated solely by reference to the conditions on existing parallel state highways. Even though the condition of such parallel routes is a consideration in programming interstate projects, factors not pertinent to urgency must be taken into account.

Accordingly, it was decided that former interstate routes would be regarded as rural federal aid highways and would be rated as such. Furthermore, no attempt would be made to rate present deficiencies on existing state highways in Tennessee's four major cities until the interstate urban freeway program had definitely taken shape.

This decision was based on the premise that the greatest congestion exists in Memphis, Nashville, Chattanooga and Knoxville where interstate routes are to be built to freeway standards. The locations of freeways in these cities have been fixed and consulting firms are now at work on detailed surveys. Initially, interstate funds will be devoted to completing all urban and rural surveys and plans as quickly as possible and to acquisition of rights-of-way in the larger cities. Earliest construction will take place, for the most part, on those sections for which right-of-way can be acquired most readily and which, when completed, will represent usable and complete improvements within themselves.

The scheduling of interstate freeway construction in the four major cities will vitally affect the scheduling of work on other state highways in these cities. For example, it would be unwise to schedule major construction on a surface highway for the same time a nearby freeway is to be built, since the present street must remain open to carry traffic while the freeway is being completed. The freeways will be the principal traffic arteries of these cities and it is apparent that the construction as well as the operation of other major streets be correlated with theirs. In programming, however, several improvement projects to correct critically deficient sections in these cities were included when their location was such that there would be no conflict with construction on the freeways and no severe impairment of traffic service.

With the deficiency items of the study grouped according to the field divisions and the subdivisions it was necessary to develop procedures for further narrowing the area of judgment within each of these groups. To this end, rating methods were devised for application to the needs as they existed in each of the highway subdivisions.

Careful study was devoted to the selection of indices and procedures for determining the relative urgency of the deficiencies. Sufficiency rating formulas adopted by other states were examined and members of the study staff visited three states, California, Oregon and Colorado, to see the operation and results of rating and programming procedures.

## TENNESSEE'S RATING REQUIREMENTS

The purposes of the Tennessee study project did not require a rating for every section of the state highway system. What was required was a screening process which would array the total number of deficient sections within each highway subdivision into a reasonable number of priority groups—in this case, five groups comprising, successively, conditions of greatest to less urgency with each group representing approximately one-fifth of the total cost of correcting all of the critically deficient sections.

The process selected derives from the experience of Tennessee people and agencies in their progress from the early wagon roads to present day transportation arteries.

Tennessee's highway problem at the beginning of the modern highway era was to build a system of roads for going any where at any time. The next phase of the problem was to provide the facilities for expeditious and comfortable travel. Obviously, freedom from hazard was an important characteristic of such travel.

The three major objectives which motivated this historic process—dependability or structural condition, facility of movement, and safety—were chosen as the major criteria in formulating the program to correct the critical deficiencies on the state's present primary system. All these criteria are included in some form in sufficiency rating procedures; what is particularly noteworthy are the methods adopted for measuring facility of movement on rural roads and urban streets.

These criteria could not be applied in the same form to rural and urban conditions. However, their basic significance in relation to efficient traffic accommodation, was used with reasonable effectiveness as a guide in determining priorities in both kinds of areas.

### Rural Priority Rating Procedures

The process of segregating the critically deficient sections on the rural state highway system into five priority groups, was accomplished in two stages: (1) the individual sections in each highway subdivision of each field division were analyzed and rated; (2) the sections were then arrayed in order of their rated urgency and arranged into five groups.

Selection of the sections for correction and the determination of their sequence in the construction program required the judgment of the highway engineer and administrator.

## RATING CRITERIA

Each of the three rating criteria chosen for this programming study—dependability, facility of movement and safety—retains its own identity throughout the rating process; each is weighed with the others, but is not lost in a single index figure.

### Dependability or Structural Condition

Dependability is measured by structural condition. The existing condition of the roadbed and road surface of every section of the rural state highway system was reported as a part of the highway needs study. Four elements of the roadway structure were reported: subgrade, drainage, base, and surface. The original field survey indicated the condition relating to each of these elements as good, substandard occasionally, substandard substantially, or substandard continuously.

The reported conditions of these elements were incorporated in an index by means of a scoring system which was to give each its due weight as a component of structural condition. This scoring system is illustrated in Table 1.

By these point values, a section where subgrade, drainage and base, and subbase were occasionally substandard, and the surface was substantially substandard, would be scored 50 points; if maintenance costs were excessive, the score would be 55 points.

These point values were selected as the result of a considerable process of trial and fitting. They were derived empirically to arrive at a set of indices representative of known conditions and which, at the same time, arrayed those conditions in usable order. They also avoid the tendency for a number of sections with varying deficient elements to fall into the same group.

TABLE 1

STRUCTURAL CONDITION INDEX

| | Point Values [a] | | | |
|---|---|---|---|---|
| | Subgrade | Drainage | Base and Subbase | Surface |
| Good | 0 | 0 | 0 | 0 |
| Substandard occasionally | 2 | 2 | 6 | 10 |
| Substandard substantially | 8 | 8 | 24 | 40 |
| Substandard continuously | 10 | 10 | 30 | 50 |

[a] For excessive maintenance, add 5 points

Considering the use of this rating scheme in retrospect, the possibility of something other than purely technical approach to structural condition may be considered. Some states rate only surface condition or "ridability." From the point of view of the motorist, the "ridability" of the road is probably the most important factor. He has little or no knowledge of the technicalities of subgrade quality, drainage, or base adequacy. He does not care which of these is causing the bad riding condition.

A rating system could be devised and aimed to measure the effects which represent a deficiency from the viewpoint of the motoring public and not the causes which produce those effects. Such a rating scheme would have to include some means for the field engineer to note the structural causes separately and to indicate that, although the present riding quality is good, the need for corrective measures rates the section high.

When the structural condition of all the critically deficient sections of a highway subdivision in one of the four divisions had been rated, their rating scores were arrayed in the descending order of their magnitude. They were then divided into ten groups, each comprised of sections with similar condition ratings. These groups were given a numerical designation ranging from 9 to 0, as indicated by the first digit of the rating scores of its included sections. Those with rating scores of 90 or over were in group 9; those with scores 80 to 89, in group 8; and those with scores 0 to 9, in group 0, etc. These digits are the indices of structural condition for the contained sections and are given the first, or left-hand place in the final 3-place index of the section's urgency.

## Facility of Movement

Facility of movement was chosen as an index to measure the degree to which the existing road and traffic conditions permit vehicle drivers to travel safely at reasonable operating speeds, in comfort and without undue mental or physical strain. Modern design standards are intended to provide such operating speeds and conditions within the traffic volumes for which they are planned. The amount by which an existing road fails to provide the standard operating speeds is a measure of its deficiency in providing facility of movement.

Aside from poor surface condition, which is an element of the structural condition criterion, and regulatory speed limits, which are outside the field of this study, the factors that are impediments to the attainment of standard operating speeds are excessive traffic, too steep grades, bad alignment, lack of passing sight distance, narrow pavements and narrow shoulders. Other procedures have attempted to rate several of these roadway factors by assigning arbitrary point values to each one. Most of them, however, do not give adequate weight to the adverse effect of traffic congestion.

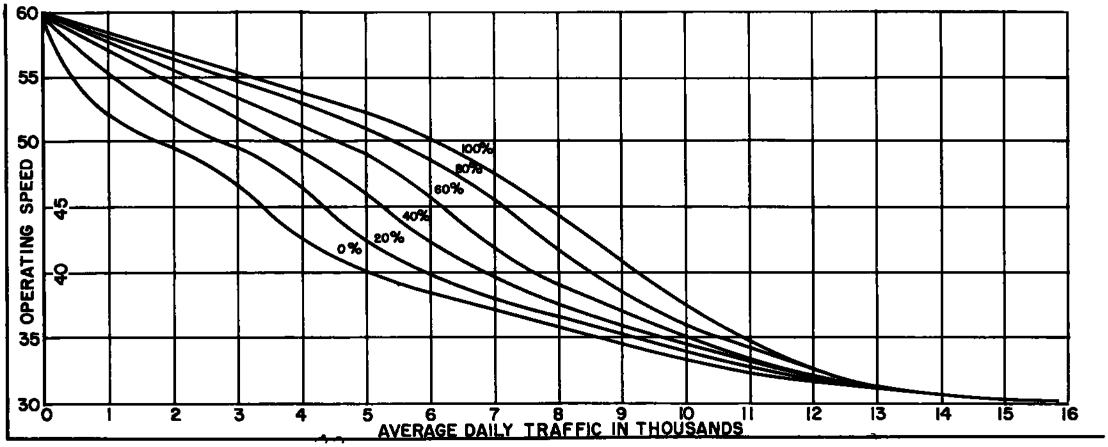


Figure 1. Effect of traffic volume and available passing sight distance on operating speed with average design speed of 60 mph. (Computed on the basis of no grades exceeding 3 percent, 12-ft lanes, 12 percent design hour, 5 percent dual-tired commercial vehicles in the design hour, and a truck equivalent of 2.)

At the request of the Tennessee Highway Department, O. K. Normann, Chairman of the Highway Research Board's Committee on Highway Capacity, developed for the first time a set of basic curves which show the operating speeds that can be obtained in the design hour under various existing conditions. This discussion is confined to the application of these devices to the Tennessee programming study.

The curves and correction factor table stem from three basic items: design speed, operating speed, and design hour traffic.

Design Speed. Used for purposes of highway design, design speed is the highest continuous speed at which individual vehicles can travel when conditions of weather and traffic are favorable and the design features of the highway are the governing conditions for safety. Design standards for a primary highway with design speed of 70 mph, tolerate no horizontal curves which require a lower rate of travel.

Operating Speed. This is the highest over-all speed, exclusive of stops, at which a driver can travel on a given highway under prevailing conditions without at any time exceeding the design speed. Therefore, in hours of very light traffic, operating speed equals design speed. As traffic increases, operating speed falls off because of the interference of other vehicles and reaches its lowest point in the hour of maximum traffic.

Design Hour Traffic. Design hour traffic is that volume of traffic (in Tennessee the 30th highest hour, or 12 percent of average daily traffic) which guides the design of highway features. In this study, design hour traffic was considered the maximum hourly traffic, which is the maximum hour except for the few hours in the year when the hourly traffic exceeds the design hour.

The design speeds and corresponding operating speeds in the design hour, adopted as design standards for the needs study were used as par values in facility of movement in hours of light traffic and of heavy traffic.

The Normann curves are based on what is called "actual average design speed," and they show, for various highway and traffic conditions in the design hour, the "actual operating speed."

Actual Average Design Speed. The calculated average speed at which a vehicle could traverse a given highway section under favorable conditions of weather and traffic when the existing horizontal alignment of the highway is the governing condition for safety is the actual average design speed. It was obtained by noting the length of subsections where too sharp horizontal curvature cut speed below the standard design rate and then averaging the speeds for the whole length of the section. Thus, for a section where sharp curvature cuts speed to 40 mph for a third of its length but where 70 mph is practical for the rest of its length, the actual average design speed would be 60 mph.

Average design speeds were computed for every rural highway section as a part of the Tennessee study. Considered in relation to standard design speed, they are indications of the degree of deficiency in operating speed at low traffic volume.

Actual Operating Speed. This is the operating speed that is estimated to prevail under the actual conditions of highway and traffic existing on a specific section. Actual operating speed in the design hour is read off the pertinent Normann curve and is a reference point for determining deficient facility of movement in hours of maximum traffic volume.

Seven sets of curves were constructed for 2-lane highways for actual average design speeds of 70, 60, 55, 50, 45, 40 and 35 mph. For each average design speed, actual operating speed in the design hour for any volume of traffic can be read off curves

TABLE 2

NEEDS STUDY SPEED STANDARDS

| | Average Daily Traffic | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Less than 1,000 | | | 1,000-3,000 | | | 3,000 and more | | |
| Terrain | Flat | Rolling | Mountainous | Flat | Rolling | Mountainous | Flat | Rolling | Mountainous |
| Design speed | 60 | 50 | 40 | 70 | 60 | 50 | 70 | 70 | 60 |
| Operating speed in design hour | 45-50 | 40-45 | 35-40 | 45-50 | 45-50 | 40-45 | 50-55 | 45-50 | 45-50 |

representing all percentages of available passing sight distance. The curves in each case are computed on the basis of no grades exceeding 3 percent, 12-ft lanes, 3- to 4-ft shoulders, 12 percent design hour traffic, with 5 percent dual-tired vehicles in the design hour representing a truck equivalent of two passenger cars in flat terrain.

All of the five latter highway and traffic conditions which are taken as fixed quantities in the computation of the curves, actually are highly variable. It was necessary to make adjustments that would reflect these variations.

Inasmuch as facility of movement is a function of traffic, means were found to compensate for these variations in traffic terms. Accomplishment of this purpose was aided by the existence of a wealth of factual information demonstrating the effect of variation of these conditions on highway capacity and movement. Most of these data had been produced through research and observation.

The first step in the procedure of appraising a section for facility of movement, was the selection of the proper set of curves indicated by the section's actual average design speed as determined by the highway needs study. Next, adjustment factors for whatever variant conditions might exist were applied to the section's average daily traffic. This produced a weighted traffic volume figure which, when used with the selected curve, gave the actual operating speed on that section.

Rating the section for facility of movement was then a mechanical process. Deficiency of movement in hours of low traffic and of maximum traffic was obtained by subtracting actual average design speed from standard design speed and actual operating speed from standard operating speed. The average of the two differences (plus differences were disregarded) was taken as a measure of the over-all deficiency throughout the range of hourly volumes. This figure was multiplied by the section's average daily traffic to give recognition to the amount of traffic affected. The resulting figure indicated the section's weighted deficiency in facility of movement.

Rated sections of a highway subdivision in a single geographic division, were arrayed in descending order and were then arranged in 10 groups each representing a like range in the weighted index and comprising approximately the same number of sections. The sections in these groups were given index numbers 9 to 0, indicating their degree of, or freedom from, deficiency. This digit was entered second in and became a part of the section's 3-place priority index.

The index of facility of movement has distinct advantages over an index of the relationship between practical capacity and existing traffic volume, usually expressed as a ratio in which all values greater than one indicate the degree to which existing traffic exceeds practical capacity. But even on very heavily traveled routes, traffic will exceed capacity only during a few hours of the day. During the remaining hours there is no capacity problem, but operating speed may be seriously reduced by a combination of lower volumes and deficient geometrics and alignment. Adequate capacity is only one of the several features that traffic is entitled to expect in its use of a highway. Traffic is vehicles in motion, and the rate, freedom and convenience of its movement at all times are factors of basic importance in measuring highway adequacy. To a very large degree these factors are reflected in the computation of the facility of movement index.

## Safety

Accidents are the true measure of lack of safety. If all accidents were reported and if the reports pin-pointed the location of each accident, then accident occurrence would provide a reliable index of highway hazard.

However, no state has accident records which approach this degree of completeness and accuracy. Fatal accidents usually are reported with details as to time, place and other major facts. It is estimated that on rural state highways there are over 100 non-fatal accidents for each accident in which a fatality occurs, but in only one state do the records show a ratio of as high as 75 to 1, and in the remaining states ratios vary from 60 down to 13 to 1. In Tennessee in 1955, the ratio of non-fatal to fatal accidents on rural state highways was 23 to 1, according to the best available records.

There are differences in the completeness of accident reporting in the different parts of Tennessee as there are between the several states. The range of these differences is indicated by the 1955 ratio of non-fatal to fatal accidents on rural state highways as reported in Tennessee's four field divisions (Table 3).

TABLE 3

| | Non-Fatal | Fatal | Ratio |
|---|---|---|---|
| Division I (Knoxville) | 3,560 | 155 | 23 |
| Division II (Chattanooga) | 1,863 | 88 | 21 |
| Division III (Nashville) | 3,498 | 122 | 29 |
| Division IV (Memphis) | 2,219 | 115 | 12 |
| All four divisions | 11,148 | 480 | 23 |

These data make it obvious that there was very incomplete reporting of non-fatal accidents throughout the state. However, except for Division IV, there is a certain degree of consistency in the ratios and the reported accidents probably reflect the relative distribution of accident occurrence with a tolerable degree of accuracy.

All accident records for 1955 were located in the road sections where they occurred and the number of accidents per mile was computed for each section. For the most part, accident occurrence on the rural state system ranged from no accidents per mile to 10 accidents per mile in 1955. Thus, the rating scale for the safety factor was practically ready-made by the data.

Selection of the rate per mile rather than the rate per 100 million vehicle miles of travel was premised on the fact that the latter method distorts the seriousness of the hazards on both high and low volume roads. This fact can be illustrated briefly from a study of accident rates made in Ohio in 1955.

Examination of data for the 39 high accident sections on the rural state highways show the following inconsistencies between per mile and per 100 million vehicle mile rates. One section 1.8 miles long carrying an average of 15,600 vehicles per day had 90 accidents; on a per mile basis it rated 3rd among all sections, but in terms of rate per 100 million vehicle miles it ranked 128th. Another section 2.5 miles long and with an average daily traffic load of 12,500 vehicles had 72 accidents; its 28.9 accidents per mile made it 7th on the list, but its rate of 6.3 accidents per 100 million vehicle miles put it down in the 258th place. Among lower volume sections, one with a length of 1.68 miles and 5,600 average daily traffic, had 33 accidents; its per mile rate put it in 16th place, but in terms of volume it was 120th.

It was believed that the per mile method relates accident occurrence more directly to the roadway itself, whereas the rate per volume reflects the character of accident occurrence as a by-product of traffic movement. Therefore, this method focuses attention on those sections having a large number of accidents and points to the need for elimination of possible hazards.

The numerical rate for safety was used as the third digit in the section's 3-place index figure.

## DETERMINATION OF URGENCY

Completion of the rating procedure was followed by the determination of priorities among the rated sections. In carrying out this operation, it was necessary to give particular attention to two special types of circumstances. Where, in the course of stage construction, a temporary gravel or similar surface had been laid on a roadbed of approved design, the section was given a score of 5-0-0 as a means of identifying its status as a stage construction project. Also, in the case of planned new construction on a new route not now existing, the projected section was given a special 0-0-0 rating to indicate its special status.

The process of determining the relative urgency of the other sections demonstrated the advantages of the 3-digit form of the rating index. The digits 0 to 9 were used to designate increasing degrees of deficiency in structural condition, facility of movement and safety, and the rating digits of these factors were arranged in the order named from left to right to form the total index of deficiency for each section.

The order in which the factors were represented in the rating index indicates the order in which they were used in determining the sections' relative priority. As the process of determining priorities shows, individual adequate consideration was given to each of the factors. Throughout the procedure, careful consideration was given to instances where the other factors were associated as causes or effects with the controlling factor in each stage of the process.

The final operation in the process of urgency determination consisted of arranging all the rated sections of each highway subdivision in the order of their urgency. This was done by making five successive arrays of the sections in each subdivision, the order of the array in each instance being determined by a different combination of the rated factors.

The first array consisted of those sections with deficiency ratings for structural condition of 9, 8 and 7 arranged in that order. Each of these groups of like appraised structural deficiency was further arrayed according to the amount of the rating of the sections for facility of movement and, then, of their rating for safety. The sections so arranged were set aside as constituting the situations of highest urgency.

The second array consisted of the remaining sections with deficiency ratings for facility of movement of 9, 8 and 7 in that order. Sections in each of these groups of like deficient facility of movement were further arrayed according to the amount of their rating for structural condition and, then, of their safety rating. These sections so arranged, were added to those previously arranged, as constituting the situations of next highest priority.

The third array consisted of the sections remaining with deficiency ratings for safety of 9, 8 and 7 arranged in descending order and then further arrayed according to their structural and facility of movement ratings. So arranged, they were the sections of next priority.

The fourth array consisted of the remaining sections which had a rating for structural condition of 6 and 5 and arrayed according to their facility of movement and then according to their safety ratings. These sections were of still lower priority.

The fifth and final array consisted of arranging all of the remaining sections in order of their rating for facility of movement and then arranging them in order of their structural condition rating and of their rating for safety. These were the sections of lowest priority.

The total array was then divided into five groups which represented successive degrees of urgency, and like estimated total cost of correction.

## Priority Rating for Urban State Highways

Determination of priorities among the critically deficient conditions on urban state highway routes was concerned with sections in municipalities of from 1,000 to 35,000 population. State highway routes in municipalities with under 1,000 people were processed along with the rural highways with which they connect. Tennessee has no cities in the population range, 35,000 to 100,000, and, as has been explained, rating on the system's extensions in the four largest cities was postponed until interstate system plans for freeway development in these centers have matured.

The reasons for delimiting the urban problem in this manner are clear. In the smallest places (those under 1,000) the problems are not urban, but continuations of rural problems; in such places the city streets are only "bridges" in the rural state highway system. On the other hand, the largest cities can be considered entities in themselves since the size of their construction needs permits and requires programming over a period of years. Moreover, very often, the improvements needed in these latter places are not definable in terms of existing deficiencies on present state highway routes.

### CRITERIA FOR APPRAISING PRIORITIES

The task of selecting factors by which priorities among critically deficient urban sections could be determined, was made difficult by conflicting conditions. There should be some degree of consistency in the criteria applied to all parts of the system, rural and urban, but the availability of data differed in the two kinds of areas and there are basic differences in the characteristics of the service demanded of rural highways and city streets.

Various highway planning engineers have commented on the difficulty of rating urban street systems according to the same criteria used in rural areas. Some of the weaknesses common to such methods are especially apparent in urban ratings. A more objective method is needed and it has been suggested that a congestion index would be useful (1).

The methods for priority determination in this study were chosen after study of experience and opinion in the highway planning field. The choice was shaped by differences in the data available for and the service required of rural and urban highways. These divergencies were reconciled in a way that permitted appraisal of urban sections from viewpoints similar to, though by no means identical with, those used in judging the rural sections.

The factors selected are listed below along with the comparable factors used for rural priority determination.

| Urban State Highways | Rural State Highways |
|---|---|
| 1. Condition | 1. Structural condition |
| 2. Congestion | 2. Facility of movement |
| 3. Route characteristics | 3. Safety |

## Condition

The condition factor used for determining priorities on urban sections does not measure deficiency by such fine gradations as does the structural condition factor used for the rural sections. Although the needs study noted four degrees of condition for each of four elements of the rural roadways, it lacked the data to do more than appraise the whole structure of a city street as a single unit and judge it merely as tolerable or as failing structurally and needing immediate attention. In rating sections, therefore, their condition was designated as either 0, acceptable, or as 9, meaning that they were in critical need of resurfacing or other reconstruction. There was no middle ground between tolerable and critical conditions.

The structural condition of most arterial streets is not up to rural standards; however, on these streets where rate of movement usually is limited by other factors, structural condition is not as important as on rural highways where higher speeds are the rule. This fact was given recognition in the final process of arraying sections for priority determination where congestion, and not condition, was used as the initial control factor in arrangement.

## Congestion

Facility of movement was used as the basic factor for determining the service rating of both urban and rural sections. However, facility of movement is a general term which has specific meaning only in relation to the particular conditions to which it is applied. On rural highways it means rapid travel by individual vehicles with wide latitude in their choice of speed. On urban arteries it means free and steady flow of traffic streams with minimum interruption of the movement. Congestion was adopted as the index of an urban section's deficiency in facility of movement in the same manner that restriction of speed was adopted for that purpose on rural sections. The amount of congestion was measured in terms of vehicle-miles of travel inconvenienced by congestion.

The method for identifying the locations where congestion exists and measuring the amount of such congestion was based on traffic observation data. In the past few years, numerous traffic counts had been made on the state highway routes in all of the cities and these provided adequate information about the distribution of travel in relation both to time and to sections.

These data were first used in total to ascertain the state-wide average distribution of Tennessee's urban traffic in the 24 hours of the day. The percent of total daily traffic occurring in each hour was computed and the hours were then arranged in the descending order of the percentages. A table of hourly percentages and accumulated percentages of average daily urban traffic was then constructed (Table 4).

The highest traffic hour accounts for 8.5 percent of the whole day's traffic while the lowest, or 24th, traffic hour accounts for 0.4 percent. The accumulative percentages show what proportion of the total daily traffic movement occurs in all hours accounting

TABLE 4

HOURLY PERCENTAGES OF AVERAGE DAILY TRAFFIC[a]

| Hours | Percent in Each Hour | Accumulated Percent | Hours | Percent in Each Hour | Accumulated Percent |
|---|---|---|---|---|---|
| 1 | 8 5 | 8 5 | 13 | 4 9 | 81 0 |
| 2 | 7 5 | 16.0 | 14 | 4.0 | 85 0 |
| 3 | 7.4 | 23.3 | 15 | 3 9 | 88.9 |
| 4 | 6 3 | 29 7 | 16 | 3.4 | 92 3 |
| 5 | 6.2 | 35 9 | 17 | 2 5 | 94.8 |
| 6 | 6 0 | 41.9 | 18 | 1.3 | 96.1 |
| 7 | 6.0 | 47 9 | 19 | 1.3 | 97.4 |
| 8 | 5 9 | 53 8 | 20 | 0.8 | 98 2 |
| 9 | 5 8 | 59 6 | 21 | 0.5 | 98.7 |
| 10 | 5 6 | 65.2 | 22 | 0 5 | 99.2 |
| 11 | 5 5 | 70.7 | 23 | 0.4 | 99.6 |
| 12 | 5.4 | 76 1 | 24 | 0.4 | 100 0 |

[a] Urban areas in Tennessee arrayed in descending order.

for as much as, or more than, a given percent of the day's traffic. For example, the 6th highest hour has 6.0 percent of the day's traffic and the six hours when as much as, or more than, this proportion of the day's traffic is passing, account for 41.9 percent of the total daily traffic movement.

Records of traffic surveys and counts in individual cities provided traffic volume data for all state highway urban routes and included the average daily traffic volume on each section. The capacity per hour of each of these sections had been estimated by the 1955 highway needs study.

Determining the amount of congestion on an urban section was begun by computing the percentage of the section's average daily traffic which is represented by its capacity per hour. Referring this percentage to the table of the hourly distribution of Tennessee's urban traffic, showed how many hours there are when the section's capacity is exceeded and what proportion of its daily traffic passes in those hours. Application of these latter percentages to average daily traffic gives the number of vehicles affected; and when this figure is multiplied by the length of the section, the vehicle-miles of inconvenience due to congestion is obtained.

For example, on a section with average daily traffic of 10,000 and estimated capacity of 600 vehicles per hour, the existing roadway could accommodate 6 percent of the day's traffic in one hour without congestion. Referring this 6 percent figure to the table, shows that, on the average, there are six hours when more than 6 percent of the day's traffic will pass, and that these six hours together account for 41.9 percent of the whole 24-hour movement. That would mean that 4,190 vehicles would be passing during hours of congestion; if the section is one-half mile long, there would be 2,095 vehicle-miles of inconvenienced operation.

The number of vehicle-miles of inconvenience computed for each section was considered the section's score for determining its congestion rating. All of the critically deficient urban sections in municipalities of from 1,000 to 35,000 population in each of the department's field divisions, were then arrayed in the descending order of their scores.

It was intended that the array would be broken at approximately equal intervals of the scoring scale to form 10 groups of varying deficiency status. However, the array revealed such a preponderance of sections in the lower end of the scale that it was evident that this grouping not only would assign few sections to the higher deficiency groups, but would make it difficult to discriminate in rating the sections in the lower brackets.

This difficulty was overcome by breaking the array into groups at progressively wider intervals in the scale as the score for inconvenienced vehicle-miles increased. The method and the resulting groups are shown in Table 5.

Sections in the groups formed in this way were assigned congestion rates 0 to 9 according to the indicated absence or degree of congestion. This procedure resulted in a more equal distribution of sections among the several deficiency rating groups, but it was something more than a mere arbitrary statistical device. It tended to give due weight to the critical significance of even small degrees of congestion in a period when traffic is increasing at the currently established rate.

The digit representing the congestion index was placed second in the deficiency index on the urban sections.

TABLE 5

CODE FOR VEHICLE-MILES INCONVENIENCED

| Code | Vehicle-Miles Inconvenienced | Interval |
|---|---|---|
| 0 | None | |
| 1 | 1 - 99 | 100 |
| 2 | 100 - 299 | 200 |
| 3 | 300 - 599 | 300 |
| 4 | 600 - 999 | 400 |
| 5 | 1,000 - 1,499 | 500 |
| 6 | 1,500 - 2,099 | 600 |
| 7 | 2,100 - 2,799 | 700 |
| 8 | 2,800 - 3,599 | 800 |
| 9 | 3,600 and over | |

## Route Characteristics

TABLE 6

| Feature | Deficiency Score |
|---|---|
| Traffic lanes | |
| 7 foot | 50 |
| 8 foot | 40 |
| 9 foot | 30 |
| 10 foot | 20 |
| 11 foot | 10 |
| Bad curves | 10 |
| Offset in alignment | 10 |
| Right angle turns | 10 |
| Wandering alignment | 10 |
| Rural cross-section where urban cross-section is needed | 50 |
| Mainline railroad grade crossing | 50 |
| Restricted clearance, both horizontal and vertical | 50 |

The lack of adequate urban accident records made it impossible to rate urban sections for safety by the method used for rural sections. Not only did the existing data indicate that reporting of the number of accidents was far from complete, but individual reports in many cases failed to locate the occurrence with even relative accuracy. A substitute was required and a factor called "route characteristics" was adopted.

As a factor in priority determination, route characteristics include a number of dimensional features of the roadway cross-section and certain features of alignment and development. The deficiency scores adopted for these features are shown in Table 6.

The character of this factor as adopted, has a relationship with safety, but the relationship is not sufficiently close or direct to make route characteristics a completely satisfactory substitute. However, the factor as used also reflects conditions related to both facility of movement and adequacy of design and development, and so has real value as an indication of deficiency.

After scoring for route characteristics was completed, the sections in each field division were arranged in the descending order of their scores and divided into 10 groups, each group comprising sections of similar deficiency. The sections in the successive groups were given ratings for route characteristics ranging from 9 to 0, depending on the degree or absence of deficiency. This rating figure was then set in third place in the 3-place index of the sections priority index.

| COUNTY | ROUTE | SECTION | SUB-SECTION | TERMINI OF SECTION | LOG MILES From | LOG MILES To | LENGTH | EXISTING LANES Number | Width | Shoulder Width | Surface Type | 1955 AVERAGE DAILY TRAFFIC | PERCENT CAPACITY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Knox | 1 | 2 | 3 | Knoxville City Limits To The Grainger Co Line | 30 55 | 36 34 | 5 79 | 2 | 11 | 4 | A | 3551 | 87 |
| Knox | 73 | 11 | 1 | Knoxville City Limits To The Blount Co Line | 0 37 | 5 81 | 5 44 | 2 | 11 | 4 | A | 7201 | 197 |
| Scott | 29 | 1 | 2 | Morgan Co Line To Oneida City Limit | 3 60 | 11 52 | 7 92 | 2 | 11 | 4 | A | 1810 | 101 |
| Cocke | 35 | 6 | 1 | Newport City Limits To The Greene Co Line | 2 85 | 11 67 | 11 82 | 2 | 9 | 6 | B | 1310 | 35 |

Match Line

RURAL STATE HIGHWAYS

Division 1
System FAP
Sheet No. 1 Of 7

| PROPOSED IMPROVEMENTS Design Standard Number | Description Of Work | COST IN THOUSANDS OF DOLLARS Right-Of-Way | Construction | Total | Vehicle Mile Per Year | PRIORITY Number | Class | PROGRAM YR | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 17 | Widen & Resurface The Existing 2-Lanes And Build 2-New Parallel Lanes To Make 4-12' Lanes Divided With 10' Shoulders | 165 | 1124 | 1289 | 0 22 | 514 | 3 | 3 | |
| 17 | Widen & Resurface The Existing 2- Lanes And Build 2-New Parallel Lanes To Make 4-12' Lanes Divided With 10' Shoulders | 225 | 1611 | 1836 | 0 15 | 158 | 2 | 283 | Have A Survey But No Plans |
| 12 | 7 10 Miles Of New Construction To 2-12' Lanes With 10' Shoulders With 2 40 Miles Of Truck Lanes | 41 | 1664 | 1705 | 0 33 | 120 | 4 | 4 | Section Short-ened 0 82 Mi |
| 8 | New Construction To 2-12' Lanes With 8' Shoulders | 169 | 1475 | 1644 | 0 29 | 711 | 1 | 3 | |

Figure 2. Priority listing.

| COUNTY | ROUTE NO | SECTION NO | DESCRIPTION (Termini, Description Of Proposed Improvements And Design Standard) | PROJECT NO | LOG MILES From | LOG MILES To | LENGTH | PRIORITY CLASS |
|---|---|---|---|---|---|---|---|---|
| Knox | 1 | 2 | Beginning At The Jct Of FAS Rt No 2505 & Extending To The Grainger Co Line—Widen & Resurface The Existing Lanes & Build 2 Parallel Lanes To Make The Section 4-12' Lanes Divided With 10' Shoulders | | 30.55 | 36.34 | 5.79 | 3 |
| Knox | 73 | 11 | Beginning At The Knoxville City Limits & Extending To The Blount Co Line—Widen & Resurface The Existing Lanes & Build 2 Parallel Lanes To Make The Section 4-12' Lanes Divided With 10' Shoulders | | 0.37 | 5.81 | 5.44 | 2 |
| Scott | 29 | 1 | Beginning At Elgin & Extending To A Point 8.05 Miles South Of Oneida City Limits—7.10 Miles Of New Construction On New Location To 2-12' Lanes With 10' Shoulders Including 2.40 Miles Of Truck Lanes | | 3.60 | 11.52 | 7.92 | 4 |
| Cocke | 35 | 6 | Beginning At The Newport City Limits & Extending To The Greene Co Line—Existing 2-9' Lanes With 6' Shoulders To Be Constructed New To 2-12' Lanes With 8' Shoulders | | 2.85 | 14.67 | 11.82 | 1 |

RURAL STATE HIGHWAYS

Division 1
System FAP
Sheet No 1 Of 5

| ESTIMATED COST IN THOUSANDS OF DOLLARS | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT ESTIMATE | | | 1957-58 | | 1958-59 | | 1959-60 | | 1960-61 | | 1961-62 | | REMARKS |
| R/W | Constr | Total | R/W | Constr | R/W | Constr | R/W | Constr | R/W | Constr | R/W | Constr | |
| 165 | 1124 | 1289 | | | | | 165 | 1124 | | | | | |
| 225 | 1611 | 1836 | | | 225 | | | 1611 | | | | | |
| 41 | 1664 | 1705 | | | | | | | 41 | 1664 | | | |
| 169 | 1475 | 1644 | | | | | 169 | 1475 | | | | | No Survey Or Design Data Available |

Figure 3. Program schedule.

## DETERMINATION OF PRIORITIES

When the rating process was complete, the urban sections in each field division were put through a procedure of arrays similar to that employed in determining priorities among the rural sections, but with certain differences dictated by the character of the factors used.

It was decided that congestion should control the initial selection for priority determination. Consequently, the first array consisted of sections with congestion ratings of 9, 8, 7, 6, and 5, grouped in that order. Each group was then further arrayed according to its condition rating and, then, according to its route characteristics rating.

Next, all remaining sections rated 9 for condition were arrayed according to their rating for congestion and route characteristics. All these sections were then put aside in this order as those having the highest priority. Since rating for condition was 9 or 0, this array completed processing of all sections in which this factor was deficient.

The next array consisted of all remaining sections with ratings for route characteristics of 9, 8, 7 and 6, arranged in that order. These groups were then further arrayed according to their congestion ratings, and were then added to the sections already arrayed.

The final array consisted of all remaining sections with congestion ratings of 4, 3, 2 and 1. So arranged, they were further arrayed in order of their route characteristic ratings. As with rural sections, urban sections which were planned for construction where there was no existing street, were marked 0-0-0, but sections where only the surface was needed to complete their stage construction were given a special 9-0-0 index. This completed the determination of priorities among the urban sections.

### Treatment of Bridges

No satisfactory method was developed to include deficient bridges in the rating procedures for rural or urban roadway sections. Structurally deficient bridges are not related to structurally deficient roadway sections, nor do narrow bridges affect operating speeds seriously over roadway sections of significant length. The hazards of narrow bridges would be reflected in the safety index to the extent they caused accidents in 1955.

Deficient bridges were not entirely ignored. The highway department has had underway for several years a program for widening short span, narrow bridges and is eliminating this hazard. In the programming process described below, small deficient bridges were taken into account in scheduling improvement of roadway sections, and larger bridges seriously deficient structurally were scheduled for early replacement as separate bridge projects.

Priority Lists and Formulation of Program

Throughout the process of priority determination, the rural and urban sections with critical deficiencies were treated separately and this separation was continued through the final operation of forming the programs. Priority lists by routes, were made of the rated rural sections, one for each highway subdivision in each field division. Similar lists of the rated urban sections were made for each field division. Each of these lists served as the basis for setting up a 5-year construction program.

This separate treatment of rural and urban deficiencies and programs was made necessary by the differences between the services demanded of the roadways, the problems involved in construction, and the funds available for highway improvement in the two areas.

The 5-year programs to correct the critical deficiencies on the rural and urban routes of the state highway system were formulated from the priority lists. These lists provided the raw materials from which the programs were built; the materials were carefully selected but they had to be tested to assure a sound and practical program structure.

## CHECKING PRIORITY LISTS

As a necessary preliminary to program building, the lists of priorities were taken to the field division offices for checking. There, each list was inspected by the staff engineers most familiar with the conditions involved.

Particular attention was given to instances where stopgap or other construction completed since the needs study appraisal had changed the deficiency status of a section. Also checked were cases where there had been unexpectedly rapid deterioration of surface or other roadway elements. The priority lists were revised accordingly.

In addition, the experience, judgment and special knowledge of the division engineers were called upon to check the practical validity of the results of the priority rating. They sometimes were cognizant of road conditions and traffic usage not included in the needs study data, which had a bearing on the priority rating. They also were familiar with such operational factors as the progress and time requirements of plan preparation and right-of-way procurement which affect the sequence in which projects can be undertaken.

## THE PROGRAMMING PROCEDURE

Actual formulation of the construction programs is based on the fiscal realities of the situation. The amount of construction that could be programmed in each field division was limited by the amount of funds that would be available there during the program period. The initial step was the apportionment of estimated funds available during the next five years to the four field divisions according to their proportion of the total needs reported by the highway needs study.

The amount that could be programmed for any highway subdivision in a division depended on the funds which had been allotted to that subdivision from the field division's apportioned share of the department's income. This allotment also had been made on the basis of needs as indicated by the study.

The amount that could be programmed for each year of the 5-year program was determined by the proportion of the total approtioned funds which would be available in that year. Finally, since carrying through the construction of the Tennessee routes of the National System of Interstate and Defense Highways was considered of highest importance, estimated annual expenditures for this purpose were set aside in the field divisions where such routes were located.

Within the limits established by these several apportionments and allotments of available construction funds, the actual formulation of the 5-year programs was accomplished. The program for each highway subdivision was set up for the successive years by selecting sections from the upper ranges of the priority list for that highway subdivision.

Ordinarily, the stage construction situations, carrying an index of 5-0-0 in rural sections and 9-0-0 in urban sections, were given first consideration since completion of such projects would provide full benefits to traffic. Next, the sections indexed 0-0-0, representing projected new routes were considered because these usually represented correction of serious traffic conditions. Where construction would provide significant relief, these sections were selected for the program.

Selection of other sections proceeded, the sections being taken up in the order of their priorities but with careful consideration for several factors which have basic importance in the practical operation of a construction program.

Reference was made constantly to the estimated cost of the proposed project per vehicle-mile of annual traffic which had been computed for each of the critically deficient sections. Sections with excessively high cost per vehicle mile frequently were in difficult terrain with poor alignment and geometrics and carried low traffic volumes. Where there was little prospect that traffic would increase materially after a complete improvement, the complete improvement was deferred beyond the 5-year program. Such sections will serve their low volume traffic by stop-gap improvements, such as resurfacing and minor widening and alignment corrections.

Interference with traffic movement which would result from construction operations on adjacent or parallel routes was studied. Availability of contractor services, forces, and equipment in different areas of the state was considered, and so were such items as the status of surveys, plans and right-of-way.

Programming construction on the urban highway sections was influenced by most of these factors. There were limits to the funds available for projects in municipalities and, where additional or new right-of-way was required, the costs and time required for its procurement usually were greater than on rural sections. The need or the desirability to program work on an urban section at the same time as on the rural sections with which it connected had to be weighed.

All these factors were considered by the program study staff in its initial operations, and they were given further attention and study in several conferences with the engineering and administrative officers of the department. In these meetings, such matters as joint state-city improvement agreements to which department funds had been committed and other practical considerations, were discussed and, where necessary, the programs were revised.

The programs as completed and as adopted by the Tennessee Highway Department, conform with the priorities established in this study, modified only by the limitations of funds available and by the requirements of engineering and construction operation.

This 5-year construction program does not provide for the correction of all the critical deficiencies now existing, the funds available for the program did not permit such complete correction. However, the deficiencies left uncorrected are the least critical.

A process must be devised and adopted which will provide not only for correction of the remaining existing deficiencies, but for identifying and remedying future deficiencies as they occur and for the development of the system with the increasing demands for its services.

As a sequel to the present programming study, the same study staff is engaged in a research project to determine principles, criteria, and data required for a continuing construction program and to formulate the procedures essential for establishing such planning as a routine function of the department. This task has not yet progressed to a point where results can be reported.

# REFERENCES

1. Schroeder, Walter R., "A Suggested Congestion Rating for Urban Highways," Institute of Transportation and Traffic Engineering, University of California.

# Effect of Traffic Growth Projections upon Estimates of Highway Needs and Revenue

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ONE of the essential first steps in the making of a highway needs study is to estimate what future travel will be. It sets the stage for the measurement of needs, and it provides the framework for the development of financing structures.

Every projection of future travel is the composite of a number of assumptions. The resultant future trend (Figure 1) is generally one of three types: concave upwards, straight-line, or convex. Needs and revenue estimates will vary, and they will vary in different degrees, depending upon the type of projection or "forecast."

The purpose of this paper is not to discuss the merits of one type of forecast over another. The purpose is to show how, and to what extent, the type of forecast affects needs and revenue estimates. This progress report covers only straight-line forecasts. Analyses are currently under way for the curved-type of projections, and these will be covered in a future report.

Three straight-line forecasts were used, a 3-, 4-, and 5-percent annual increase over present traffic. The 4-percent rate, for example, means that there would be a 40-percent increase in travel in 10 years and an 80-percent increase in 20 years. For the 3- and 5-percent rates, the 20-year increase would be 60 and 100 percent, respectively. In some instances, these rates will be exceeded, but in general they fall within the range of future straight-line travel estimates found in a number of states.

Estimates of needs were then computed by the investment analysis approach (1). The investment data used for this purpose are a composite for primary rural state highway mileages in Missouri, Washington and West Virginia. Estimates of needs, thus derived, are illustrative only. A specific analysis for any given state would undoubtedly show somewhat different results due to such variables as construction costs, service lives, existing condition, and traffic density.

A straight-line traffic increase of 4 percent was used as a starting point. Needs were then computed for a 10-year catch-up period, a 20-year catch-up period, and a 30-year catch-up period. The 30-year catch-up period was included to show how much (or how little) effect the lengthening of the catch-up interval has upon the total cost over a long range period.

The cost of catching-up for each of these three periods is shown in Figure 2. Needs during a 10-year catch-up period are $500 million; for a 20-year catch-up period they are $850 million; and for a 30-year catch-up period they are $1,250 million. But this is only part of the picture, and the question can be asked: "What are the future needs after the 10- and 20-year catch-up periods, and how do the total 30-year costs compare for each catch-up program?" The answer to this is shown in Figure 3. The heavily outlined bars are the same as on Figure 2, but to the bar for the 10-year catch-up program has been added the cost of meeting needs during the second 10 years and the third 10 years. These added costs are those necessary to keep the highway system adequate, after adequacy is once attained.

The heavy bar for the 20-year catch-up program has been divided into two parts showing the relative needs during the first 10 years and the second 10 years. On top of the 20-year catch-up bar is shown the additional needs during the third decade which is the amount required to sustain adequacy once it is attained.

The heavy bar for the 30-year catch-up program has been divided into three parts to show the needs that should be met each 10-year period in an orderly schedule of catching up in 30 years.

The differences in 30-year total cost for each catch-up program are rather small. In fact, the difference between the 10-year and the 30-year catch-up programs is only 5 or 6 percent.

The significant difference between the 3 catch-up programs is not in their total 30-year cost; it is in the distribution of this total within the 30-year period. The relative

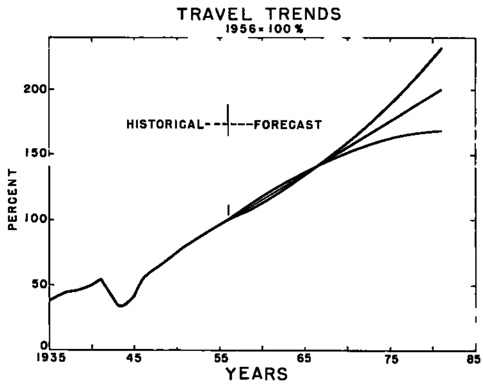


Figure 1.

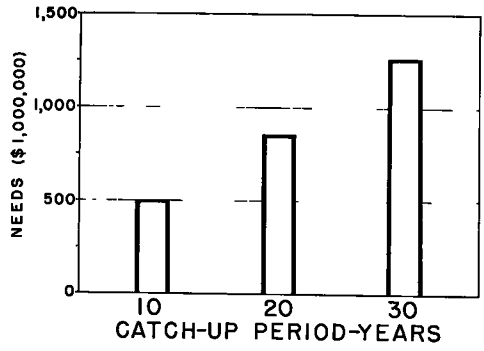


Figure 2. Cost of catch-up programs (4% straight line increase in traffic).

height of the bars for the first 10 years of each catch-up program shows, for example, that the cost during the first 10 years of the 10-year catch-up program is 50 percent greater than for the 30-year catch-up program but adequacy is reached in one-third the time.

The needs shown in Figure 3 are based on 4 percent straight-line traffic increase. Figure 4 shows how they compare with needs based on 3- and 5-percent straight-line traffic increases.

The middle bars for each of the three groups in Figure 4 are the same as those in Figure 3. To either side have been added the bars for the 3 percent and 5 percent traffic increases.

Traffic has a noticeable affect upon costs. Within each catch-up program, the total height of the bars shows a spread of about 30 percent between the 3- and the 5-percent forecasts. This 30 percent spread is about the same as the spread in total traffic which is 190 percent (in 30 years) for the 3-percent forecast and 250 percent (in 30 years) for the 5-percent forecast. This preliminary finding suggests, therefore, that for a 30-year period, the total cost of any given catch-up program will vary in direct proportion to the total travel on the system at the end of the 30-year period. This relation does not, however, hold for shorter periods than 30 years.

Figure 5 shows the relation between revenue and needs for a 4-percent straight-line traffic forecast. The revenue bar, to the left, is based on the assumption that the income designed to meet needs over a 30-year period will follow the travel trend. Under this assumption, 25 percent of the income will be obtained during the first 10 years, another 33 percent during the second 10 years, and the remaining 42 percent during the third 10 years. For the 30-year catch-up program, these percentages by 10-year periods are almost identical. Therefore, based on the assumption that revenue follows

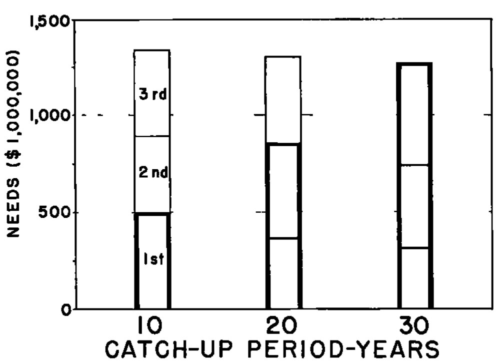


Figure 3. Cost of programs by decades (4% straight line increase in traffic).

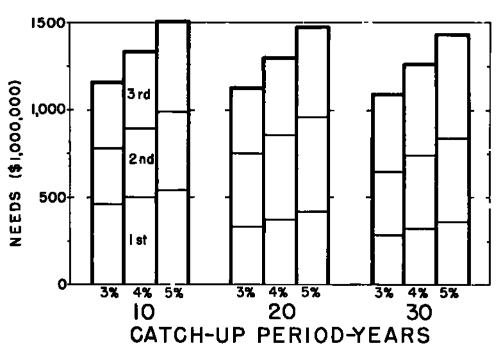


Figure 4. Cost of programs by decades (3, 4, and 5% straight line increases in traffic).

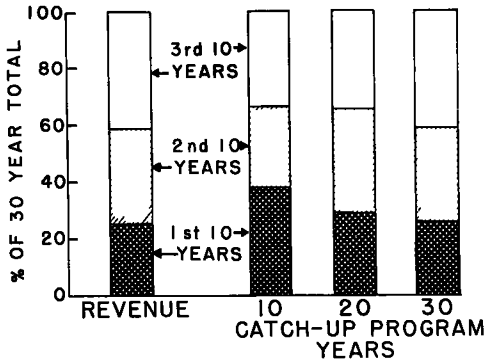


Figure 5. Distribution of revenue and needs (based on 4% straight line traffic increase).

the travel trend, a revenue structure can be designed on a pay-as-you-go basis which will produce the required income to meet scheduled needs in a 30-year catch-up program. But for the 10- and 20-year catch-up programs the total height of the bars for the first 10 and 20 years is greater than the revenue. Therefore, supplemental sources of revenue should be obtained to make up the difference. If it is made up by borrowing, such borrowing should take place in the early years and be repaid in the later years when the revenue exceeds needs. At a 3½-percent interest rate on borrowed money, the total revenue requirements would be increased by 8⅛ percent in the case of the 10-year catch-up program and 5 percent for the 20-year catch-up program. These increases would be somewhat lower if based on a 3-percent straight-line traffic forecast and somewhat higher for a 5-percent forecast.

The foregoing findings are preliminary. It is expected that, upon completion of this study, a better understanding will be gained as to the influence of travel forecasts upon needs and revenue estimates. This will serve to bring closer together the engineering and financial phases of highway needs studies.

## REFERENCE

1. Fred B. Farrell, "The Investment Analysis Approach to Estimating Highway Needs." Proceedings, Highway Research Board, Vol. 35 (1956).

# Methods of Estimating Improvement Costs on County FAS Systems in Minnesota

CLINT BURNES, Assistant Traffic and Planning Engineer
Research Minnesota Department of Highways

●REFERENDUMS failed to amend the state constitution regarding the distribution of road user money in Minnesota, partially because of the lack of information as to the proper percentages of distribution. Interested groups of road users refused to sanction or support any measure of fund distribution not based on knowledge of the requirements of the various road systems. Because of the lack of both support and knowledge, the state legislature in 1953 created a highway study commission to investigate all matters related to highways (their adequacy, needs, and financing) for the purpose of determining the sound and reasonable requirements for all highways and street systems within the state. The commission entered into two agreements for technical services to carry out the directive of the legislature. One was with the Automotive Safety Foundation of Washington, D. C., to direct and supervise an engineering analysis. The second was with the Public Administration Service of Chicago, to conduct a financial study of highway taxation and revenue distribution.

The Automotive Safety Foundation made two major determinations affecting local roads and streets: (1) a need for a 30, 000 mile county state-aid system and a 1, 200 mile municipal state-aid system, and (2) the program cost of such systems.

This determination of the county state-aid and municipal state-aid costs was based on minimum tolerable standards, and reported only in totals for the entire state in order to establish the proper relationship between the state, county and municipal needs.

The Public Administration Service determined from their analysis that the present level of income would be adequate to finance the A. S. F. recommendation over a program period of 15 years.

Based on a review of the two consultants' reports, the commission recommended to the legislature a bill for an act proposing a constitutional amendment. The legislature in turn approved the recommendations and proposed an amendment to the constitution that provided for a redistribution of road user funds, 62 percent to state trunk highways, 29 percent to the county state-aid system, and 9 percent to the municipal state-aid system; also the establishment of a county state-aid and municipal state-aid system of highways, not to exceed 30, 000 and 1, 200 miles respectively. This 1955 Minnesota legislature also appointed an interim commission on highway taxes distribution to study the method of distribution of the three funds to the various governmental units.

The County Engineers Association, and the County Commissioners Association, together with Minnesota highway department personnel, as consultants, assisted the commission by developing a formula for distributing the county state-aid fund (29 percent of road user fund). This formula was presented to the interim commission late in January 1956 for consideration. The commission, after reviewing the principles and resultant factors, accepted the formula with little revision.

The formula recommended by the commission provides for prorating 50 percent of available road-user funds among counties on the basis of total construction money needs, 30 percent according to the distribution of state-aid road mileages, and 10 percent according to the distribution of motor vehicle registrations. The remaining 10 percent is to be distributed equally among the 87 counties as an equalization factor.

Using the latest available data, the county's proportional share of the four factors is totaled to provide a distribution factor. This distribution factor is applied to the total amount of user funds set aside for county state-aid purposes to determine each county's apportionment.

The interim commission recognized that accurate data on state-aid road mileage and motor vehicle registration are readily available, but existing data for prorating

## ____________ COUNTY ROAD NEEDS
## COUNTY PRIMARY SYSTEM CONTROL SHEET

County Number____________ District Number____________

The estimated costs per mile for the several classes of work, as listed herewith for the various traffic classifications, are based upon actual experience under current price levels.

| | Under 100 | 100 - 400 | 400 - 1000 | Over 1000 |
|---|---|---|---|---|
| **GRADING (1)** | | | | |
| Low | ____ | ____ | ____ | ____ |
| Normal | ____ | ____ | ____ | ____ |
| High | ____ | ____ | ____ | ____ |
| **STABILIZED GRAVEL BASE (2)** | | | | |
| Low | | ____ | ____ | ____ |
| Normal | | ____ | ____ | ____ |
| High | | ____ | ____ | ____ |
| **BITUMINOUS STABILIZED BASE (2)** | | | | |
| Low | | ____ | ____ | ____ |
| Normal | | ____ | ____ | ____ |
| High | | ____ | ____ | ____ |
| **SOIL CEMENT BASE (2)** | per 24' width | | | |
| Low | | ____ | ____ | ____ |
| Normal | | ____ | ____ | ____ |
| High | | ____ | ____ | ____ |
| **TRAFFIC BOUND AGGREGATE SURFACE (3)** | | | | |
| Low | ____ | | | |
| Normal | ____ | | | |
| High | ____ | | | |
| **STABILIZED AGGREGATE SURFACE (3)** | | | | |
| Low | ____ | | | |
| Normal | ____ | | | |
| High | ____ | | | |
| **ROAD MIX BITUMINOUS SURFACE (3)** | | | | |
| Low | | ____ | | |
| Normal | | ____ | | |
| High | | ____ | | |
| **PLANT MIX BITUMINOUS SURFACE (3)** | | | | |
| Low | | ____ | ____ | ____ |
| Normal | | ____ | ____ | ____ |
| High | | ____ | ____ | ____ |
| **STANDARD P. C. CONCRETE (3) PAVEMENT 9"-7"-9"** | per 24' width | | | |
| Low | | | | ____ |
| Normal | | | | ____ |
| High | | | | ____ |

Date____________________ Signed______________Co. Hwy Engr.

Figure 1.

RURAL STATE-AID STANDARDS - DESIRABLE MINIMUMS

| Average Daily Traffic | Surface Type | WIDTHS Sub-grade | WIDTHS Finished Roadway | WIDTHS Sur-face | DESIGN SPEED Flat | DESIGN SPEED Roll-ing | DESIGN SPEED Mtns * | SHARPEST CURVE Flat | SHARPEST CURVE Roll-ing | SHARPEST CURVE Mtns * | MAXIMUM GRADIENT Flat | MAXIMUM GRADIENT Roll-ing | MAXIMUM GRADIENT Mtns. * | NON-PASSING SIGHT DISTANCE Flat | NON-PASSING SIGHT DISTANCE Roll-ing | NON-PASSING SIGHT DISTANCE Mtns * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Under 100 | Traffic Bound Aggregate | 24 | 24 | 22 | 45 | 40 | 30 | 10 | 12 | 22 | 5 | 7 | 10 | 320 | 300 | 275 |
| 100-400 | 5-Ton - Base and Road Mix Mat | 30 | 26 | 22 | 50 | 50 | 40 | 8 | 10 | 14 | 4 | 5 | 8 | 350 | 350 | 300 |
| 400-1000 | 7-Ton Base and Hot Mix Mat | 32-34 | 28-30 | 24 | 60 | 50 | 45 | 5 | 8 | 10 | 3 | 5 | 7 | 475 | 350 | 320 |
| Over 1000 | 7-T Ult 9 T Base and Hot Mix Mat | 36-38 | 30-32 | 24 | 60 | 50 | 45 | 4 | 5 | 8 | 3 | 4 | 6 | 475 | 350 | 320 |

Note Where conditions justify design geometrics below the Desirable Minimums as shown herein, the Department can in its discretion approve of such design modifications within the Absolute Limits recognized by the AASHO and as recorded under Manual No 090 201 - (Rev. 12-21-55) * Mtns = Mountainous

BRIDGE STANDARDS

| | NEW BRIDGES Clear Width (ft.) | NEW BRIDGES Design Load (AASHO) | BRIDGES TO REMAIN Clear Width (ft.) | BRIDGES TO REMAIN Safe Load (Posting Basis in Tons) |
|---|---|---|---|---|
| Under 100 | 24 | H-20 | 18 | 10 T |
| 100-400 | 24 *[1] | H-20 | 24 | 15 T |
| 400-1000 | 30 | H-20 | 24 | 15 T |

Note *[1] - Minimum of 24' but not less than 2 ft wider than surfaced width on structures of 80 ft or less in length.
GENERAL NOTE. Consideration should be given to constructing all short span structures to full shoulder width.

Figure 2.

funds to be allotted on the basis of total construction money needs are not satisfactory. It recommended to the legislature in September 1956 that a new survey of road needs be conducted by the county engineers with the commissioner of highways cooperating.

Upon release of this report and assuming the amendment would pass at the general election in November, the executive committee of the county highway engineers association requested the county division of the highway department to institute a county needs study to provide the basis for distributing the road-user fund as proposed.

The amount of work involved in computing the needs and selecting the county state-aid system prior to the effective date of the amendment did not permit waiting until the amendment passed before starting the study.

Also, because of a legislative recommendation to include all federal-aid secondary roads in the county state-aid system and an anticipated future request from the Bureau of Public Roads for a comprehensive road study which would include federal-aid secondary (FAS), any hesitancy on starting the study immediately was removed. The study was started, but only on the federal-aid secondary portion of the system, which amounts to approximately 16,000 miles of the proposed 30,000 mile state-aid system. This saved over two months of time of an already tight schedule, as the amendment passed with a majority vote of approximately 80 percent, and the Bureau of Public Roads is requesting a needs study pursuant to the 1956 Federal-Aid Act, Section 210.

## ASSUMPTIONS

This study could be called a "Modified 25-Year Needs Study"—modified in the respect that it does not permit the inclusion of theoretical replacements to proposed improvements. For example, a presently inadequate bituminous road needing grading, base and bituminous surfacing, may need one or possibly two additional bituminous mats in 25 years; however, this study permits including only the actual need of one mat at a time. Recurring studies at 2-year intervals will pick up the subsequent replacement needs at each stage of construction.

The rural design standards established as a minimum are slightly higher than those presently used, and while considered as desirable minimums, they establish the maxi-

MUNICIPAL CONTROL SHEET

COUNTY STATE-AID EXTENSIONS IN MUNICIPALITIES OVER AND UNDER 5,000 POPULATION

County Number ______________ District Number ____________

The estimated costs per mile for the several classes of work, as listed herewith for the various traffic and street classifications, are based upon actual experience under current price levels.

| | | | | |
|---|---|---|---|---|
| Type of Street | NORMAL STREET | | WIDE STREET MAJOR ARTERIAL | |
| Surface Width | 28 foot | 44 foot | 62 foot | 62 foot Plus Median |
| | Light | Medium | Not Divided | Divided |
| Traffic | Traffic | Traffic | Heavy Traffic | |
| Design Section | Rural Sec. | Munic. Sec. | Munic. Sec. | Munic. Sec. |
| Design Type | Interm. Type | High Type | High Type | High Type |
| Design Load | 5 ton | 7 ton* | 9 ton | 9 ton |
| GRADING (1) | | | | |
| Low | ______ | ______ | ______ | ______ |
| Normal | ______ | ______ | ______ | ______ |
| High | ______ | ______ | ______ | ______ |
| STABILIZED GRAVEL BASE (2) | | | | |
| Low | ______ | ______ | ______ | ______ |
| Normal | ______ | ______ | ______ | ______ |
| High | ______ | ______ | ______ | ______ |
| BITUMINOUS STABILIZED BASE (2) | | | | |
| Low | ______ | ______ | ______ | ______ |
| Normal | ______ | ______ | ______ | ______ |
| High | ______ | ______ | ______ | ______ |
| SOIL CEMENT BASE (2) | | | | |
| Low | ______ | ______ | ______ | ______ |
| Normal | ______ | ______ | ______ | ______ |
| High | ______ | ______ | ______ | ______ |
| ROAD MIX BITUMINOUS SURFACE (3) | | | | |
| Low | ______ | | | |
| Normal | ______ | | | |
| High | ______ | | | |
| PLANT MIX BITUMINOUS SURFACE (3) | | | | |
| Low | ______ | ______ | ______ | ______ |
| Normal | ______ | ______ | ______ | ______ |
| High | ______ | ______ | ______ | ______ |
| STANDARD P C. CONCRETE (3) PAVEMENT | | 8" Uniform | 9" Uniform | 9" Uniform |
| Low | | ______ | ______ | ______ |
| Normal | | ______ | ______ | ______ |
| High | | ______ | ______ | ______ |

*7 ton Load Design will attain 9 ton loading with the addition of a future 2" plant mix mat.

Date________________ Signed____________________________

County Highway Engineer

Figure 3.

mums or the level at which the study is measured. These design standards were a result of conferences of the county engineers' executive committee and highway department personnel. It is proposed to relate estimated 1975 traffic volumes to these design standards to measure the deficiencies of the existing road. Under this proposal, a road, although presently adequate or meeting tolerable standards, could show up as deficient within 20 to 25 years, and as such would be eligible for partial widening, reshaping, regrading, and/or surfacing sometime in the future. The total estimated construction costs are the 25-year need amount. It was necessary to adopt this approach so as not to penalize those counties which had made considerable progress in providing needed improvements. After measuring and recording these needs, it will be possible to review the data of this study and make an adjustment every two years in a very simple manner. An accomplishment study made at the time of adjustment will assist in determining whether or not construction progress is keeping up with replacement requirements.

## PROCEDURE

A review of some of the many procedures that have been used in determining needs disclosed methods ranging from the most detailed and costly to the inexpensive and sometimes valueless "shotgun" estimates.

Keeping within the bounds of a realistic estimate and yet conserving money and manpower, a simple procedure has been devised that accomplishes the following fea-

____________COUNTY SUMMARY SHEET

Percentage of Miles in the various cost ranges by traffic volume groups on the County State-Aid System

| | Grading | | | Base | | | Bit. Surface | | | Aggregate Surfaces | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low | Normal | High | Low | Normal | High | Low | Normal | High | Low | Normal | High |
| Under 100 | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% |
| 100 - 400 | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% |
| 400 - 1000 | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% |
| Over 1000 | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% |

Signed________________________

County Highway Engineer

Dated________________________

Figure 4.

tures: (1) Eliminates the review, adjusting and recomputing of the many individual project sheets; (2) utilizes a digital computer to eliminate the many computations by the county engineer necessary to arrive at project costs; (3) establishes uniformity of control by using previously established prices; (4) permits the maintaining of a perpetual inventory of needs.

## Control Sheet

As the initial step in the procedure, the county engineer establishes the estimated average cost per mile for the several classes of work based upon minimum rural design standards for the various traffic categories, and reflecting his experience under current price levels (Figures 1 and 2). The prices established by each county engineer are the basis for the cost computations and, as such, control the accuracy and effectiveness of the study. Such prices, therefore, must be conscientiously estimated with consideration given to the scarcity of materials, labor costs, roughness of terrain, soil conditions, material costs, and all favorable or adverse conditions of his county. These prices must be governed by conditions in his county only in order to reflect his needs properly.

These individual county prices are screened with the neighboring counties at a district meeting to obtain cost estimates from each county. Each county engineer is called upon to substantiate his judgment by explaining excessive costs caused by topography, shortage of materials, etc. County engineers are familiar enough with adjacent counties to approve or disapprove of any substantial deviation from normal costs. This very important district meeting eliminates arbitrary decisions in the future state-wide screening. After the control sheets have been approved by district action, the state-wide screening committee (consisting of a minimum of two county engineers from each of the eight districts) will meet to review all control sheets and determine the proper relationships between districts. Any considerable variation between districts can thus be adjusted percentagewise by raising or lowering an entire district or districts.

## County Summary Sheet

The County Summary Sheet was established for another means of control by the state-wide screening committee. This sheet, compiled after the data is recorded, requires the reporting of the percentage of miles, in the low, normal or high range of costs of the various traffic volume groups for the various construction items (Figure 3). If a county engineer were to report, under Grading in the Traffic Volume Group 1-400, 0 percent in the low category, 10 percent in the normal category, and 90 percent in the high cost category, one of two possibilities could have occurred: (1) the estimated costs submitted on the control sheet were too low and his high cost should have been used as the normal, or (2) proper consideration was not given in selection of the cost category. This Summary Sheet will be reviewed by the state-wide screening committee which will determine whether or not the percentages are out of line.

In determining the municipal needs, the same procedure is followed.

The city engineers, working cooperatively with the Commissioner of Highways, are responsible for their needs.

CODE SHEET FOR COUNTY AND CITY NEEDS
BASIC DATA FOR FUND DISTRIBUTION
ROAD DATA

Sheet Number________

| | Item No | For M H D use only | Column No |
|---|---|---|---|
| **IDENTIFICATION** | | | |
| 1 County________ 2 Control Section________ 3 Segment________ | 1 | | 1-2 |
| 4 Termini________ | 2-3 | | 3-8 |
| 5. Incorporate Name________ 6 Length of Segment________ | 5 | | 9-10 |
| 7 Fed Aid Sec ☐(1) Fed Aid Urban ☐(2) Non Fed Aid ☐(3) | 6 | | 11-13 |
| 8 System Designation | 7-8 | | 14-15 |
| County State-aid ☐(1) Municipal State-aid ☐(2) Combination ☐(3) | | | |
| **ROAD DATA EXISTING** | | | |
| 9 Existing Surface Type________ 10 Surface Width________ 11 Road Width________ | 9-11 | | 16-20 |
| 12 Year of Latest Grading________ 13 Year of Latest Surface________ | 12-13 | | 21-24 |
| 14 Number of Lanes________ 15 Divided ☐(1) Not Divided ☐(2) | 14-15 | | 25-26 |
| 16 1955 Traffic V P D ________ 17 Expansion Factor to 1975 Traffic V P D ________ | 16 | | 27-31 |
| 18 Adequate for Present Traffic ☐(1) Deficient for Present Traffic ☐(2) | 17 | | 32-34 |
| | 18 | SKIP | 35-40 |
| **ROAD DATA PROPOSED** | | | |
| | | SKIP | 41-49 |
| 19 Priority Number________ | 19 | | 50-51 |
| 20 Proposed Surface Type________ 21 Surface Width________ 22 Roadway Width________ | 20-22 | | 52-56 |
| 23 Terrain Flat ☐(1) Rolling ☐(2) Mountainous ☐(3) | 23-24 | | 57-58 |
| 24 Design Load Under 5 Ton ☐(1) 5 Ton ☐(5) 7 Ton ☐(7) 9 Ton ☐(9) | 25-26 | | 59-60 |
| 25 No of Lanes________ 26 Divided ☐(1) Not Divided ☐(2) | Type Proj. | | 61-62 |

| RANGE OF COST OF IMPROVEMENT | Low (1) | Normal (2) | High (3) | Item No | Identity of Improvement Item / Type / Percent / Range of Cost | Column No |
|---|---|---|---|---|---|---|
| 27 Grading | | | | | | |
| 1 Complete Grading | ☐ | ☐ | ☐ | 27 | 1 0 SKIP | 63-74 |
| 2 Reshape or Widen % of grading cost________ | ☐ | ☐ | ☐ | | | |
| 28 Base | | | | | | |
| 1 Complete Base Type________ | ☐ | ☐ | ☐ | 28 | 2 SKIP | 63-74 |
| 2 Base Strengthening % of base cost________ | ☐ | ☐ | ☐ | | | |
| 29 Surface | | | | | | |
| 1 Initial Surface Type________ | ☐ | ☐ | ☐ | | | |
| 2 Additional Mat Type________ | ☐ | ☐ | ☐ | 29 | 3 0 SKIP | |
| 30 Right of Way | Est Cost | $________ | | 30 | 40000 | |
| 31 Adjustment of Utilities | | $________ | | 31 | 50000 | |
| 32 Traffic Signals | | $________ | | 32 | 60000 | |
| 33 Street Lighting | | $________ | | 33 | 70000 | |
| 34 Miscellaneous Const (Includes curb & gutter, storm sewer, sidewalks, etc ) | | $________ | | 34 | 80000 | 63-74 |

County Engineer________ Date________

City Engineer________ Date________

Figure 5.

## Recording Data

The second step involves the recording of the data on the Road Data Sheet (Figure 5) and the Bridge and Railroad Crossing Sheet (Figure 6).

Examination of these forms will reveal the ease of recording data. Recording the majority of the data, already a matter of record in the county engineer's files, is either the writing of a few numbers or the simple checking of a box.

Before recording data, a county map showing the established control sections of the designated system is examined to determine segment lengths. This important de-

DATA SHEET FOR COUNTY AND CITY NEEDS
BASIC DATA FOR FUND DISTRIBUTION
BRIDGE AND RAILROAD CROSSING

Bridge Sheet No ____

| | Item No | For M H D use only Column No |
|---|---|---|
| **IDENTIFICATION** | | |
| 1 County________ 2 Control Section________ 3 Segment________ | | |
| 4 Incorporate Name________ | 1 | 1-2 |
| 5 Name of Stream, Road, or Railroad________ | 2-3 | 3-8 |
| 6 Fed Aid Sec ☐(1) Federal Aid Urban ☐(2) Non Fed Aid ☐(3) | 4 | SKIP 9-13 |
| 7 System Designation | 6-7 | 14-15 |
| County State-aid ☐(1) Municipal State-aid ☐(2) Combination ☐(3) | | |
| **EXISTING CONDITIONS Structures Only** | | |
| 8 Type of Service: Stream Crossing ☐(1), Highway over R R ☐(2), Highway under R R ☐(3), Highway Separation ☐(4) | 8-9 | SK 16-18 |
| 9 Type of Structure: Timber ☐(1), Concrete Slab ☐(2), Concrete T Beam ☐(3), Steel I Beam ☐(4), Steel Girder ☐(5), Steel Truss ☐(6), Other (Specify) ☐(7) ________ | | |
| 10 Roadway Width________ | 10 | 19-20 |
| 11 Year Built________ | 11 | 21-22 |
| 12 No of Spans________ | 12 | 23-24 |
| 13 No of Lanes________ | 13-14 | 25-26 |
| 14 Divided ☐(1) Not Divided ☐(2) | | |
| 15 1955 Traffic V P D________ | 15 | 27-31 |
| 16 Expansion Factor________ | 16 | 32-34 |
| 17 Adequate ☐(1) Not Adequate ☐(2) | 17 | SKIP 35-40 |
| 18 Safe Loading________ | 18 | 41-42 |
| 19 Vertical Clearance________ | 19 | 43-45 |
| 20 Length in feet________ | 20 | 46-49 |
| **PROPOSED IMPROVEMENTS Structure Only** | | |
| 21 Priority Number________ | 21 | 50-51 |
| 22 Type of Service: Stream Crossing ☐(1), Highway over R R ☐(2), Highway under R R ☐(3), Highway Separation ☐(4) | 22-23 | 52-53 |
| 23 Type of Work: Recondition Existing Structure ☐(1), Replace - Same Location ☐(2), Replace - New Location ☐(3), New Structure ☐(4) | | |
| 24 Type of Structure________ | 24 | 54 |
| 25 Roadway Width________ | 25 | 55-56 |
| 26 Design Loading________ | 26 | 57-58 |
| 27 No of Lanes________ | 27-28 | 59-60 |
| 28 Divided ☐(1) Not Divided ☐(2) | | |
| 29 Length in feet________ | 29 | 61-64 |
| **EXISTING CONDITIONS R R Grade Crossing Only** | | |
| 30 No Trains per day________ | | |
| 31 No of Tracks (Main)________ | | |
| 32 No of Tracks (Siding)________ | | |
| 33 Type of Protection: Signs Only ☐(1), Signals ☐(2), Signals and Gates ☐(3) | 33 | 65 |
| **PROPOSED IMPROVEMENT R R Grade Crossing Only** | 34 | 66-67 |
| 34 Signs Only ☐(1) Signals ☐(2) Signals and Gates ☐(3) | | |
| **COST ESTIMATE** | | 68-74 |
| 35 Structures $________ | 35 | |
| 36 R R Protection $________ | 36 | 75-80 |

County Engineer________ Date________

City Engineer________ Date________

Figure 6.

termination of segments must be made on the individual characteristics of the road section, keeping in mind the difference in traffic volume groupings, roughness of the terrain, rural or municipal designation, design geometrics, and surface types, or any other difference that would reflect a variance in construction design or costs.

As an aid to the selection of design standards of the segments and establishing priority numbers for construction, each county engineer was requested to designate all roads upon which bituminous surface is proposed by drawing a blue line above the road band on the control section maps. Above the blue line, using 1, 2, or 3 within a circle, the engineer denotes the first, second, or third 5-year period to which the bituminous project would be assigned. This assists the engineer and provides the means for a screening committee to determine the eligibility of a road not having the traffic volume necessary for initial bituminous improvement, yet included in the bituminous program to provide continuity for economy in construction, maintenance, and service. This blue line portrayal also provides an over-all view of the proposed system based on 1975 minimum standards.

## Range of Cost of Improvement

Grading is divided into two sections: 1. complete grading, and 2. reshape or widen. The reshape or widen class is used for roads with a lesser degree of deficiency based on minimum standards. Such roads would not require complete grading, therefore, the percentage of a complete grading cost is noted for use in the computer.

Base, is also divided into two portions to allow for base strengthening. The percentage of a complete base cost is estimated and noted, as well as the type of base considered.

Surface is divided into two classes, initial surface for the first surface over grading or base, and additional mat for the second bituminous surface over an existing bituminous surface. In computing the needs, only one surfacing cost is allowed at one time, either initial or additional.

Right-of-way, adjustment of utilities, traffic signals, street lighting, miscellaneous construction, are items that apply to the municipalities over 5, 000 only, with the exception of miscellaneous construction within the curb to curb limitation of municipalities under 5, 000, and within the center 24 ft limitation of municipalities over 5, 000.

## Coding

The third step involves the coding of the recorded information which is merely the assigning of a number to written or "X'd" data, and recording such number in the prescribed columnar arrangement of rectangles on the right-hand side of the data sheet. This method of coding on the data sheet provides an easier way to check the coder's work, and permits all pertinent notations to be shown on the same sheet.

After the sheets are coded, cards are punched. In this step, the data are punched through the first construction item, either grading, base, or surface. If the first item is grading, the card is punched through item 27. The second card is duplicated by automatic machine operation through type of project and then punched regularly for item 28. The same procedure is followed for all items 27 through 34; thus, it is possible to have eight cards for the single segment in municipalities over 5, 000 population. This multicard procedure is necessary as the number of columns available for punching is limited to 80.

## Computations

The first step of the computer is to multiply the 1955 Traffic in V. P. D. by the 1975 traffic expansion factor, and punch the value of the product in the blank squares marked "Skip", opposite item 18.

In the second and more involved operation of determining item costs, the control sheet cost per mile estimates are fed into the storage facility of the computer for reference. In the cards for grading, base, and surfacing, the machine reads the 1975 traffic volume from the card and searches the control data for the proper traffic volume group, which narrows the selection down to one vertical column (Figure 1); the machine determines the identity of the improvement item, such as grading, which narrows the selection down to a single horizontal grouping leaving only three costs eligible. A final determination from the low, normal, or high range of cost selects the specific cost for the item. This specific cost per mile is multiplied by the length of the segment, the product is multiplied by the percentage of cost required, and the value of the final product or item cost is punched into the card.

The actual operation is measured in milliseconds.

Items 30 through 34 are reported lump sum and as such are coded directly.

Under the item column, following items 25 - 26, is "Type of Project". A numerical value is given various types of projects to enable selection of data for programming use. Such data as miles and cost of grading, base or surfacing, either individually or collectively, and in various combinations, permit fiscal programming studies and accomplishment studies to be made for the cities and counties.

## CONCLUSION

This study is predicated upon the assumption that extensive field work is required only once in the initial survey and that maintaining a continuing needs study can be handled with ease by removing cards after construction accomplishments and replacing them with new cards describing the future requirements or needs of the section. It also accepts the use of average costs to arrive at total needs, rather than attempting to estimate accurately each individual section or project. Periodic review of traffic groupings may require minor changes, but the study should provide a stable means of needs measurement. Adjustments of the money requirements because of a rising or falling price index can be made percentagewise where needed.

This method, though not complex, is an engineering procedure and therefore is only applicable where professional engineers are in charge of the county's road construction and maintenance.

In the establishment of the procedure, careful analysis of each assumption, each determination and each regulation, together with the degree of refinement obtainable, assures that an acceptable needs study will be attained at a minimum of cost; and it will provide a reasonable basis for determining the money needs factor in the formula for distributing road-user funds.

This method is not the only possible way to arrive at a suitable estimate of county and city needs, but it is one solution to Minnesota's problem of effectively measuring the needs of the specific county state-aid and municipal state-aid systems, and it provides a method for maintaining a perpetual inventory of these systems.

# Analysis of Sampling County Road Needs In Minnesota

CLINT BURNES, Assistant Traffic and Planning Engineer, Research
Minnesota Department of Highways

● A COMPREHENSIVE needs study was completed, in 1954, for a highway study commitee of the Minnesota legislature. The needs were developed by section appraisal. Standard reporting forms served as a basis for the field appraisal and made possible a high degree of uniform reporting of existing conditions and determining needed improvements.

The 87 county engineers of the state made the appraisal of the county and township road systems by completing work sheets for each road section of these systems. All work sheets were reviewed by the study staff to insure that procedures had been followed and that improvements proposed were justified and costs were accurately estimated.

These established needs for the county and township systems were separately tabulated for each county and totaled to establish state totals. After this tabulation was completed, it was decided to explore methods of sampling and compare the results obtained with the table of the comprehensive study. If a sample would give reasonable results, it could be used in future years to arrive at state needs to date or it could be used in other states to determine a state needs total.

For administrative purposes, Minnesota is divided into eight construction districts by the Department of Highways. These eight districts are geographically located to provide reasonably comparable areas for administration of the state trunk highway system and also for the administration of inter-related road affairs between the state and local authorities. Because of the geography the counties within each district should be somewhat similar with respect to factors, such as terrain, economic conditions, population density, relative wealth, and general road policy. As these factors affect road needs, each district could be used as a basis for sampling.

A tabulation was prepared in which the counties were grouped by districts showing the existing miles, deficient miles and percent deficient for the state aid, county and township systems, and corresponding total data for all systems within the county. These data were accumulated in district totals and also in statewide totals.

As the tabulated data were taken from a preceding needs appraisal, a test of sampling methods could be made by comparison of the sample expansions to the actual state totals. It was decided to use two methods of sampling and to test the expanded percentage of miles deficient for the two samples against the corresponding known data. Both samples were chosen by selecting one county from each district. Sample A was chosen by an engineer familiar with state conditions and his sample was to reflect his judgment of counties which would have average needs for the districts. Sample B chose a random county from each district.

The expansion of sample A showed 3.0 percent more deficient mileage than actual; whereas, expansion of sample B showed 5.3 percent more than actual. These differences are relatively small and indicate that sampling procedure, if carefully done, would produce a reliable estimate of the total state needs.

To test the sampling further, tests were also made of the two samples within the three system categories of state aid roads, county aid and county roads, and township roads. Sample A produced expanded estimates differing from actual values by -0.49 percent for state aid roads, +1.83 percent for county aid and county roads, and +7.81 percent for township roads. The second sample produced corresponding values of +1.90 percent, -5.04 percent, and +18.77 percent.

Both samples show a high degree of accuracy in the higher system category, a lesser degree of accuracy in the intermediate system category and the poorest degree of accuracy in the low system category.

It is not logical to assume that this difference in degree of accuracy can be attributed to sampling technic. There is probably less accuracy in the actual estimates in the lower system category than in the higher system category.

TABLE 1

DEFICIENT MILES BY COUNTY AND DISTRICT

| County | State Aid Miles Exist | State Aid Miles Def | % Def | Co Aid & Co Miles Exist | Co Aid & Co Miles Def | % Def | Township Miles Exist | Township Miles Def | % Def | Total Miles Exist | Total Miles Def | % Def |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **District I** | | | | | | | | | | | | |
| Carlton | 145 | 73 10 | 50 41 | 264 | 76 40 | 28 94 | 462 | 102 20 | 22 12 | 871 | 251 70 | 28 90 |
| Cook | 65 | 35 00 | 53 85 | 92 | 60 10 | 65 33 | 290 | 130 85 | 45 12 | 447 | 225 95 | 50 55 |
| Itasca | 148 | 81 51 | 55 07 | 686 | 388 00 | 56 56 | 1,099 | 348 05 | 31 67 | 1,933 | 817 56 | 42 29 |
| Koochiching | 76 | 30 00 | 39 47 | 315 | 119 20 | 37 84 | 361 | 46 60 | 12 91 | 752 | 195 80 | 26 04 |
| Lake | 46 | 8 86 | 19 26 | 130 | 124 70 | 95 92 | 412 | 104 20 | 25 29 | 588 | 237 76 | 40 44 |
| Pine | 175 | 114 80 | 65 60 | 443 | 237 20 | 53 54 | 775 | 226 95 | 29 28 | 1,393 | 578 95 | 41 56 |
| St Louis | 430 | 141 70 | 32 95 | 2,391 | 563 71 | 23 58 | 1,132 | 127 70 | 11 28 | 3,953 | 833 11 | 21 08 |
| Total | 1,085 | 484 97 | 44 70 | 4,321 | 1,569 31 | 36 32 | 4,531 | 1,086 55 | 23 98 | 9,937 | 3,140 83 | 31 61 |
| **District II** | | | | | | | | | | | | |
| Beltrami | 195 | 111 69 | 57 28 | 406 | 196 20 | 48 33 | 927 | 173 87 | 18 76 | 1,528 | 481 76 | 31 53 |
| Clearwater | 143 | 67 66 | 47 31 | 355 | 181 86 | 51 23 | 555 | 75 25 | 13 56 | 1,053 | 324 77 | 30 84 |
| Hubbard | 79 | 29 02 | 36 73 | 428 | 233 49 | 54 55 | 689 | 132 30 | 19 20 | 1,196 | 394 81 | 33 01 |
| Kittson | 179 | 84 90 | 47 43 | 251 | 87 00 | 34 66 | 1,373 | 354 60 | 25 83 | 1,803 | 526 50 | 29 21 |
| Lake of the Woods | 59 | 13 50 | 22 88 | 346 | 125 30 | 36 21 | 258 | 25 80 | 10 00 | 663 | 164 60 | 24 83 |
| Marshall | 193 | 51 50 | 26 68 | 549 | 155 30 | 28 29 | 1,790 | 930 00 | 51 96 | 2,532 | 1,136 80 | 44 90 |
| Norman | 114 | 44 90 | 39 39 | 570 | 296 70 | 52 05 | 746 | 85 25 | 11 43 | 1,430 | 426 85 | 29 84 |
| Pennington | 121 | 109 79 | 90 74 | 508 | 103 75 | 20 42 | 434 | 100 30 | 23 11 | 1,063 | 313 84 | 29 52 |
| Polk | 272 | 124 79 | 45 88 | 617 | 217 90 | 35 32 | 2,078 | 645 50 | 31 06 | 2,967 | 988 19 | 33 31 |
| Red Lake | 105 | 75 20 | 71 62 | 301 | 67 40 | 22 39 | 270 | 24 00 | 8 88 | 676 | 166 60 | 24 64 |
| Roseau | 137 | 24 80 | 18 10 | 617 | 78 45 | 12 71 | 1,040 | 180 30 | 17 34 | 1,794 | 283 55 | 15 81 |
| Total | 1,597 | 737 75 | 46 20 | 4,948 | 1,743 35 | 35 23 | 10,160 | 2,727 17 | 26 84 | 16,705 | 5,208 27 | 31 18 |
| **District III** | | | | | | | | | | | | |
| Aitkin | 132 | 123 60 | 93 64 | 337 | 196 10 | 58 19 | 813 | 154 60 | 19 02 | 1,282 | 474 30 | 37 00 |
| Benton | 190 | 134 60 | 70 84 | 235 | 129 60 | 55 15 | 261 | 106 00 | 40 61 | 686 | 370 20 | 53 97 |
| Cass | 107 | 75 20 | 70 28 | 577 | 351 73 | 60 96 | 1,084 | 265 45 | 24 49 | 1,768 | 692 38 | 39 16 |
| Crow Wing | 114 | 71 10 | 62 37 | 259 | 127 60 | 49 27 | 788 | 204 45 | 25 95 | 1,161 | 403 15 | 34 72 |
| Isanti | 122 | 76 70 | 62 87 | 218 | 135 65 | 62 22 | 471 | 199 50 | 42 36 | 811 | 411 85 | 50 78 |
| Kanabec | 114 | 33 30 | 29 21 | 294 | 116 80 | 39 73 | 235 | 79 10 | 33 66 | 643 | 229 20 | 35 65 |
| Mille Lacs | 116 | 90 70 | 78 19 | 221 | 195 70 | 88 55 | 399 | 182 20 | 45 66 | 736 | 468 60 | 63 67 |
| Morrison | 238 | 141 50 | 59 45 | 372 | 267 80 | 71 99 | 916 | 353 90 | 38 64 | 1,526 | 763 20 | 50 01 |
| Sherburne | 152 | 55 05 | 36 22 | 259 | 86 90 | 33 55 | 305 | 60 06 | 19 69 | 716 | 202 01 | 28 21 |
| Stearns | 336 | 151 00 | 44 94 | 476 | 287 60 | 60 42 | 1,370 | 191 80 | 14 00 | 2,182 | 630 40 | 28 89 |
| Todd | 287 | 214 90 | 74 88 | 301 | 167 95 | 55 80 | 974 | 197 25 | 20 25 | 1,562 | 580 10 | 37 14 |
| Wadena | 121 | 89 60 | 74 05 | 324 | 259 90 | 80 22 | 309 | 136 00 | 44 01 | 754 | 485 50 | 64 39 |
| Wright | 249 | 114 20 | 45 86 | 175 | 52 80 | 30 17 | 855 | 282 15 | 33 00 | 1,279 | 449 15 | 35 12 |
| Total | 2,278 | 1,371 4[illegible] | 60 20 | 4,048 | 2,376 13 | 58 70 | 8,780 | 2,412 46 | 27 48 | 15,106 | 6,160 04 | 40 78 |
| **District IV** | | | | | | | | | | | | |
| Becker | 164 | 81 80 | 49 88 | 360 | 261 45 | 72 63 | 1,306 | 165 85 | 12 70 | 1,830 | 509 10 | 27 82 |
| Big Stone | 127 | 39 70 | 31 26 | 267 | 209 00 | 78 28 | 442 | 96 50 | 21 83 | 836 | 345 20 | 41 29 |
| Clay | 213 | 118 75 | 55 75 | 473 | 131 10 | 27 72 | 1,067 | 189 00 | 17 71 | 1,753 | 438 85 | 25 03 |
| Douglas | 324 | 185 23 | 57 17 | 259 | 146 01 | 56 37 | 479 | 84 80 | 17 70 | 1,062 | 416 04 | 38 18 |
| Grant | 116 | 29 00 | 25 00 | 329 | 92 45 | 28 10 | 428 | 44 30 | 10 35 | 873 | 165 75 | 18 99 |
| Mahnomen | 91 | 37 25 | 40 93 | 160 | 104 69 | 65 43 | 304 | 96 25 | 31 66 | 555 | 238 19 | 42 92 |
| Otter Tail | 324 | 170 10 | 52 50 | 698 | 339 60 | 48 65 | 1,950 | 163 20 | 8 37 | 2,972 | 672 90 | 22 64 |
| Pope | 172 | 73 90 | 42 97 | 132 | 119 80 | 90 76 | 555 | 241 50 | 43 51 | 859 | 435 20 | 50 66 |
| Stevens | 171 | 77 85 | 45 53 | 203 | 137 00 | 67 49 | 531 | 168 00 | 31 64 | 905 | 382 85 | 42 30 |
| Swift | 181 | 147 90 | 81 71 | 422 | 170 70 | 40 45 | 594 | 197 25 | 33 21 | 1,197 | 515 85 | 43 10 |
| Traverse | 139 | 106 10 | 76 33 | 318 | 115 30 | 36 26 | 594 | 58 70 | 9 88 | 1,051 | 280 10 | 26 65 |
| Wilkin | 162 | 93 10 | 57 47 | 293 | 117 30 | 40 03 | 734 | 93 70 | 12 77 | 1,189 | 304 10 | 25 58 |
| Total | 2,184 | 1,160 68 | 53 14 | 3,914 | 1,944 40 | 49 68 | 8,984 | 1,599 05 | 17 80 | 15,082 | 4,704 13 | 31 19 |

TABLE 1 (Cont )

DEFICIENT MILES BY COUNTY AND DISTRICT

| County | State Aid Miles Exist | State Aid Miles Def | State Aid % Def | Co Aid & Co Miles Exist | Co Aid & Co Miles Def | Co Aid & Co % Def | Township Miles Exist | Township Miles Def | Township % Def | Total Miles Exist | Total Miles Def | Total % Def |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **District V** | | | | | | | | | | | | |
| Anoka | 113 | 76 84 | 68 00 | 169 | 104 34 | 61 74 | 395 | 173 54 | 43 93 | 677 | 354 72 | 52 40 |
| Carver | 124 | 68 30 | 55 08 | 103 | 43 10 | 41 84 | 366 | 104 70 | 28 61 | 593 | 216 10 | 36 44 |
| Chicago | 116 | 87 80 | 75 69 | 164 | 111 40 | 67 93 | 386 | 144 70 | 37 49 | 666 | 343 90 | 51 64 |
| Dakota | 226 | 105 10 | 46 50 | 146 | 95 90 | 65 68 | 475 | 124 45 | 26 20 | 847 | 325 45 | 38 42 |
| Hennepin | 252 | 98 00 | 38 89 | 189 | 32 20 | 17 04 | 506 | 128 45 | 25 39 | 947 | 258 65 | 27 31 |
| Ramsey | 97 | 13 95 | 14 38 | 46 | 6 31 | 13 72 | 96 | 5 35 | 5 57 | 239 | 25 61 | 10 72 |
| Scott | 144 | 113 54 | 78 85 | 153 | 31 75 | 20 75 | 230 | 32 50 | 14 13 | 527 | 177 79 | 33 74 |
| Washington | 104 | 40 90 | 39 33 | 140 | 92 50 | 66 07 | 422 | 194 00 | 45 97 | 666 | 327 40 | 49 16 |
| Total | 1,176 | 604 43 | 51 40 | 1,110 | 517 50 | 46 62 | 2,876 | 907 69 | 31 56 | 5,162 | 2,029 62 | 39 32 |
| **District VI** | | | | | | | | | | | | |
| Dodge | 136 | 56 90 | 41 84 | 151 | 26 10 | 17 28 | 430 | 91 65 | 21 31 | 717 | 174 65 | 24 36 |
| Fillmore | 252 | 49 70 | 19 72 | 137 | 47 70 | 34 82 | 914 | 214 20 | 23 44 | 1 303 | 311 60 | 23 91 |
| Freeborn | 254 | 110 00 | 43 31 | 329 | 88 25 | 26 82 | 633 | 148 90 | 23 52 | 1,216 | 347 15 | 28 55 |
| Goodhue | 248 | 110 20 | 44 44 | 137 | 8 30 | 6 06 | 828 | 230 10 | 27 79 | 1,213 | 348 60 | 28 73 |
| Houston | 77 | 77 45 | 100 58 | 153 | 9 20 | 6 01 | 458 | 101 85 | 22 24 | 688 | 188 50 | 27 40 |
| Mower | 209 | 59 10 | 28 28 | 114 | 35 30 | 32 09 | 921 | 104 50 | 11 35 | 1,244 | 198 90 | 15 99 |
| Olmstead | 279 | 119 92 | 42 98 | 42 | 19 85 | 47 26 | 733 | 307 80 | 41 99 | 1,054 | 447 57 | 42 46 |
| Rice | 217 | 117 30 | 54 06 | 221 | 107 35 | 48 57 | 375 | 117 30 | 31 28 | 813 | 341 95 | 42 06 |
| Steele | 160 | 37 50 | 23 44 | 105 | 20 00 | 19 05 | 419 | 46 90 | 11 19 | 684 | 104 40 | 15 26 |
| Wabasha | 151 | 62 00 | 41 06 | 148 | 54 75 | 36 99 | 432 | 133 60 | 30 93 | 731 | 250 35 | 34 25 |
| Winona | 157 | 71 40 | 45 48 | 186 | 107 00 | 57 53 | 452 | 131 18 | 29 02 | 795 | 309 58 | 38 94 |
| Total | 2,140 | 871 47 | 40 72 | 1,723 | 523 80 | 30 40 | 6,595 | 1,627 98 | 24 69 | 10,458 | 3,023 25 | 28 91 |
| **District VII** | | | | | | | | | | | | |
| Blue Earth | 286 | 207 60 | 72 59 | 377 | 211 85 | 56 19 | 579 | 123 90 | 21 40 | 1,242 | 543 35 | 43 75 |
| Brown | 202 | 148 40 | 73 47 | 67 | 39 40 | 58 81 | 693 | 253 00 | 36 51 | 962 | 440 80 | 45 82 |
| Cottonwood | 210 | 131 10 | 62 43 | 197 | 127 50 | 64 72 | 706 | 349 40 | 49 49 | 1,113 | 608 00 | 54 63 |
| Faribault | 138 | 75 20 | 54 49 | 237 | 92 20 | 38 90 | 828 | 289 90 | 35 01 | 1,203 | 457 30 | 38 01 |
| Jackson | 244 | 108 40 | 44 43 | 205 | 35 80 | 17 46 | 769 | 172 95 | 22 49 | 1,218 | 317 15 | 26 04 |
| Le Sueur | 281 | 136 90 | 48 72 | 201 | 15 00 | 7 46 | 256 | 51 85 | 20 25 | 738 | 203 75 | 27 61 |
| Martin | 185 | 83 30 | 45 03 | 350 | 147 05 | 42 01 | 730 | 137 80 | 18 88 | 1,265 | 368 15 | 29 10 |
| Nicollet | 151 | 104 80 | 69 40 | 133 | 86 20 | 64 81 | 380 | 96 50 | 25 39 | 664 | 287 50 | 43 30 |
| Nobles | 216 | 129 40 | 59 91 | 155 | 70 80 | 45 68 | 927 | 268 69 | 28 98 | 1,298 | 468 89 | 36 12 |
| Rock | 132 | 90 95 | 68 90 | 170 | 108 90 | 64 06 | 570 | 147 90 | 25 95 | 872 | 347 75 | 39 88 |
| Sibley | 194 | 110 40 | 56 91 | 171 | 104 40 | 61 05 | 570 | 211 90 | 37 18 | 935 | 426 70 | 45 64 |
| Waseca | 204 | 163 55 | 80 17 | 159 | 76 79 | 48 30 | 334 | 126 85 | 37 98 | 697 | 367 19 | 52 68 |
| Watonwan | 176 | 34 70 | 19 72 | 175 | 14 00 | 8 00 | 406 | 96 90 | 23 87 | 757 | 145 60 | 19 23 |
| Total | 2,619 | 1,524 70 | 58 22 | 2,597 | 1,129 89 | 43 51 | 7,748 | 2,327 54 | 30 04 | 12,964 | 4,982 13 | 38 43 |
| **District VIII** | | | | | | | | | | | | |
| Chippewa | 138 | 82 90 | 60 07 | 102 | 72 70 | 71 27 | 779 | 117 10 | 15 03 | 1,019 | 272 70 | 26 76 |
| Kandiyohi | 259 | 142 20 | 54 90 | 428 | 228 20 | 53 32 | 577 | 117 05 | 20 29 | 1,264 | 487 45 | 38 56 |
| Lac qui Parle | 216 | 84 30 | 39 03 | 271 | 210 90 | 77 82 | 784 | 97 17 | 12 39 | 1,271 | 392 37 | 30 87 |
| Lincoln | 188 | 111 25 | 59 18 | 242 | 84 55 | 34 94 | 517 | 75 90 | 14 68 | 947 | 271 70 | 28 69 |
| Lyon | 282 | 37 40 | 13 26 | 158 | 119 40 | 75 57 | 753 | 148 55 | 19 73 | 1,193 | 305 35 | 25 60 |
| Mc Leod | 140 | 67 20 | 48 00 | 156 | 61 30 | 39 29 | 518 | 78 00 | 15 06 | 814 | 206 50 | 25 37 |
| Meeker | 152 | 117 05 | 77 01 | 805 | 486 30 | 60 41 | 77 | 8 80 | 11 43 | 1,034 | 612 15 | 59 20 |
| Murray | 179 | 71 40 | 39 89 | 217 | 149 00 | 68 66 | 816 | 221 71 | 27 17 | 1,212 | 442 11 | 36 48 |
| Pipestone | 192 | 121 85 | 63 46 | 228 | 111 90 | 49 08 | 393 | 91 60 | 23 31 | 813 | 325 35 | 40 02 |
| Redwood | 197 | 75 90 | 38 53 | 271 | 123 95 | 45 74 | 975 | 213 05 | 21 85 | 1,443 | 412 90 | 28 61 |
| Renville | 260 | 114 45 | 44 02 | 381 | 56 45 | 14 82 | 1,032 | 77 50 | 7 51 | 1,673 | 248 40 | 14 85 |
| Yellow Medicine | 214 | 55 00 | 25 70 | 247 | 43 31 | 17 53 | 818 | 67 50 | 8 25 | 1,279 | 165 81 | 12 96 |
| Total | 2,417 | 1,080 90 | 44 72 | 3,506 | 1,747 96 | 49 86 | 8,039 | 1,313 93 | 16 34 | 13,962 | 4,142 79 | 29 67 |
| State Total | 15,496 | 7,836 35 | 50 57 | 26,167 | 11,552 34 | 44 15 | 57,713 | 14,002 37 | 24 26 | 99,376 | 33,391 06 | 33 60 |

## CONCLUSIONS

These investigations did not attempt to show that an accurate needs estimate could be obtained for a large area by sampling the needs in a few small areas. This probably could be done for a reasonably homogeneous large area. However, if the large area is heterogeneous, this estimate could probably be accomplished by taking a random sample of 10 percent of the area of each county and thereby having conditions applicable to every county represented in the total sample.

If time and cost are important considerations in the estimate procedure, if the desired result is to obtain a long range estimate of the total needs of a large area, and if the estimate is to be used for long range financial planning which is flexible rather than

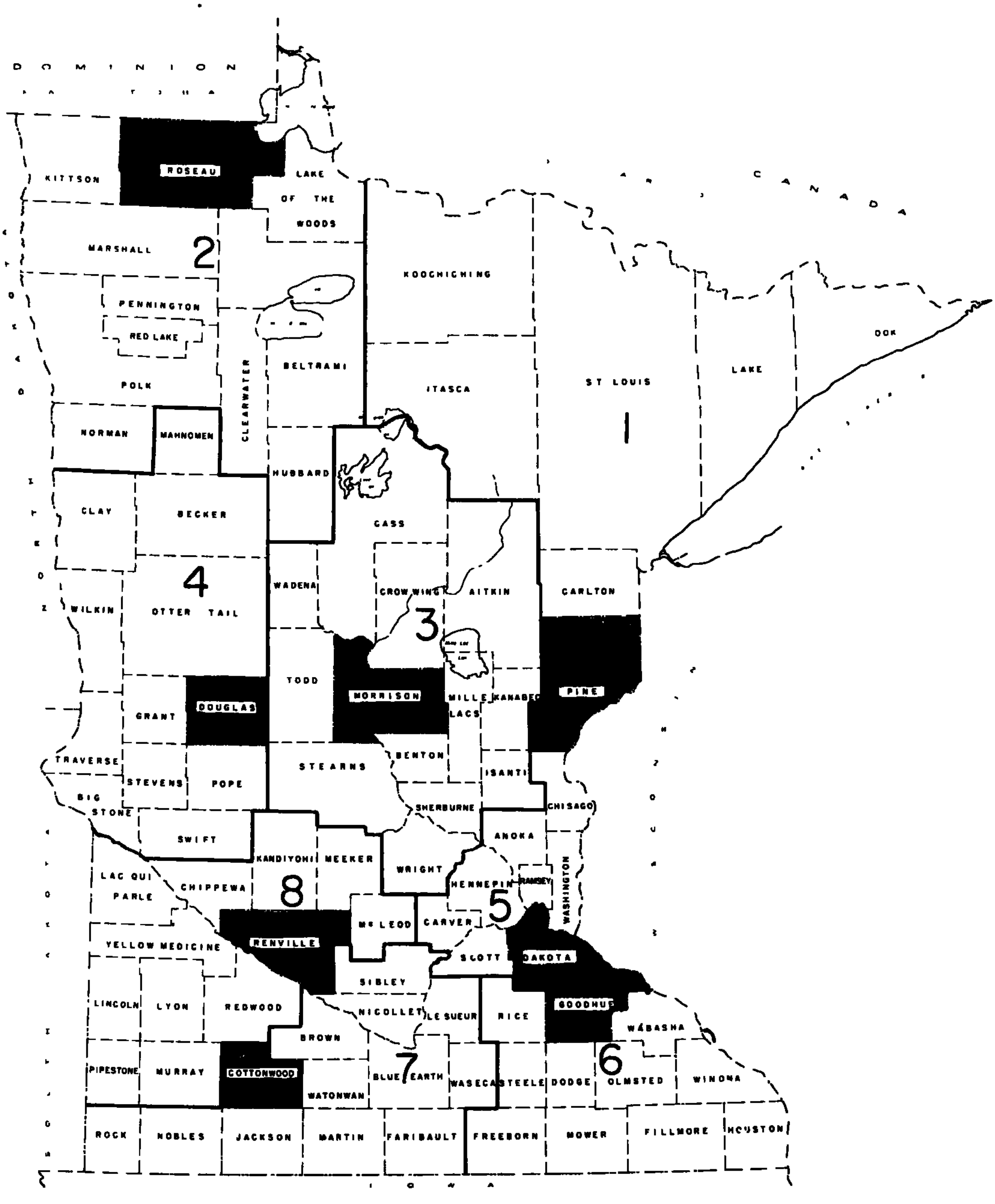


Figure 1. Map of Minnesota district boundaries and counties selected for sample A.

TABLE 2

SAMPLE A

| Dist. No. | Sample County | Counties: Total Miles | Counties: Def. Miles | Counties: % Def. | District: Total Miles | District: Def. Miles Expan. | District: Def. Miles Actual |
|---|---|---|---|---|---|---|---|
| | | | | STATE AID SYSTEM | | | |
| 1 | Pine | 175 | 114.80 | 65.60 | 1,085 | 712 | 485 |
| 2 | Roseau | 137 | 24.80 | 18.10 | 1,597 | 286 | 738 |
| 3 | Morrison | 238 | 141.50 | 59.45 | 2,278 | 1,354 | 1,371 |
| 4 | Douglas | 324 | 185.23 | 57.17 | 2,184 | 1,249 | 1,161 |
| 5 | Dakota | 226 | 105.10 | 46.50 | 1,176 | 547 | 604 |
| 6 | Goodhue | 248 | 110.20 | 44.44 | 2,140 | 951 | 871 |
| 7 | Cottonwood | 210 | 131.10 | 62.43 | 2,619 | 1,635 | 1,525 |
| 8 | Renville | 260 | 114.45 | 44.02 | 2,417 | 1,064 | 1,081 |
| | Total | | | | 15,497 | 7,798 | 7,836 |
| | Sample Error | | | | | -0.49% | |
| | | | | COUNTY AID AND COUNTY SYSTEM | | | |
| 1 | Pine | 443 | 237.20 | 53.54 | 4,321 | 2,313 | 1,569 |
| 2 | Roseau | 617 | 78.45 | 12.71 | 4,948 | 629 | 1,743 |
| 3 | Morrison | 372 | 267.80 | 71.99 | 4,048 | 3,582 | 2,376 |
| 4 | Douglas | 259 | 146.01 | 56.37 | 3,914 | 2,206 | 1,944 |
| 5 | Dakota | 146 | 95.90 | 65.68 | 1,110 | 729 | 518 |
| 6 | Goodhue | 137 | 8.30 | 6.06 | 1,723 | 104 | 524 |
| 7 | Cottonwood | 197 | 127.50 | 64.72 | 2,597 | 1,681 | 1,130 |
| 8 | Renville | 381 | 56.40 | 14.82 | 3,506 | 520 | 1,748 |
| | Total | | | | 26,167 | 11,764 | 11,552 |
| | Sample Error | | | | | +1.83% | |
| | | | | TOWNSHIP SYSTEM | | | |
| 1 | Pine | 775 | 226.95 | 29.28 | 4,531 | 1,327 | 1,087 |
| 2 | Roseau | 1,040 | 180.30 | 17.34 | 10,160 | 1,762 | 2,727 |
| 3 | Morrison | 916 | 353.90 | 38.64 | 8,780 | 3,393 | 2,412 |
| 4 | Douglas | 479 | 84.80 | 17.70 | 8,984 | 1,590 | 1,599 |
| 5 | Dakota | 475 | 124.45 | 26.20 | 2,876 | 754 | 908 |
| 6 | Goodhue | 828 | 230.10 | 27.79 | 6,595 | 1,833 | 1,628 |
| 7 | Cottonwood | 706 | 349.40 | 49.49 | 7,748 | 3,834 | 2,328 |
| 8 | Renville | 1,032 | 77.50 | 7.51 | 8,039 | 604 | 1,314 |
| | Total | | | | 57,713 | 15,097 | 14,003 |
| | Sample Error | | | | | +7.81% | |

TABLE 3

SAMPLE B

| Dist. No. | Sample County | Counties: Total Miles | Counties: Def. Miles | Counties: % Def. | District: Total Miles | District: Def. Miles Expan. | District: Def. Miles Actual |
|---|---|---|---|---|---|---|---|
| | | | | STATE AID SYSTEM | | | |
| 1 | Pine | 175 | 114.80 | 65.60 | 1,085 | 712 | 485 |
| 2 | Marshall | 193 | 51.50 | 26.68 | 1,597 | 426 | 738 |
| 3 | Todd | 287 | 214.90 | 74.88 | 2,278 | 1,706 | 1,371 |
| 4 | Clay | 213 | 118.75 | 55.75 | 2,184 | 1,218 | 1,161 |
| 5 | Washington | 104 | 40.90 | 39.33 | 1,176 | 463 | 604 |
| 6 | Mower | 209 | 59.10 | 28.28 | 2,140 | 605 | 871 |
| 7 | Brown | 202 | 148.40 | 73.47 | 2,619 | 1,924 | 1,525 |
| 8 | Redwood | 197 | 75.90 | 38.53 | 2,417 | 931 | 1,081 |
| | Total | | | | 15,496 | 7,985 | 7,836 |
| | Sample Error | | | | | +1.90% | |
| | | | | COUNTY AID AND COUNTY SYSTEM | | | |
| 1 | Pine | 443 | 237.20 | 53.54 | 4,321 | 2,313 | 1,569 |
| 2 | Marshall | 549 | 155.30 | 28.29 | 4,948 | 1,400 | 1,743 |
| 3 | Todd | 301 | 167.95 | 55.80 | 4,048 | 2,259 | 2,376 |
| 4 | Clay | 473 | 131.10 | 27.72 | 3,914 | 1,085 | 1,944 |
| 5 | Washington | 140 | 92.50 | 66.07 | 1,110 | 733 | 518 |
| 6 | Mower | 114 | 35.30 | 32.09 | 1,723 | 553 | 524 |
| 7 | Brown | 67 | 39.40 | 58.81 | 2,597 | 1,023 | 1,130 |
| 8 | Redwood | 271 | 123.95 | 45.74 | 3,506 | 1,604 | 1,748 |
| | Total | | | | 26,167 | 10,970 | 11,552 |
| | Sample Error | | | | | -5.04% | |
| | | | | TOWNSHIP SYSTEM | | | |
| 1 | Pine | 775 | 226.95 | 29.28 | 4,531 | 1,327 | 1,087 |
| 2 | Marshall | 1,790 | 930.00 | 51.96 | 10,160 | 5,279 | 2,727 |
| 3 | Todd | 974 | 197.25 | 20.25 | 8,780 | 1,778 | 2,412 |
| 4 | Clay | 1,067 | 189.00 | 17.71 | 8,984 | 1,591 | 1,599 |
| 5 | Washington | 422 | 194.00 | 45.97 | 2,876 | 1,322 | 908 |
| 6 | Mower | 921 | 104.50 | 11.35 | 6,595 | 749 | 1,628 |
| 7 | Brown | 693 | 253.00 | 36.51 | 7,748 | 2,829 | 2,328 |
| 8 | Redwood | 975 | 213.05 | 21.85 | 8,039 | 1,757 | 1,314 |
| | Total | | | | 57,713 | 16,632 | 14,003 |
| | Sample Error | | | | | +18.77% | |

rigid, then it is entirely feasible and desirable to resort to sampling technics as an economy measure. The state could be resampled every three years with approximately the same cash outlay for needs estimates over a 30-year period as a single total needs estimate would cost. It is almost essential that there be reappraisals of needs at short intervals. If these reappraisals are each to be on a total basis, the expenditure of money and engineering manpower becomes excessive. Sampling tecnics, if acceptable, would be a conservation measure and produce the desired result.

## Assembled Data

The data assembled in this investigation includes, two state maps showing the con-

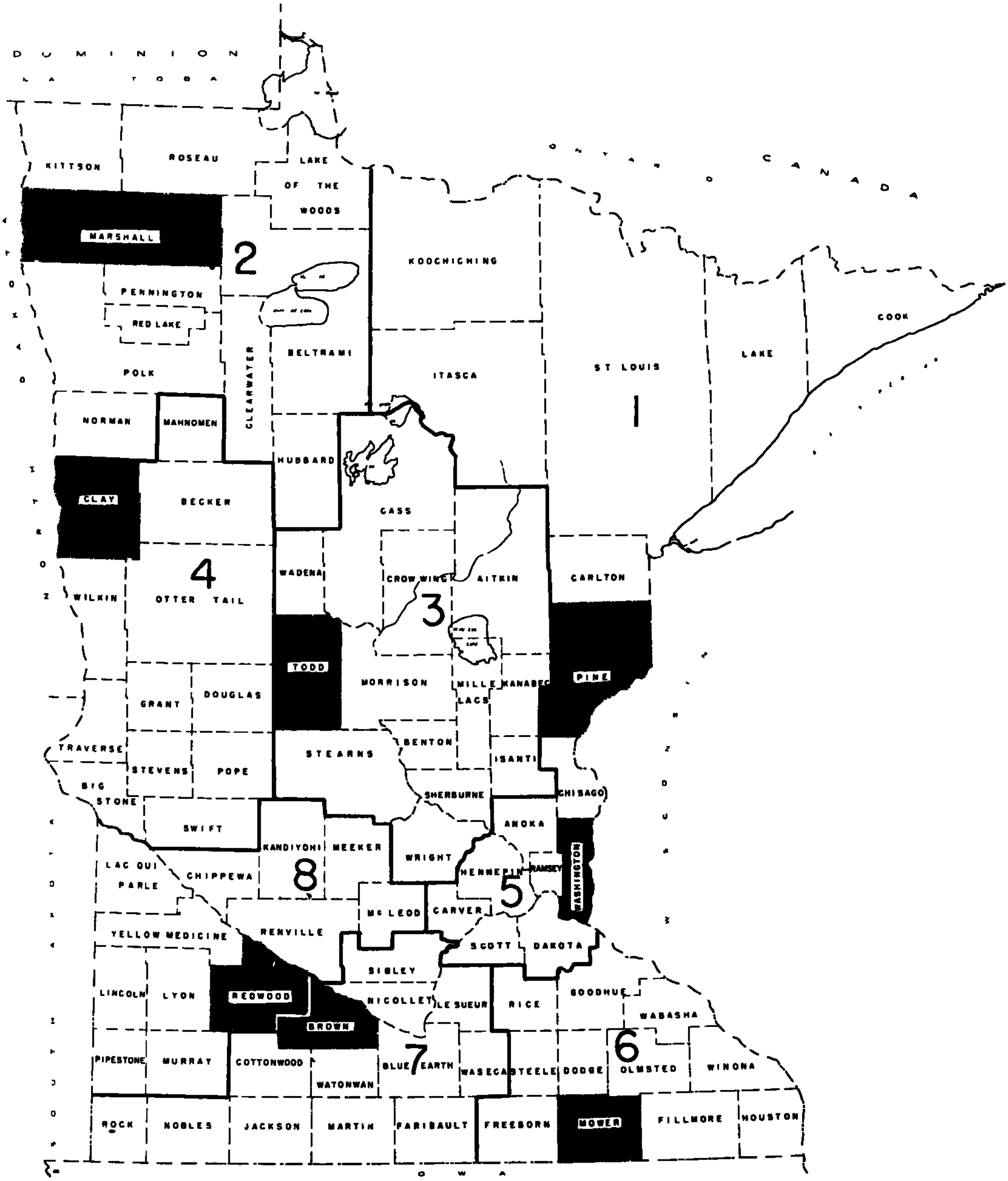


Figure 2. Map of Minnesota district boundaries and counties selected for sample B.

TABLE 4

EXPANSION OF ALL SYSTEMS

| | | Counties | | | District | | |
|---|---|---|---|---|---|---|---|
| Dist. No. | Sample County | Total Miles | Def. Miles | % Def. | Total Miles | Def. Expan. | Miles Actual |
| | | | SAMPLE A | | | | |
| 1 | Pine | 1,393 | 579 | 41.56 | 9,937 | 4,130 | 3,141 |
| 2 | Roseau | 1,794 | 284 | 15.81 | 16,705 | 2,641 | 5,208 |
| 3 | Morrison | 1,526 | 763 | 50.01 | 15,106 | 7,555 | 6,160 |
| 4 | Douglas | 1,062 | 416 | 39.18 | 15,082 | 5,909 | 4,704 |
| 5 | Dakota | 847 | 325 | 38.42 | 5,162 | 1,983 | 2,030 |
| 6 | Goodhue | 1,213 | 349 | 28.73 | 10,458 | 3,005 | 3,023 |
| 7 | Cottonwood | 1,113 | 608 | 54.63 | 12,964 | 7,082 | 4,982 |
| 8 | Renville | 1,673 | 248 | 14.85 | 13,962 | 2,073 | 4,143 |
| | Totals | | | | 99,376 | 34,378 | 33,391 |
| | Sample Error | | | | | +2.96% | |
| | | | SAMPLE B | | | | |
| 1 | Pine | 1,393 | 579 | 41.56 | 9,937 | 4,130 | 3,141 |
| 2 | Marshall | 2,532 | 1,137 | 44.90 | 16,705 | 7,500 | 5,208 |
| 3 | Todd | 1,562 | 580 | 37.14 | 15,106 | 5,610 | 6,160 |
| 4 | Clay | 1,753 | 439 | 25.03 | 15,082 | 3,775 | 4,704 |
| 5 | Washington | 666 | 327 | 49.16 | 5,162 | 2,538 | 2,030 |
| 6 | Mower | 1,244 | 199 | 15.99 | 10,458 | 1,672 | 3,023 |
| 7 | Brown | 962 | 441 | 45.82 | 12,964 | 5,940 | 4,982 |
| 8 | Redwood | 1,443 | 413 | 28.61 | 13,962 | 3,995 | 4,143 |
| | Total | | | | 99,376 | 35,160 | 33,391 |
| | Sample Error | | | | | +5.30% | |

struction district boundaries and the counties selected for samples A and B; a tabulation of deficient miles by county, district and system as determined from the actual needs study; two tabulations in which the deficient miles for each sample were expanded into state totals by system; and one tabulation in which each sample was expanded into state totals for all systems.

# Evaluating Contract Costs in Highway Needs Studies

ROBERT D. JORDAN, Alabama State Highway Department

● HIGHWAY NEEDS STUDIES usually include three phases: the nature and quantity of work needed, the cost of the work, and the programming and financing of the work. The evaluation of contract costs is an essential part of the determination of the cost of work needed. All highway departments have an abundance of data on contract unit prices on the several hundred contract items now in general use. However, it is impractical in highway needs studies, where there are usually no detailed plans, to express work needed in the same items and units as are used for contract prices, or to use as many different items.

Because highway needs studies must use a different and smaller number of work items from that used in contracts, it is necessary to select the work items and units to be used and to determine the proper unit costs for these items. Using the best cost data available (contract unit prices) the items and unit prices used in contracts must be expressed in terms of those items and unit costs to be used in the needs estimate. This is the problem of evaulating contract costs.

All state highway departments and the Bureau of Public Roads are now engaged in a major highway needs study, although it does not include the programming and financing phase mentioned above. The instruction manual issued by the Bureau of Public Roads as a guide in the preparation of the interstate highways cost estimate, required by the 1956 Federal-Aid Highway Act, specifies the fourteen items to be estimated separately, and gives the types of work to be included in each item. It also specifies that costs shall be based on contract prices as of the last half of 1956.

At the time this interstate cost estimate problem developed, the Automotive Safety Foundation was engaged in making a comprehensive needs study of the Alabama state highway system and has advised and assisted the highway department in the preparation for this cost estimate including the evaluation of contract costs.

Because the evaluation of construction costs in highway needs studies involves the evaluation of both contract work units and contract unit prices the methods used for both of these evaluations in the interstate cost estimate study will be outlined.

A general procedure was adopted in staff meetings. This included the adoption of certain sub-items for each of the fourteen estimate cost items specified in the instruction manual. These would provide for a more detailed statement of work needed and still be general enough for this study. It was also decided that forms would be prepared for use as work sheets in arriving at the quantities and costs of each sub-item; and, when completed, the work sheets would serve as records for use in reviewing or defending the estimate. There are 21 of these forms which were designed to provide space for the quantities and costs entering into each sub-item of work, as shown in Estimate Form No. 10. Twenty-seven general data tables were also prepared which show typical quantities and cost for various designs and conditions, as shown in one sample (Table 1). The use of the forms and the general data tables would promote speed, accuracy, and uniformity in preparing the estimate. Their use would relieve the estimating teams of much of the detail calculation work on their site inspections, and would also serve as a check list to prevent overlooking some items of work needed. Then it was decided that there should be prepared a manual of instructions which would guide the field estimating teams in analyzing conditions along each estimate section of interstate route, selecting the appropriate data from the tables with such modifications as needed for special conditions, and entering these on the proper forms and completing the section cost estimate. Various units of the department were assigned different parts of this task.

Studies were made to determine what contract work items could be combined into suitable sub-items of work for estimate purposes. For example, all pipe cross drains are to be listed as either 24-in., 36-in., 48-in. or 60-in. pipe, reducing the usual number of sizes from 9 to 4. Larger minor cross drains are to be either 20-, 40-, Sheet ___ of ___

OTHER BRIDGES & TUNNELS

Route ______________ Section ______________

Description (If Sub-section) ______________________________

Typical Section Code __________ Length ______________

(See Tables 21 and 23 for cost data)

| Bridges (Other than Bridge Culverts) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Str. No. | Name of Stream | Skew Angle | Single or Parallel Str. | Deck Width | Lin.Ft. Reqd. | Cost per Lin.Ft. (All Lanes) | Cost | Cost of Misc. Add Items | Total Cost |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

Sub Total ______________

| Bridge Culverts (Use Average Openings of 200, 300, 400 & 500 Sq. Ft.) | | | | | | |
|---|---|---|---|---|---|---|
| Structure No. | Average Opening Req'd (Sq.Ft.) | Skew Angle | Fill Ht. (Ft.) | Length (Ft.) | Cost per Foot | Cost |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Sub Total ______________

Tunnels & Viaducts

Tunnels & Viaducts to be worked individually and work sheets attached.

Sub Total ______________

Total this Sheet ______________

Remarks ______________________________

Total for Section ______________ = ______________

By ______________________ Date ______________

Alabama Interstate Estimate Form No. 10

Figure 1.

# TABLE 1

## COST PER LINEAR FOOT OF BRIDGE CULVERTS FOR VARYING FILL HEIGHTS *

(Prices based on bids received last half of 1956)

### 200 Sq. Ft. Opening

0° Skew Angle

| Fill Ht. | Cost Per Lin.Ft. |
|---|---|
| 0 | $ 174.00 |
| 10 | 200.31 |
| 20 | 250.42 |
| 30 | 271.04 |
| 40 | 321.08 |
| 50 | 368.93 |

30° Skew Angle

| Fill Ht. | Cost Per Lin.Ft. |
|---|---|
| 0 | $ 174.05 |
| 10 | 200.37 |
| 20 | 250.48 |
| 30 | 272.37 |
| 40 | 321.52 |
| 50 | 368.77 |

45° Skew Angle

| Fill Ht. | Cost Per Lin.Ft. |
|---|---|
| 0 | $ 177.01 |
| 10 | 203.95 |
| 20 | 255.22 |
| 30 | 273.01 |
| 40 | 322.14 |
| 50 | 366.34 |

### 300 Sq. Ft. Opening

0° Skew Angle

| Fill Ht. | Cost Per Lin.Ft. |
|---|---|
| 0 | $ 240.82 |
| 10 | 276.05 |
| 20 | 342.95 |
| 30 | 376.95 |
| 40 | 444.93 |
| 50 | 512.89 |

30° Skew Angle

| Fill Ht. | Cost per Lin.Ft. |
|---|---|
| 0 | $ 241.11 |
| 10 | 276.37 |
| 20 | 343.25 |
| 30 | 377.23 |
| 40 | 445.22 |
| 50 | 513.18 |

### 400 Sq. Ft. Opening

0° Skew Angle

| Fill Ht. | Cost Per Lin.Ft. |
|---|---|
| 0 | $ 295.77 |
| 10 | 322.19 |
| 20 | 400.97 |
| 30 | 440.08 |
| 40 | 517.96 |
| 50 | 595.83 |

30° Skew Angle

| Fill Ht. | Cost Per Lin.Ft. |
|---|---|
| 0 | $ 296.63 |
| 10 | 323.05 |
| 20 | 401.79 |
| 30 | 440.89 |
| 40 | 518.78 |
| 50 | 596.66 |

### 500 Sq. Ft. Opening

0° Skew Angle

| Fill Ht. | Cost Per Lin.Ft. |
|---|---|
| 0 | $ 383.52 |
| 10 | 460.01 |
| 20 | 578.86 |
| 30 | 630.35 |
| 40 | 733.32 |
| 50 | 836.31 |

30° Skew Angle

| Fill Ht. | Cost Per Lin.Ft. |
|---|---|
| 0 | $ 398.68 |
| 10 | 466.76 |
| 20 | 582.57 |
| 30 | 627.11 |
| 40 | 716.19 |
| 50 | 804.69 |

* Prices include unclassified excavation and foundation backfill.

70-, 100-, 140- or 180-sq ft openings. In each case, the lengths shown in the tables for each size, for each typical cross-section, and for various fill heights include an estimated amount to take care of the usual percentage of skew lines and angles of skew. The unit costs shown include allowance for the incidental items such as excavation and foundation backfill material. As another example, all grade separations are shown in the tables as crossing at either right angles, or on a skew of 15 degrees, 30 degrees, or 45 degrees. Special cases are to be estimated separately. Quantities and costs were assembled for each type of separation and angle of crossing and include enough of the usual contract items to cover the total cost of a typical case, including sufficient quantities for a variation in crossing angle of 7½ degrees either way. Practically all work items were grouped, or standardized, in the same general way. Thus, work items used in contracts were expressed in terms of work sub-items for the interstate needs estimate.

While the grouping of items was being studied by some department units, others were analyzing the contract unit prices received during the last half of 1956 as a first step in expressing these in terms of unit costs for the estimate sub-items adopted. It was necessary to study the various contract unit prices on each contract work item, and to do a certain amount of culling of individual prices where the nature or quantity of the work in a contract was clearly such as to result in a unit price that is clearly not typical. This culling is especially important where the number of different contract prices of an item is relatively small, and the non-typical unit price would carry a weight in determining the average price much different from the relation which the quantity of work represented by the price bears to the total quantity of that item in the needs estimate. As an example, a contract price on roadway excavation on a street widening job should not be used to determine cost on the relatively heavy grading of rural interstate work which will usually be on new location. Contract prices materially affected by local soils, labor rates, or other local conditions should not be permitted to influence unduly the unit cost selected for the needs estimate.

Since standards of work are occasionally raised and specifications tightened, consideration must be given to the likelihood of such changes; and appropriate adjustment should be made in the selected average contract prices where such changes will materially affect the cost.

Needs estimates often include items of work not frequently used or not obtained by contract method such as right-of-way fence, highway signs, pavement striping, and highway lighting. Cost can usually be obtained from other states obtaining these by contract method, such as those building toll roads, or extensive urban expressways, or from reputable material or equipment producers.

After analyzing and culling contract unit prices, averages of those to be used were obtained and the average contract price for each item studied for any adjustment needed because of changes anticipated in designs or specifications that would affect cost. The average contract unit prices with any adjustment found advisable were then selected for use in the needs cost estimate.

With the items of work to be used in arriving at the cost estimate determined and the representative contract prices determined for the units of work used in highway contracts during the last half of 1956, it remained to apply the representative contract prices to the estimate work sub-items. To do this it was determined what units of work appearing as items in the contracts should be included in each estimate sub-item work unit, and then the amount of each contract work unit contained in a given quantity of each estimate work unit. By applying the predetermined representative contract unit prices in the same proportions, the contract cost of each unit of each estimate work sub-item was obtained.

It then remained to determine the quantities of each estimate sub-item of work. The quantity tables included in the twenty-seven general data tables were prepared to enable the field estimating teams to arrive at the quantities rapidly, uniformly, and with a minimum of calculations. These quantity tables include data; such as, area in acres per mile for different widths of right-of-way, excavation quantities per station for different depths of cut for different typical cross-sections and for different heights of fill on borrow sections, and lengths of minor cross drain structures for each size and for various fill heights. Other tables deal with items for which the quantity is uniform and can be given on a per mile basis; such as, soil aggregate base course, subbase, shoulder construction, surfacing courses, blanket course (under concrete pavement), and fences. These tables are so arranged that the different local materials available in different parts of the state and the percentages of commercial aggregate admixtures required, can be selected for any material combination for any given estimate section. Where quantity per mile in an estimate unit is constant the table gives the various cost figures per mile for the varying conditions.

Special tables have been prepared for determining excavation quantities where no profile is available from either field survey or suitable contour maps. Several recently constructed projects were selected and the quantities expanded to what they would have been had interstate standards been used. Some of these were selected in each of the six divisions in the state, so that each division estimating team could determine quantities for a section without profile by comparison with the known projects considering the terrain, drainage, soils, etc.

Some mention should be made of the organizational procedure in utilizing these data in producing a cost estimate for an interstate route section.

Strip maps were prepared for each interstate route using the one inch to one mile county road maps. On these the routes were plotted as accurately as practical, and the estimated traffic volumes for the year 1975 indicated on both interstate routes and the intersecting roads and streets. Tentative section limits were then indicated on the map and the map sent to the appropriate division (or district) office. The division, having designated a work team of at least three engineers with one as a captain, had the line plotted on aerial photographs and adjusted by stereoscopic examination, and also had the line plotted on contour maps if available. Where profiles could be prepared, grades were laid and the line marked on the ground for easy identification.

Then a representative of the interstate office of the highway department and a representative of the Bureau of Public Roads accompanied the division estimating team over the route for determination of the general design. They decided on the suitability of the line and grades as proposed, the typical section, the location and type of interchanges, the separations (both highway and railroad), the road or street terminations, and the frontage roads.

With this data the central office completes the strip maps with appropriate symbols, copies of which are sent to the division. Then the division team estimates; earthwork from profile and tables, or from tables prepared for comparison method; number and size of minor drainage structures; areas of different classes of clearing and grubbing; dimensions and types of structures on right-of-way; data on utility adjustments, etc. The field team accompanied by representative from the interstate office and the Bureau of Public Roads, goes over the section route with maps, profiles and other data for the purpose of reviewing the quantity data already obtained for the section and completing the estimate of quantities and costs. They make certain that the proper data is selected from the various tables for that particular section and that proper allowance is made for any special conditions encountered warranting variation from the standard table data. The division team later completes simple calculations and extensions, and completes each of the twenty-one different forms, or work sheets, for each estimate section. These are then assembled by sections and forwarded to the interstate office for review and use in preparing the full route estimate report.

Alabama has just completed the general data, forms, tables, etc., and has just begun the field estimate team work on rural sections. The time spent in preparing the forms and general data tables has been well spent, however.

When the estimation of cost on the urban section begins, some variation in the procedure and some supplementing of the general data will be needed.

Although the forms, the general data tables, and the state manual of instructions regarding their use have been printed and copies are available they are not in suitable form for printing as a part of this paper other than for the examples given. The detailed data used in arriving at representative contract unit prices has not yet been printed and is still in work sheet form.

Those preparing the general data tables and the forms to facilitate their use, and other personnel who will take part in the cost estimate study have been impressed with the danger of overlooking items of work that will be needed, and underestimating the cost. Also, the importance of not padding the estimate has been stressed. If in the preparation of general tables, they include for a given cross-section more erosion control work than is customary or based cost data on higher percentages of aggregate in base course then previously required, this is not padding, but is an effort at realistic estimating where standards are being raised or designs modified. Since the estimates must be defensible as well as adequate and uniform, there should be no padding even though without extreme care there may be some overlooking of significant items.

ACKNOWLEDGMENT

This paper is based on the work done in Alabama on the interstate cost estimate. Most of the credit for this work should go to the representatives of the Automotive Safety Foundation and the Bureau of Public Roads in Alabama, and to the various staff members of the highway department assigned to this task.

# A Review of Travel Forecasts

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● LOOKING AHEAD for the purpose of estimating future conditions and events is a commonplace and necessary thing to do. Although most forecasting is short range and often handled informally, long-range forecasts serve an important role in planning large scale public works.

One of the factors which can add materially to the cost of public improvements is premature obsolesence. Where the use of public facilities can be expected to increase in future years, it is in the public interest to appraise that future use as accurately as possible in order to conserve the public wealth.

In the field of highways, during the past ten years increased attention has been given by highway administrators to evaluating the extent of future motor vehicle travel on roads and streets under their jurisdiction. They have learned that highways built to exacting structural standards can become obsolete years before their anticipated life is reached if the volume and character of traffic exceeds expectations. This has led to the practice of preparing forecasts of travel to aid in determining the traffic volumes and parking demands which can reasonably be expected in the future.

Forecasts of travel are sometimes used to estimate future maintenance requirements and the need for future road construction and reconstruction. In some states, such information is used in preparation of budgets. Estimating future road user revenues cannot be done realistically without some knowledge of road use in future years. These forecasts are also fundamental in the preparation of long-range plans for highway development.

## SOURCE OF DATA AND METHOD OF ANALYSIS

The information on which this report is based was taken from published reports on long-range highway needs prepared by 28 states. The data pertain to each state as a whole rather than to a particular system of roads or streets within the state.

No attempt was made to analyze the methods by which the forecasts were made. Forecasts can be developed in whatever amount of detail may be desired. Methods have been developed in forecasting population of a single city which are so complex as to require solution by high speed electronic computing machines. Forecasts may also be as simple as free-hand line drawn on a piece of paper. However, since data on methodology were not available and since the purpose of this study was to determine how successful the forecasts were (particularly in the light of what transpired after the forecast was made), methodology was not analyzed.

In every instance, the forecast of travel included study of several related elements which have a direct and controlling effect. Not all of the states included the same elements in their published reports, and none attempted to include directly an evaluation of future economic forces although each forecast certainly included some consideration of these matters. Generally an analysis and forecast of several items were made and then related to the forecast of travel. Included in the reports are the following: population; motor vehicle registration; motor vehicle ownership; total motor vehicle travel, or total highway use of motor fuel; and travel per motor vehicle, or highway use of motor fuel per vehicle.

Although none of the state reports included a forecast of future economic conditions, some reports indicated their forecasts were valid only if certain conditions prevailed during the forecast period. Generally, these included such items as continued prosperity, absence of a full-scale war, and other matters pertaining to economic conditions.

## FORECASTS COMPARED

The forecasts were all made in the years since 1945. Actual data for the year 1955 were then obtained to permit comparing at least a portion of the forecast with a record

TABLE 1

RATIO OF FORECASTED CHANGES TO ACTUAL CHANGES SINCE FORECAST WAS MADE [a]

Population, Motor Vehicle Registration, Ownership, Travel per Vehicle and Total Travel

| Region and State | Period Covered by Forecast | Start of Forecast Period to 1955 (years) | Population | Motor Vehicle Registration | Motor Vehicle Ownership | Travel per Motor Vehicle, or Highway Use of Motor Fuel per Vehicle | Total Travel or Total Highway Use of Motor Fuel |
|---|---|---|---|---|---|---|---|
| New England | | | | | | | |
| Maine | 1947-70 | 8 | 1 5 | 3.3 | 4 8 | | 3.8 |
| New Hampshire | 1947-60 | 8 | | 14 0 | 24 8 | 3 2 | 12.5 |
| Middle Atlantic | | | | | | | |
| New York | 1948-65 | 7 | 2.1 | 2.6 | 2.5 | | 2 5 |
| Pennsylvania | 1950-61 | 5 | 3 5 | 3.4 | 4 9 | 0 0 | 2 5 |
| East North Central | | | | | | | |
| Ohio | 1949-70 | 6 | 5.0 | 8.2 | 9 6 | 2 3 | 5.6 |
| Indiana | 1947-70 | 8 | 2.3 | 2.6 | | | 2 8 |
| Illinois | 1947-60 | 8 | 4.0 | 5 7 | 6 7 | 0.1 | 3 9 |
| Michigan | 1946-70 | 9 | 2 8 | 5.2 | 7 4 | Forecast an increase—actually declined | 4.1 |
| Michigan | 1954-75 | 1 | | 3 2 | 9.3 | | 2.3 |
| South Atlantic | | | | | | | |
| Delaware | 1954-70 | 1 | 4 3 | 1.4 | | | 2.0 |
| Maryland | 1951-65 | 4 | | | | | |
| Virginia | 1950-70 | 5 | 1 5 | 2.8 | 3 8 | 2.6 | 2.7 |
| Virginia | 1952-65 | 3 | 1.2 | 2 0 | 2.7 | | Forecast not reported |
| West Virginia | 1953-75 | 2 | 3.5 | 1 9 | 2.2 | 4 6 | 2.0 |
| N Carolina | 1953-75 | 2 | 1.2 | 2.6 | 3.9 | Forecast an increase—actually declined | 2 3 |
| Florida | 1951-72 | 4 | 2.0 | 3.5 | 6 0 | 1.4 | 2.4 |
| East South Central | | | | | | | |
| Kentucky | 1954-75 | 1 | 0 8 | 3.7 | 6 6 | Forecast an increase—actually declined | |
| Tennessee | 1954-75 | 1 | 1 5 | 1 8 | 2.3 | 3.0 | |
| Mississippi | 1948-70 | 7 | 0 3 | 5 7 | 11 9 | Forecast decline exceeded by 1 3 times | 5 4 |
| West South Central | | | | | | | |
| Louisiana | 1953-75 | 2 | 2.1 | 3.7 | 7.0 | Forecast an increase—actually declined | 2 2 |
| Texas | 1955-75 | 0 | Forecast too recent for comparison | | | | |
| West North Central | | | | | | | |
| Minnesota | 1953-75 | 2 | 4 1 | 3 0 | 3 3 | 5.7 | 3.0 |
| Iowa | 1947-60 | 8 | Forecast not reported | | | | 2.9 |
| N Dakota | 1951-70 | 4 | 3.3 | 2.0 | 2.6 | 12.7 | 2 6 |
| Nebraska | 1947-70 | 8 | 2.8 | 3.4 | 0.9 | 17.2 | 10 2 |
| Kansas | 1947-70 | 8 | 6 5 | 8.6 | - | 1 9 | 5.3 |
| Mountain | | | | | | | |
| Idaho | 1953-65 | 2 | | 1.6 | 4.3 | Forecast an increase—actually declined | 1 3 |
| Colorado | 1949-69 | 6 | 3.7 | 2.7 | | 6.0 | 3.4 |
| Arizona | 1953-64 | 2 | Forecast not reported | 1 2 | | | 1 4 |
| Pacific | | | | | | | |
| Washington | 1947-70 | 8 | 1.7 | 3 5 | 8.6 | 2.0 | 2 6 |
| Washington | 1953-65 | 2 | | 1.8 | 7.2 | Forecast no change—actually declined | 1.8 |
| Oregon | 1947-70 | 8 | 1.2 | 1 6 | 7 2 | Forecast no change—actually declined | 1.7 |
| California | 1945-60 | 10 | 2 1 | 2 9 | 3.6 | Forecast no change—actually declined | 2 9 |
| California | 1951-70 | 4 | 1.3 | 1 3 | 2.9 | 0 5 | 1.2 |

[a] Ratio. Actual average annual rate of change from year when forecast was made through 1955. Divided by forecasted average annual rate of change.

of actual change for periods up to a maximum of 10 years.

Actually the forecasts for each state were compared in two ways. They were compared with conditions which developed subsequent to the forecast, and then they were compared to the trend of the 20 years preceding the forecast.

As yet there is nothing standard about the length of forecast period used by the various states. Some were only 10 years. One covered 24 years. Because of the varying time periods and in order to have a standard unit for comparison, the increases (or decreases) in the five items studied were converted to show the annual rate of change. For example, a forecast showing an expected increase in motor travel of 6 billion vehicle-miles in a 20-year period would be expressed as an average increase of 300 million vehicle-miles per year for 20 years. If during the 5 years following the forecast, travel increased two billion vehicle-miles, this would be expressed as an increase of 400 million vehicle-miles per year (for the 5 years).

This averaging of forecasts to a yearly rate creates a bias. Where the forecast was other than a straight line, the average rate does not reflect the correct position of the travel trend during intermediate years. However, in the majority of the state reports, figures for intermediate years were not available. A substantial number of forecasts differed so greatly from the actual trend that the differences between a straight and curved line were decidedly secondary.

Since the purpose of this study was to compare forecasts with actual data, the ratio of the two annual rates was computed. This was done for total travel and the components of travel as reported by each state. The resulting ratios are shown in Table 1. Ratios were computed so that a value less than one means that the rate of increase actually experienced was less than had been forecast. Correspondingly, a ratio greater than one means events following the forecast were greater than had been expected. The ratio itself gives the extent of the divergence. For example, a ratio of 0.5 means that the rate of actual increase was only half as great as had been forecast. A ratio of 1.0 indicates the rate of change actually experienced was the same as expected. A ratio of 3.5 shows the rate of change which occurred exceeded that which had been projected by 3½ times.

Table 1 gives the period covered by the forecasts and the number of years included in the comparison period for each state. For convenience, states are grouped according to the arrangement used by the U. S. Bureau of Census in its population reports. In this way, states having similar characteristics can be readily compared.

## THE GENERAL TENDENCY

Many of the ratios exceed 1.0, indicating that the rates of increase actually experienced are greater than had been forecast. To show this more clearly, Table 2 was prepared. Here the data are grouped according to size of ratio. This arrangement makes it clear that very few forecasters were too optimistic. In only a few instances was there a ratio less than 1.0 (actual rates of increase smaller than forecast).

### Population

For example, in 25 of 27 forecasts of population the actual rate of population increase was greater than expected. It is particularly significant that in 60 percent of the forecasts the actual rate of increase exceeded the forecast by more than two times.

TABLE 2

RATIO OF FORECASTED CHANGES TO ACTUAL CHANGES SINCE FORECAST WAS MADE [a]

Population, Motor Vehicle Registration, Ownership, Travel per Vehicle and Total Travel
States Grouped According to Size Ratio

| Range in Ratios From | To | Population | Motor Vehicle Registration | Motor Vehicle Ownership (vehicles per 100 persons) | Travel per Motor Vehicle or Highway Use of Motor Fuel per Vehicle | Total Travel or Total Highway Use of Motor Fuel | Range in Ratios From | To |
|---|---|---|---|---|---|---|---|---|
| 0 0 | 1. 0 | 2 | 0 | 1 | 3 | 0 | 0. 0 | 1. 0 |
| 1. 1 | 2 0 | 9 | 10 | 0 | 3 | 6 | 1 1 | 2 0 |
| 2. 1 | 5 0 | 14 | 15 | 13 | 5 | 18 | 2 1 | 5 0 |
| 5. 1 | Above 5. 1 | 2 | 6 | 12 | 5 | 5 | 5 1 | Above 5 1 |
| Decreased instead of increasing as forecast | | 0 | 0 | 0 | 8 | 0 | Decreased instead of increasing as forecast | |
| Rate of decline forecasted was exceeded | | 0 | 0 | 0 | 2 | 0 | Rate of decline forecasted was exceeded | |
| Number of forecasts | | 27 | 31 | 26 | 26 | 29 | Number of forecasts | |
| Number of states | | 25 | 27 | 22 | 23 | 26 | Number of states | |

[a] Ratio Actual average annual rate of change divided by forecasted rate.

When the trends for the 20 years preceding the forecast were studied, it was found that nearly one-half were smaller and about one-half were greater than the forecasted rates.

## Registration

In all cases, forecasted rates of increase in motor vehicle registration were below the increases actually experienced subsequent to the date of the forecast. In more than two-thirds of the states the actual rate of increase was more than double the rate forecast.

In one out of five cases the actual increase was more than five times greater than had been anticipated. There was an even division when the forecast was compared to the rates during the 20 years preceding the forecast—about one-half were smaller, the remainder were greater.

## Ownership

The rate of change in motor vehicle ownership is, mathematically speaking, a second differential. As such, it appears to be the one which gives forecasters the greatest difficulty. Only in one case was the actual rate of increase in ownership less than forecast. In 96 percent of the states actual increases were at a rate at least twice that which had been forecast. In nearly half the instances, actual increases were at a rate more than five times greater than expected.

## Travel per Vehicle

This is the only item studied in which there were decreases. A reduction in travel per vehicle is, of course, not entirely unexpected where ownership is rising. Because of the tendency for travel per vehicle in some cases to decrease or at least increase slowly, it made possible a better showing for the forecasters. Even here, however, in one-half of the states the actual increases were at a rate greater than forecast. In one out of ten cases the actual increase was at a rate less than forecast. In nearly one-third of the instances there was an actual decline in travel per vehicle rather than an increase as forecast. There were also two states where a decline had been forecast and subsequently the rate of decline was substantially exceeded.

## Total Travel

The travel trend is, in a sense, a composite of the other components. This is evident in the distribution shown in Table 2. In no case was the actual rate of increase in total travel (or total highway use of motor fuel) less than forecast. In more than three-fourths of all forecast efforts, it developed that actual increases were at a rate more than twice that expected.

Compared with the previous 20 years, it was again found that about one-half were smaller and one-half greater than forecast.

## INTERPRETATION AND SUMMARY

Forecasts of travel and related items made during the past decade have been definitely on the low side. With the exception of travel per vehicle, increases after the forecasts have been at rates greater than forecast. In roughly two-thirds of the cases investigated, actual increases were at rates more than two times greater than had been foreseen.

Motor vehicle travel is one of the factors which has an important bearing upon the nation's economy. However, little work has been done so far to relate a forecast of travel to future economic conditions, but it is important to the reasonableness of travel forecasts that this be done. If the nature of the nation's economy for the decade ahead had been foreseen in 1946, it would have greatly eased the problems of the travel forecaster. Since the extent and duration of economic prosperity in the past 10 years was not adequately anticipated, the accuracy of travel forecasts was correspondingly affected.

It is also possible that part of the reason for low forecasts is that, as a matter of policy, public officials have been unwilling to overstate themselves on the extent of future motor vehicle registrations and fuel consumption. Both of these items have a direct bearing on highway user revenues as well as on the needs of the highway systems.

Until more accurate forecasts can be made, it will be a matter of sound policy to make a periodic review of travel forecasts and related items. Forecasts should be adjusted in the light of current conditions and as new information regarding the future becomes available. As knowledge of the means for guiding the national economy increases, the ability to forecast future travel will improve.

# Charts for Highway Needs Studies

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Charts for highway needs studies must perform special functions, as they are not aimed at technical groups but at citizens who are not familiar with chart structures. Because of this non-technical aspect, charts for the studies should have proper use of color, attractive presentation, legibility, simplicity, and ease of reproduction.

This paper discusses the use of each of these items, using illustrations to point out the good and bad features of charts published in various highway needs studies.

Improvement during the past ten years has been quite noticeable. Charts in the most recent reports are far clearer and better than in the earlier reports. When charts in highway needs studies can be followed readily by the general public and those who must support the findings, it is easier to gain general acceptance of the report.

●CHARTS for highway needs studies are in a different category from most charts. Long-range highway studies are developed to show legislators, other public officials, and the general public the highway problem in a particular state. Therefore, the charts must be aimed at these individuals, who frequently do not have the technical background to grasp involved statistical or engineering charts.

Many textbooks and articles have been written concerning the mechanics of chart preparation; therefore, this subject will not be covered in this paper. Rather, it will discuss the special requirements of charts for needs studies, both for printed reports and for use with talks to various groups.

Because of the non-technical nature of the audience, all charts for highway needs studies should develop only one or two points. They should be simple, and presented so as to catch the eye and get their messages across quickly and easily.

To determine the effectiveness of the charts prepared so far, all available needs studies were reviewed to determine the type of chart used and whether or not each chart was satisfactory for its intended purpose. There were many different kinds, ranging from the simple to the involved. Most of the charts were effective presentations, but the improvement over the past 10 years was very noticeable. Charts in the most recent reports are far clearer and better than those of earlier reports.

Seven charts were selected for review to illustrate the good and bad features. Most of the figures show some printed matter on the page where the charts appear. This has been done to indicate that all charts were taken from printed reports. In this connection, the illustrations have lost some of their effectiveness because they are photographs taken of printed cuts.

Before discussing the charts individually, it should be emphasized that, obviously, there is no one type of chart that can be used universally. Each must be developed to bring out the salient point of a particular argument. There are some facets however that should be common to all charts. These are proper use of color, attractive presentation, legibility, simplicity, and ease of reproduction.

Use of color seems to be almost universal now. It can enhance the effectiveness of most charts. However, colors should be chosen with care, so there will still be contrast if the chart is reproduced in black and white. Newspapers may want to reproduce charts and their material is normally printed without color.

An attractive presentation is essential to good response. The chart must catch the eye with its message almost leaping out at the reader. The chart itself should require little or no study for the point to be understood.

Legibility ties into presentation. A chart that can be readily understood must have a good presentation. Attractiveness results from proper use of color or other dressing. Legibility is hard to define but is illustrated by the figures accompanying this article.

Simplicity primarily means developing only one major point in each chart with one, or at most, two subsidiary points. Everyone has seen charts that are so involved as to need several pages of explanation. This type is not suited for highway needs studies. Straight lines, bars, or easily recognized geometric figures or symbols are the types that should generally be used.

The charts should be drawn and color used so that engraving cuts can be made easily. When they can be reproduced readily without retouching the cost will be kept to a minimum. This is particularly important in highway needs studies as numerous charts will be required to bring out the necessary statistical information.

With the exception of Figure 1, all of the charts discussed in this paper used color in various ways. It can be seen that all lend themselves to reproduction in black and white. Figure 1 is taken from an early report. The idea behind this chart was excellent. The photographs show graphically the difference between a congested street

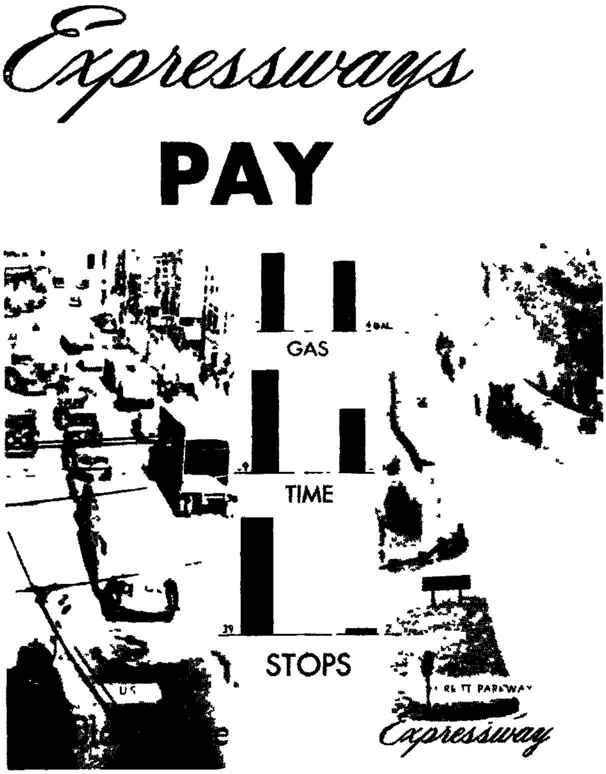


Figure 1.

and a controlled access highway. The bars emphasize the savings to motorists when using expressways. Here is a good argument for the expenditures necessary to build such facilities. However, the chart has its faults; it actually covers too much. It was not necessary to give figures with the bars. The printing could also have been better, although the old and new style lettering is clever and emphasizes the contrast.

The matter of printing is most important. There have been many reports published with excellent subject matter, but printed so poorly that most effectiveness was lost. Appearance of the report should never be sacrificed because of a relatively small advantage in cost.

Figure 2 shows an excellent chart that tells an effective story of the difference in actual and constant dollar values of state construction expenditures. The dark bars in the chart were black in the original and the gray were red. The choice of colors was such that there is contrast if the chart is reproduced in black and white. Even in this photograph Figure 2 has a good appearance. It is simple, easily understood, and reproduces well. It follows the five items basic to every chart.

Figure 3 is also taken from an early report. As in Figure 2, this shows construction expenditures; but there the resemblance ends. The designer tried to cover too much territory. Expenditures for all systems are included together with an indication of the amount spent each year. No horizontal scale is given so width of the figures means nothing, except for comparison. It certainly is not legible. It would be difficult to reproduce well.

Figure 4 is an excellent chart. It is extremely simple in form but brings out the growth of motor vehicle ownership since the early days of the automobile. The two major colors were red and black in the original chart but the black and white version still looks clear cut and has good contrast.

Proper use of color cannot be emphasized too much. Colored charts are particularly effective when used in talks before various groups. However, not all interested people can be reached in talks and some sort of publication is needed that will cover the same ground. Publications in color are usually expensive in small printings so it is necessary to go to black and white. This is the reason for the insistance on good

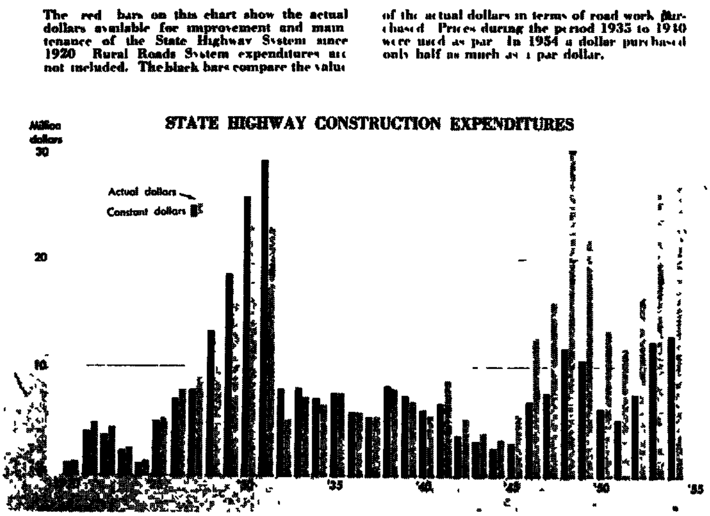


Figure 2.

contrast when color is used. It can be obtained but the colors must be chosen carefully and the printer instructed to obtain good contrast.

Figure 5 illustrates the lack of contrast in that the bars in this chart representing mileage and programs are so similar that it is impossible to tell them apart in black and white. Otherwise, the chart is good and brings out its message well.

Figure 6 covers part of the same subject as Figure 5 but illustrates a different method of presentation. Two colors and black were used in the chart and the chart had a good appearance in the report. It is also clear in the photograph used for this article.

Both figures 5 and 6 use percentages to develop the point in question. This method shows the relative positions of the various highway systems but does not show the actual travel on the systems. One of the most important factors in motor vehicle travel is the low traffic volume on the tertiary roads and streets. This fact could well be brought out in a supplementary chart giving the average daily volume of traffic on each of the systems in the state.

Figure 7 is one of the best conceived and executed charts found in all the reports. In color it is excellent. It shows the increase in federal-aid authorizations over the years, and how they have grown from nominal amounts to major sums that have had an appreciable effect on the financing of state highways. If the authorizations of the 1956 Act were added, especially those for the interstate system, the bars for the 1957-1959 fiscal years would be several times the longest now in the chart.

This chart illustrates another fact that should be brought out graphically in every needs study presentation: the important role that federal-aid for highways will play in the financing of highways.

Figure 8 was taken from a slide talk by the author given some two years ago. The slide was photographed in color from a chart. It was one of a series of slides and illustrates one point in the discussion. When the talk was later printed, a separate

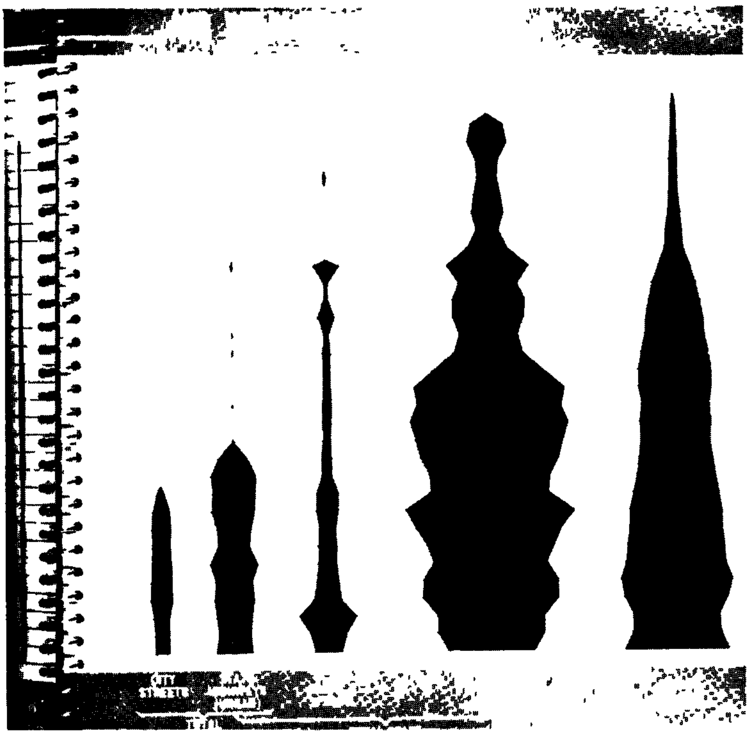

Figure 3.

black and white drawing was made of the slide. This is the best method to use when charts are very simple. The extra work required for an illustration such as this is not great and achieves a much better appearance.

The original color chart from which the slide was made still retains legibility when photographed in black and white, as was done for this paper. However, because the color used as background was not chosen with an eye for black and white reproduction, it photographed much too dark. A negative appearance was obtained, unsuitable for most publications. It was effective only as a slide.

The illustrations accompanying this article show only a few of the considerations in developing good non-technical charts. They cover charts taken from published reports and may, or may not, have been used in oral presentations to various groups. To secure adoption of a long range plan, it is necessary to reach as many citizens as possible. They should have full knowledge of the facts behind each highway needs study.

Good coverage cannot be obtained with the limited number of formal reports usually published. Supplementary booklets sometimes published for educating the general public are useful but are far more effective if given out following a talk before some civic group where the entire program was discussed.

Charts for reports fall into two classes: those for the printed report, and those for oral reports to group meetings. Through those two media, and most important, through newspaper stories, a maximum number of people can be reached in the state.

There are certain features common to all such charts that have not received full attention. The designer should never try to get too much information on one chart. This is repeated here for emphasis. It is far better to develop a series of charts, each bringing out one point. The use of overlays is particularly effective with charts accompanying talks. Occasionally, they have been used in reports but without the same effectiveness.

Color should be used extensively because more dramatic pictoralization can be obtained. It can be used as background, in letters or numbers, or to emphasize an important word or phrase. The entire chart can be developed by art work to give excellent results.

Color is difficult to work with if literature reproduction is planned or if a slide is to be made. What may look good on a chart may appear quite differently when

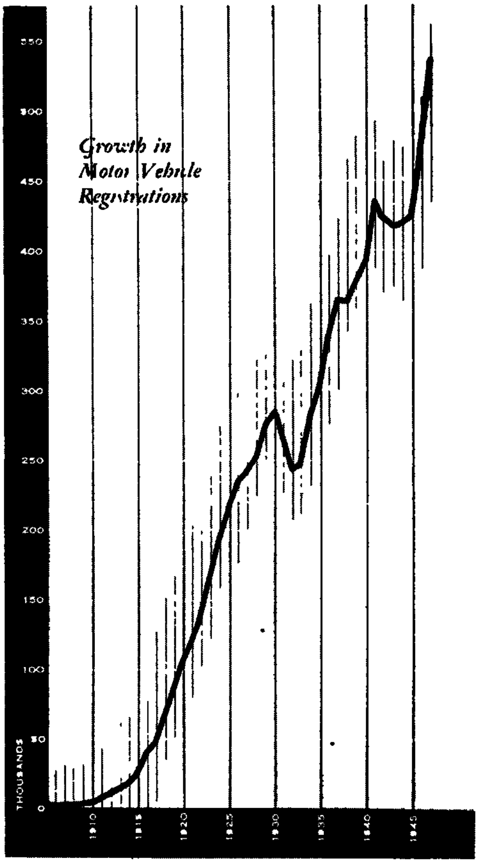


Figure 4.

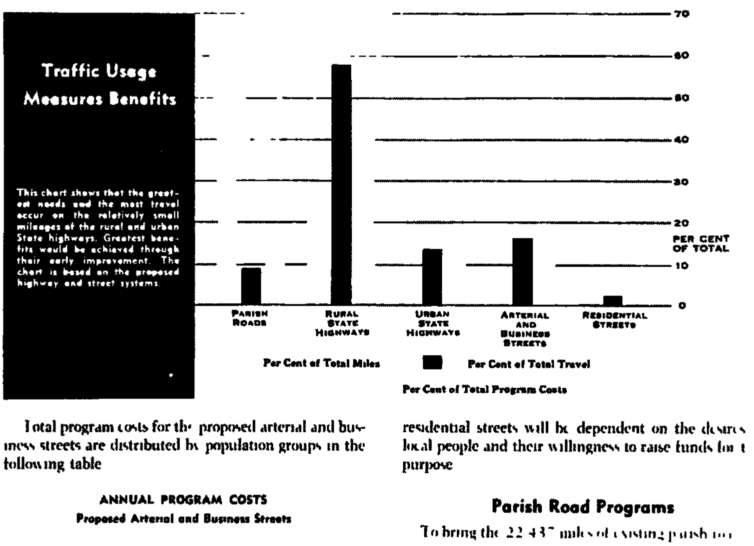


Figure 5.

photographed for a slide to be projected under strong light. Shades selected for contrast with each other give excellent contrast when reproduced in black and white.

Lettering for all charts should be easy to read. When type is to be used in the chart or for captions for printed reports, the type should be selected to blend with the pictorial matter.

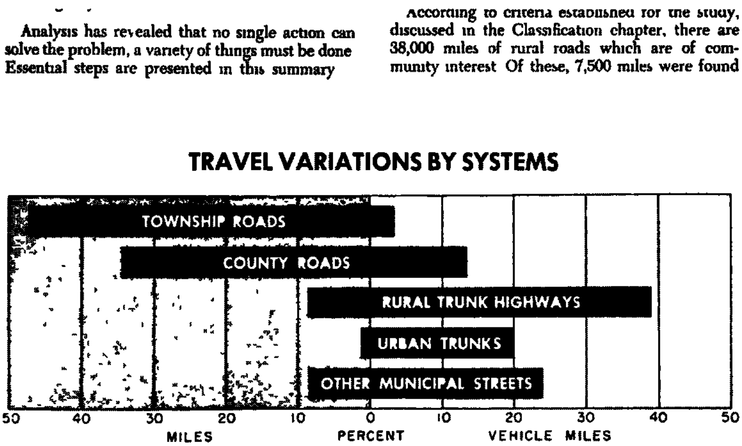


Figure 6.

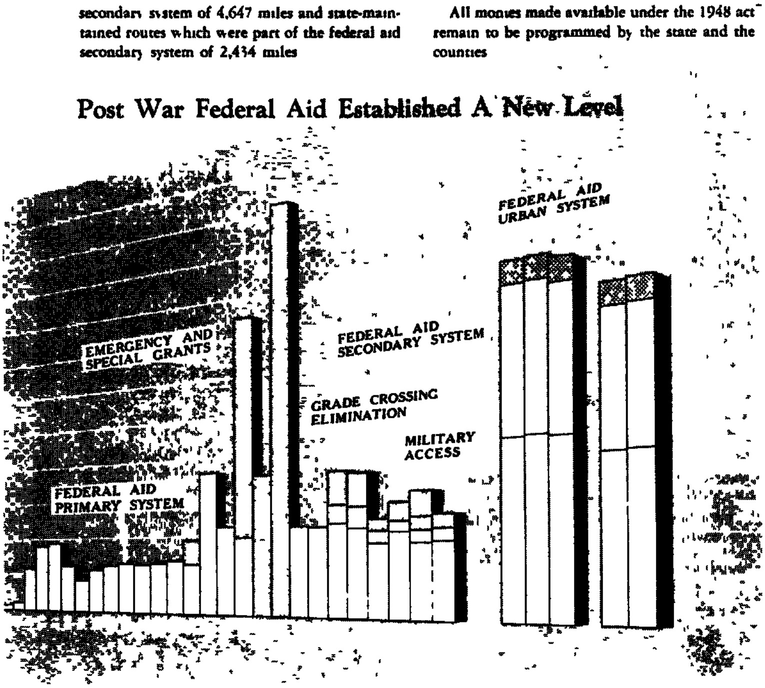


Figure 7.

In the case of charts for newspaper use, it will often be advisable to prepare special black and white charts covering the same subjects as the colored ones (Figure 8). The separate charts can be prepared with little extra work by drawing or tracing them from the colored charts. This procedure will give sharp, clean lines that will reproduce well in newspapers and inexpensive folders.

In preparing charts for use in oral presentations, the usual relationship of lettering and context must be ignored. The letters should be of such size that they can be read by someone sitting in the back row of a meeting room, anywhere from 30 to 60 ft or more from the chart. A minimum of 2⅛ in. letters has been found to be the best.

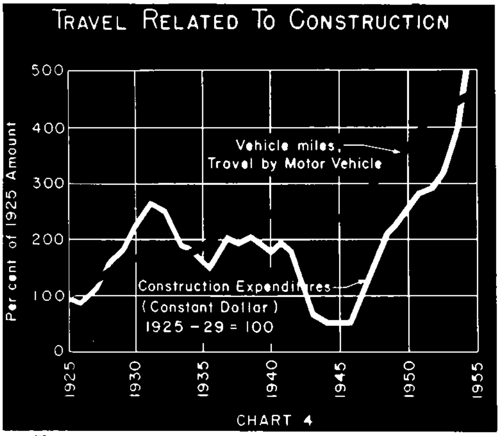


Figure 8.

With this minimum size letter, the charts must be fairly large. A size about 20 to 24 in. is easy to handle yet legible to small groups. A larger size is preferred if slides are to be made from the charts or large groups are to be addressed. Considering the sizes of letters necessary for legibility it can be seen that there is room for only a small amount of written material. There should be very little lettering on any pictorial chart. This limitation is generally beneficial in that many charts attempt to crowd too much information into too little space.

## SUMMARY

Charts for highway needs study reports have improved considerably since the first report was published. However, there is still room for improvement particularly with regard to scope, legibility, choice of colors, and simplicity.

Each chart should have a single concept, and should be legible and attractive. If these basic rules are followed, the highway needs studies will be accepted more readily by the general public and those who must support the finding. If general acceptance of the report can be gained, it will be easier to secure adoption of the recommendations, which is the aim of any study report.

# Economic Forecasting for Statewide Highway Studies*

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● THIS PAPER is directed specifically toward improving methods and procedures involved in the conduct of highway needs studies. It is limited to those problems which are common to state engineering needs studies, and finance and taxation studies.

The plan of investigation was to isolate one of the important problems, to formulate concepts for solving the problem, and to identify the techniques, methods and sources of data, but to stop short of developing the mechanics for acquiring and applying the data.

## THE PROBLEM

Engineers and economists recognize as one of the important areas for improvement of state highway needs and taxation studies the forecasting of motor vehicles and vehicle-miles of travel. Such forecasting is basic both to the engineer's estimate of highway needs and to the economist's estimate of future revenue to meet such needs.

The present forecasting procedure in use is to project for the state under study the following: population, number of motor vehicles per person, and motor fuel consumption per vehicle.

Each projection is then tested against national population forecasts and the economic prospects of the state, and adjusted as required. This procedure results in forecasts of the number of vehicles which will be registered, of the motor fuel which will be consumed, and of the travel which will develop in that state.

After several years of experience with this method of forecasting, engineers and economists have found that the results are consistently too low. The present method could be improved by injecting factors to reflect more of the economic forces at play, or that improved methods of forecasting based on such economic factors could be devised.

## PROGRESS IN ECONOMIC FORECASTING

One development that points to the desirability and feasibility of economic forecasting for highway purposes is the emergence of economic analyses and forecasts at high government levels and throughout big business.

The federal government has set as the economic goal of the nation the encouragement of economic growth and stability in terms of maximized employment, production, and purchasing power. Under the Employment Act of 1946 establishing this economic goal as a national policy, specific national objectives and procedures were outlined and the Council of Economic Advisors to the President and the Congressional Joint Committee on the Economic Report were established as implementing agencies. The Joint Committee in 1954 published a bulletin which included a 20-year forecast of gross national product, or GNP as it is frequently called (1). The GNP forecast was $530 billion for 1965 and $634 billion for 1975. The 1955 GNP was $391 billion, or 4½ percent more than the Committee forecast.

The Department of Agriculture has published projections of the demand for agricultural products in which a GNP range of from $705 to $740 billion for 1975 (in 1953 dollars) is used (2). In 1956 dollars, the GNP range would be in the neighborhood of $720 to $760 billion. The New York Port Authority is using an estimated GNP of $700 billion for 1975 for its planning purposes.

Most, if not all, of the larger corporations of the country now prepare short- and long- range forecasts of the economy as a whole and of the place their corporations oc-

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*This paper prepared under the sponsorship of the Ad Hoc Committee on State Highway Finance and Taxation Studies; C. A. Steele, Chairman.

cupy in that economy. Many business firms now find it profitable to gear their capital and sales programs to long-range forecasts.

With the federal government paving the way in the field of economic forecasting, the states and other governmental units may find it advantageous to follow suit. It should prove especially valuable to those who are involved in state highway planning.

## ECONOMIC FORECASTING FOR HIGHWAYS

The first step in the development of procedures for economic forecasting in the highway field was to review the considerable work that had been done by federal and other agencies in determining the relation between automotive transport and the accepted economic measures or indices.

The Bureau of Public Roads has explored the relation of motor vehicle travel to GNP and the national income. E. H. Holmes in 1950 observed that "traffic is a part of our economy and grows with it." (3) This statement was based on his finding that from 1932 for nearly 20 years, exclusive of the years of wartime restrictions, the increase in vehicle-miles of travel had paralleled the increase in national income and GNP. The growth was "at a rate of over 4 percent per year, compounded." He concluded, "I venture to express my confidence in the future of the country to the extent of anticipating a traffic increase of 4 percent per year for a reasonable planning period of 15 to 20 years." This forecast has had a beneficial effect on national highway planning.

The President's advisory committee on a National Highway Program in its 1955 report (4), charted the trends in motor vehicle travel and GNP from 1931 to 1953 and showed that the two lines moved along together for all except the years with wartime restrictions. This travel trend was projected to 1965 and its relation to several economic forecasts noted.

An analysis of the relation of inter-city freight movements to GNP was made by Wilfred Owen of the Brookings Institution. He found that over the years from 3 to 3.6 ton-miles of inter-city freight have been transported for each dollar of GNP. In recent years increasing amounts of such freight have moved by highway.

Other agencies have made studies of the relation of automobiles to personal income. The Federal Reserve Board, as a result of its 1954 survey of consumer finances, concluded that "automobile ownership is clearly related to income." (5) Only 25 percent of the low-income ($1,000) families owned automobiles, whereas over 92 percent of the high-income ($7,500) families owned automobiles. The number of families owning two or more cars is also related to income.

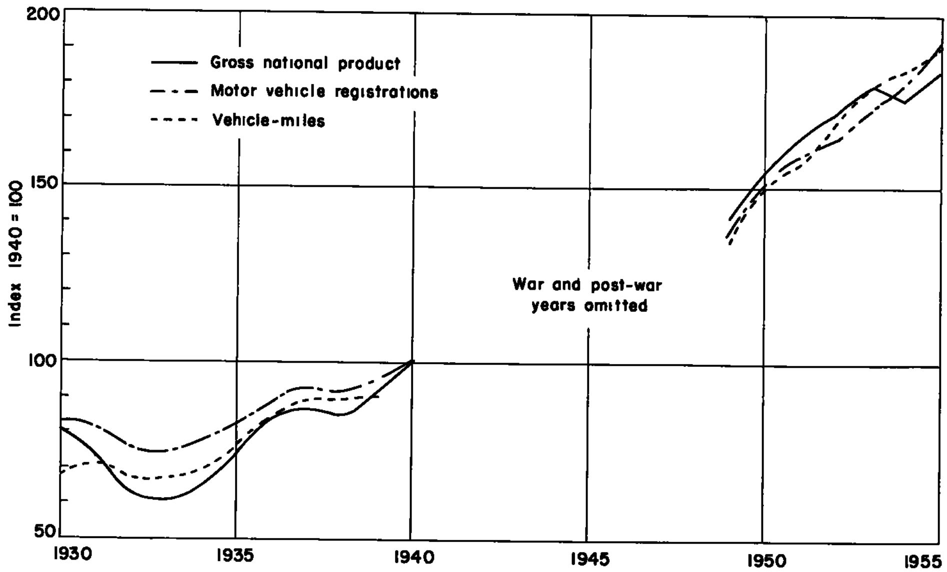


Figure 1. Relationship of motor vehicles and travel to gross national product.

TABLE 1

RELATION OF MOTOR VEHICLES REGISTERED AND TRAVEL TO GROSS NATIONAL PRODUCT, 1930-1955
(For indices, 1940 = 100)

| Year | Gross National Product[a] (10) | Index | Motor Vehicles (11) | Index | Vehicle Miles (11) | Index |
|---|---|---|---|---|---|---|
| | (billion) | | (million) | | (billion) | |
| 1930 | $165 | 80 | 27 | 83 | 206 | 68 |
| 1931 | 153 | 74 | 26 | 81 | 216 | 72 |
| 1932 | 129 | 63 | 24 | 75 | 201 | 66 |
| 1933 | 127 | 61 | 24 | 75 | 201 | 66 |
| 1934 | 140 | 62 | 25 | 78 | 216 | 71 |
| 1935 | 154 | 74 | 26 | 82 | 229 | 76 |
| 1936 | 174 | 84 | 28 | 88 | 252 | 83 |
| 1937 | 185 | 87 | 30 | 93 | 270 | 89 |
| 1938 | 177 | 85 | 29 | 92 | 271 | 90 |
| 1939 | 190 | 92 | 31 | 96 | 285 | 91 |
| 1940 | 208 | 100 | 32 | 100 | 302 | 100 |
| (War and post-war years omitted) | | | | | | |
| 1949 | 295 | 142 | 45 | 140 | 424 | 140 |
| 1950 | 322 | 155 | 49 | 154 | 458 | 151 |
| 1951 | 345 | 166 | 52 | 162 | 491 | 162 |
| 1952 | 357 | 172 | 53 | 167 | 514 | 170 |
| 1953 | 374 | 180 | 56 | 176 | 544 | 180 |
| 1954 | 365 | 176 | 59 | 183 | 561 | 185 |
| 1955 | 391(12) | 188 | 63 | 196 | 583 | 193 |

[a] 1955 prices.

TABLE 2

RELATION OF PERSONAL INCOME TO GROSS NATIONAL PRODUCT, 1930-1955

| Year | Gross National Product (10) | Personal Income (10) Amount | Personal Income (10) Percent of GNP |
|---|---|---|---|
| | (billion) | (billion) | |
| 1930 | $ 91 | $ 77 | 85 |
| 1931 | 76 | 66 | 86 |
| 1932 | 58 | 50 | 85 |
| 1933 | 56 | 47 | 85 |
| 1934 | 65 | 54 | 83 |
| 1935 | 72 | 60 | 83 |
| 1936 | 83 | 69 | 82 |
| 1937 | 91 | 74 | 81 |
| 1938 | 85 | 68 | 80 |
| 1939 | 91 | 73 | 80 |
| 1940 | 100 | 79 | 79 |
| (War and post-war years omitted) | | | |
| 1949 | 257 | 207 | 80 |
| 1950 | 284 | 227 | 80 |
| 1951 | 328 | 255 | 78 |
| 1952 | 345 | 271 | 79 |
| 1953 | 364 | 286 | 79 |
| 1954 | 360 | 288 | 80 |
| 1955 | 391 (12) | 306 (12) | 78 |

TABLE 3

PERSONAL INCOME AND MOTOR VEHICLES REGISTERED IN THE UNITED STATES, SELECTED YEARS

| Year | Personal Income (10) | Consumer Price Index (10) | Personal Income[a] | Motor Vehicles (11) | Motor Vehicles per $10,000 of Personal Income |
|---|---|---|---|---|---|
| | (billion) | | (billion—constant dollars) | (million) | |
| 1929 | $ 85 8 | 73.3 | $117.0 | 26 5 | 2.27 |
| 1940 | 78.7 | 59.9 | 131 0 | 32.0 | 2.44 |
| 1950 | 227.0 | 102.8 | 221.0 | 49.2 | 2 22 |
| 1951 | 255.3 | 111.0 | 230.0 | 51 9 | 2 25 |
| 1952 | 271 1 | 113.5 | 239.0 | 53.3 | 2.23 |
| 1953 | 286 2 | 114 4 | 249.0 | 56.3 | 2 26 |
| 1954 | 287 6 | 114.8 | 251 0 | 58 6 | 2 33 |
| 1955 | 303.4 | 114.5 | 265.0 | 62 8 | 2 37 |

[a] In 1947-1949 prices.

TABLE 4

RELATION OF MOTOR VEHICLES REGISTERED AND TRAVEL TO DISPOSABLE PERSONAL INCOME, 1930-1955
(For indices, 1940 = 100)

| Year | Disposable Personal Income[a] (10) | Index | Motor Vehicles (11) | Index | Vehicle Miles (11) | Index |
|---|---|---|---|---|---|---|
| | (billion) | | (million) | | (billion) | |
| 1930 | $119 | 82 | 26.5 | 83 | 206 | 68 |
| 1931 | 112 | 77 | 25.9 | 81 | 216 | 72 |
| 1932 | 95 | 66 | 24.1 | 75 | 201 | 67 |
| 1933 | 85 | 65 | 23.9 | 75 | 201 | 67 |
| 1934 | 104 | 72 | 25.0 | 78 | 216 | 72 |
| 1935 | 114 | 78 | 26.2 | 82 | 229 | 76 |
| 1936 | 128 | 87 | 28.2 | 88 | 252 | 84 |
| 1937 | 133 | 91 | 29 7 | 93 | 270 | 90 |
| 1938 | 125 | 86 | 29.4 | 92 | 271 | 90 |
| 1939 | 136 | 93 | 30 6 | 96 | 285 | 91 |
| 1940 | 146 | 100 | 32.0 | 100 | 302 | 100 |
| (War and post-war years omitted) | | | | | | |
| 1949 | 212 | 145 | 44.7 | 140 | 424 | 140 |
| 1950 | 230 | 158 | 49 2 | 154 | 458 | 152 |
| 1951 | 233 | 160 | 51 9 | 162 | 491 | 163 |
| 1952 | 239 | 164 | 53.3 | 167 | 514 | 170 |
| 1953 | 251 | 172 | 56.3 | 176 | 544 | 180 |
| 1954 | 254 | 175 | 58.6 | 183 | 561 | 185 |
| 1955 | 271 (12) | 186 | 62.8 | 196 | 583 | 193 |

[a] 1955 prices.

A study by the Bureau of Labor Statistics shows that the percentage of family income expended for highway transport varies greatly for cities of different sizes in different parts of the country—6 percent in New York City, 10 percent in Chicago and 15 percent in Los Angeles (6).

The results of these studies not only encouraged the investigation of economic forecasting for state highway study purposes, but gave direction to certain phases of the investigation. Among other things, the national findings pointed up the need for adjustments to reflect state differences.

## REVIEW OF NATIONAL RELATIONSHIPS

The next step was to review, up date and explore the national relationships of motor vehicles and travel to the national economic indices of GNP, personal income, and disposable personal income. The findings were briefly as follows:

1. Over the 25-year period from 1930 to 1955, except for the war-affected years,

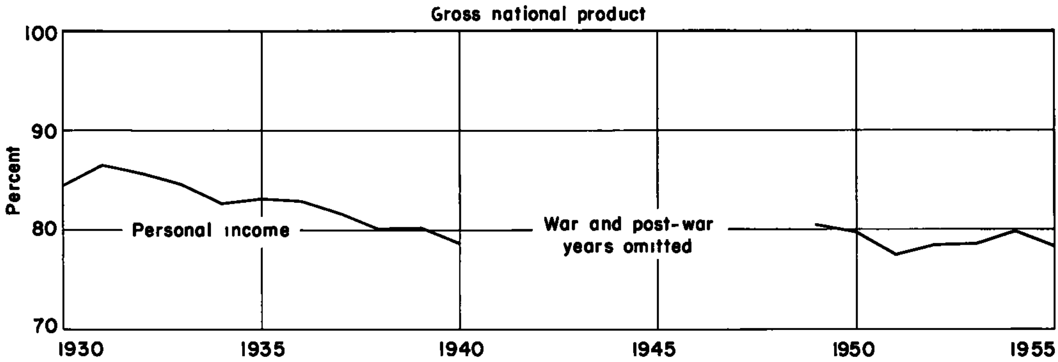


Figure 2. Personal income as a percentage of gross national product.

motor vehicle registrations and vehicle-miles of travel have generally moved along together, increasing 193 percent and 196 percent, respectively, between 1940 and 1955 (Table 1 and Figure 1). The conclusion from this finding was that subsequent explorations could be simplified by concentrating on one of the two and so the index was chosen.

2. Over the last five years of the 25-year period from 1930 to 1955, motor vehicles have been increasing at a higher rate than GNP, motor vehicles at 28.6 percent and GNP at 21.4 percent. This finding indicates that factors other than economic growth may be involved and need to be sought out. Among the possible factors are the following: the movement of substantial numbers of persons from low-income to medium-income groups with the result that many more can afford automobiles; the more rapid growth of suburban areas and their greater dependence on motor vehicle transportation as compared with central city areas; the more rapid growth of states with high dependence on motor vehicle transportation as compared with states with low dependence on such transportation; and the increase in trucking as the result of the diversion of freight from the railroads to trucks.

3. A comparison of the national economic indices of GNP and personal income from 1930 to 1955 shows that, except during the deep depression and war-affected years, they moved along together, personal income amounting to from 78 to 80 percent of GNP (Table 2 and Figure 2). This finding means that during normal years these two indices are interchangeable. Since GNP figures are not available for individual states, it was necessary to use personal income figures.

4. The relation of motor vehicles to personal income has remained remarkably constant over the years. The number of motor vehicles per $10,000 of personal income (1947-1949 prices) was 2.3 in 1929, 2.4 in 1940, 2.2 in 1950 and 2.4 in 1955 (Table 3).

5. Disposable personal income, that is, income available after taxes, logicially should be superior to other economic indices for motor vehicle comparisons since it is the income a family can spend as it wishes. Actually over the 25-year period from 1930 to 1955, exclusive of the war years, it did not differ materially from GNP in rate of increase, but in the period from 1950 to 1955 it increased at a slower rate than GNP, 17.8 percent as compared with 21.4 percent (Table 4 and Figure 3).

6. The relation of motor vehicles to disposable personal income has been a consistent upward trend over the years.

TABLE 5

DISPOSABLE PERSONAL INCOME AND MOTOR VEHICLES REGISTERED IN THE UNITED STATES, SELECTED YEARS

| Year | Disposable Personal Income (10) | Consumer Price Index (10) | Disposable Personal Income[a] | Motor Vehicles (11) | Motor Vehicles per $10,000 of Disposable Personal Income |
|---|---|---|---|---|---|
| | (billion) | | (billion—constant dollars) | (million) | |
| 1929 | $ 83 1 | 73 3 | $113 | 26 5 | 2 34 |
| 1940 | 76 1 | 59 9 | 127 | 32 0 | 2 52 |
| 1950 | 206 1 | 102 8 | 200 | 49 2 | 2 46 |
| 1951 | 226 1 | 111 0 | 203 | 51 9 | 2 55 |
| 1952 | 236 7 | 113 5 | 209 | 53 3 | 2 55 |
| 1953 | 250 4 | 114 4 | 218 | 56 3 | 2 58 |
| 1954 | 254 8 | 114 8 | 223 | 58 6 | 2 63 |
| 1955 | 269 2 | 114 5 | 235 | 62 8 | 2 67 |

[a] In 1947-1949 prices

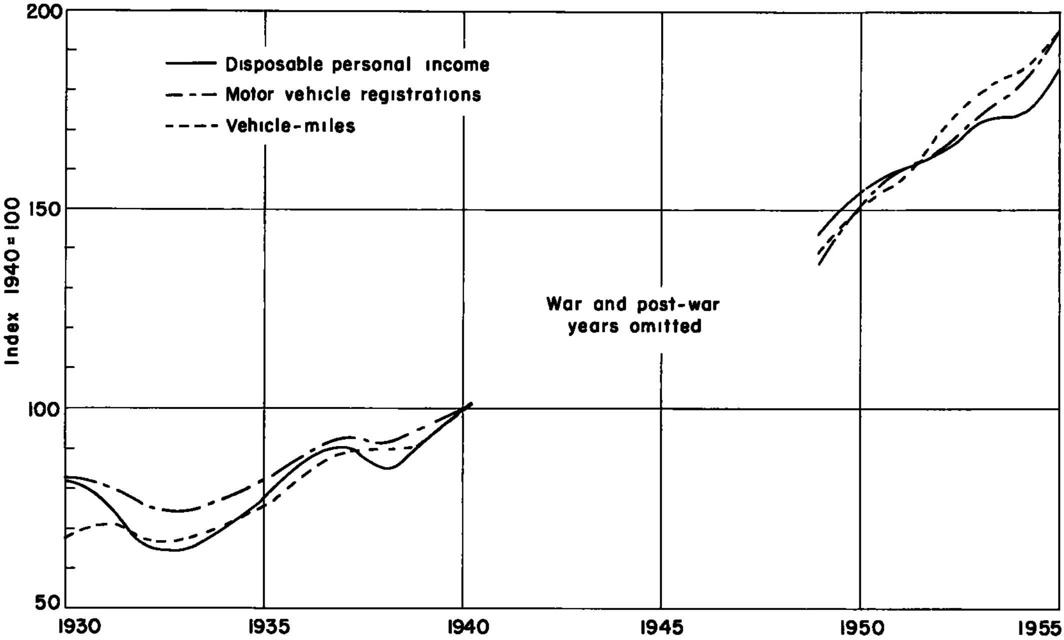


Figure 3. Relationship of motor vehicles and travel to disposable personal income.

The number of motor vehicles per $10,000 of disposable personal income (1947-1949 prices) increased from 2.3 in 1929 to 2.5 in 1940 and 1950 and to 2.7 in 1955 (Table 5). It was not possible to make further use of disposable personal income in this study since figures are not available for individual states.

## PROPOSED PROCEDURES

Three procedures have been developed for injecting economic factors into forecasting for state highway study purposes, two of them projections and one a forecast. In each procedure the number of motor vehicles and the vehicle-miles of travel can be related to an economic measure and projected or forecast.

The first procedure is to take a state economic index such as personal income, determine the historical relationship between motor vehicle registrations and vehicle-miles and the index, project the index and then project motor vehicle registrations and vehicle-miles on the basis of that relationship.

A second procedure is to take a national economic forecast such as personal income or GNP, relate a state index such as personal income to it, and project the state index on the basis of its historical relation to the national index. Then the state motor vehicle registrations and vehicle-miles can be projected by relating them to the projected state index. This procedure is better than the first, but its basic weakness of continuing past relationships in a given state can cause major errors.

The third and most comprehensive procedure is to take the national economic forecasts of GNP and national personal income, study the prospects of the major sectors of a state's economy in relation to these forecasts, and prepare a state forecast.

## ANALYSIS OF PROCEDURES

As a demonstration of the workability of the proposed procedures a determination and analysis was made of the historical relationships basic to each. Personal income was chosen as the economic index for each procedure for two reasons; (1) as previously stated, national personal income showed a consistent relationship to GNP and was therefore equally as good for out purposes, and (2) no GNP figures were available for individual states.

TABLE 6

RELATION OF MOTOR VEHICLES REGISTERED TO PERSONAL INCOME, BY STATE, 1955

| State | Personal Income (12) | Motor Vehicles (11) | Motor Vehicles per $10,000 of Personal Income |
|---|---|---|---|
| | (million) | (thousand) | |
| Alabama | $ 3,674 | 1,041 | 2.8 |
| Arizona | 1,588 | 415 | 2.6 |
| Arkansas | 1,913 | 584 | 3.1 |
| California | 29,438 | 6,190 | 2.1 |
| Colorado | 2,729 | 737 | 2 7 |
| Connecticut | 5,497 | 926 | 1.7 |
| Delaware | 980 | 154 | 1.6 |
| Florida | 5,923 | 1,616 | 2 7 |
| Georgia | 4,882 | 1,239 | 2.5 |
| Idaho | 895 | 338 | 3.8 |
| Illinois | 20,988 | 3,269 | 1 6 |
| Indiana | 8,201 | 1,763 | 2 2 |
| Iowa | 4,213 | 1,195 | 2.8 |
| Kansas | 3,393 | 1,048 | 3 1 |
| Kentucky | 3,728 | 1,032 | 2.8 |
| Louisiana | 3,910 | 952 | 2.4 |
| Maine | 1,443 | 323 | 2.2 |
| Maryland | 5,463 | 938 | 1.7 |
| Massachusetts | 10,010 | 1,546 | 1.5 |
| Michigan | 15,632 | 3,114 | 2.0 |
| Minnesota | 5,394 | 1,365 | 2.5 |
| Mississippi | 2,018 | 637 | 3.1 |
| Missouri | 7,560 | 1,490 | 2.0 |
| Montana | 1,160 | 336 | 2.9 |
| Nebraska | 2,147 | 662 | 3.1 |
| Nevada | 572 | 124 | 2.2 |
| New Hampshire | 958 | 217 | 2.3 |
| New Jersey | 12,304 | 2,071 | 1.7 |
| New Mexico | 1,134 | 340 | 3.0 |
| New York | 36,255 | 4,655 | 1.3 |
| North Carolina | 5,371 | 1,437 | 2.7 |
| North Dakota | 882 | 309 | 3.5 |
| Ohio | 18,442 | 3,526 | 1 9 |
| Oklahoma | 3,328 | 1,026 | 3.1 |
| Oregon | 3,090 | 802 | 2 6 |
| Pennsylvania | 20,724 | 3,737 | 1.8 |
| Rhode Island | 1,599 | 310 | 1.9 |
| South Carolina | 2,557 | 782 | 3.1 |
| South Dakota | 850 | 325 | 3.8 |
| Tennessee | 4,288 | 1,168 | 2.7 |
| Texas | 14,116 | 3,869 | 2.7 |
| Utah | 1,238 | 336 | 2.7 |
| Vermont | 568 | 136 | 2.4 |
| Virginia | 5,494 | 1,243 | 2.3 |
| Washington | 5,179 | 1,164 | 2.3 |
| West Virginia | 2,555 | 552 | 2.2 |
| Wisconsin | 6,569 | 1,386 | 2.1 |
| Wyoming | 547 | 174 | 3.2 |
| District of Columbia | 1,992 | 197 | 1 0 |
| Total | $303,391 | 62,794 | 2.1 |

For four selected states for selected years between 1929 and 1955, analysis was made of the historical trend in personal income and motor vehicle registrations and the relation of motor vehicles to personal income. The four states were selected as representative of an average, a high, a low and a special state in terms of motor vehicles per $10,000 of total personal income. The national average of motor vehicles per $10,000 of total personal income (1955 prices) was 2.1 and the range was from a low of 1.3 to a high of 3.8 (Table 6). California, with 2.1 vehicles, was selected as an average state; Illinois with 1.6 vehicles, as a low state; Mississippi with 3.1 vehicles, as a high state; and West Virginia with 2.2 vehicles, as a special state because it was experiencing a severe economic crisis as a result of technological unemployment in the coal mines.

## First Procedure

The historical relationships analyzed for the first procedure included the index and percentage rate of growth of personal income and the ratio of motor vehicles to personal income. In each of the four states these relationships fell into different but consistent patterns.

Personal income for the period from 1929 to 1955 increased at the fastest rate in California, 243 percent, and at the lowest rate in Illinois, 85 percent, (Tables 7 and 8). Between 1950 and 1955 there was a greater disparity in rate of increase —California leading with 35 percent and West Virginia trailing with 4 percent.

The number of motor vehicles per $10,000 of personal income (1947-1949 prices) in these states from 1929 to 1955 remained reasonably constant. In California there were 2.6 vehicles in 1929, 2.8 in 1940 and 2.4 in 1950 and 1955 (Tables 7 and 9). In Illinois in these years there were, respectively, 1.6, 1.9, 1.7 and 1.8 vehicles, and in Mississippi, 3.2, 3.3, 3.1 and 3.6 vehicles.

Under the first procedure a state would project its personal income based on the historical trend and then project the number of vehicles based on the historical trend of the ratio of motor vehicles to personal income.

## Second Procedure

The historical relationships analyzed for the second procedure included for the selected states their percentage shares of the national personal income for the selected years. Here again the percentage ratio for each state from 1929 to 1955 assumed a consistent pattern. The California percentage increased from 6.4 to 9.7 and the Illinois ratio decreased from 8.5 to 6.9 (Table 10). Mississippi's percentage fluctuated from 0.6 to 0.7 throughout the period. West Virginia's percentage was 0.9 in 1929,

## TABLE 7

### TREND OF PERSONAL INCOME, MOTOR VEHICLES REGISTERED AND RELATION OF MOTOR VEHICLES TO INCOME, IN SELECTED STATES, SELECTED YEARS
(Indices, 1940 = 100)

| Year | Personal Income (12) | Consumer Price Index (10) | Adjusted Personal Income[a] Amount | Adjusted Personal Income[a] Index | Motor Vehicles Number (11) | Motor Vehicles Index | Motor Vehicles per $10,000 of Personal Income |
|---|---|---|---|---|---|---|---|
| | (million) | | (million) | | (thousand) | | |
| | | | California | | | | |
| 1929 | $ 5,502 | 73.3 | $ 7,500 | 76 | 1,974 | 71 | 2.64 |
| 1940 | 5,839 | 59.9 | 9,840 | 100 | 2,774 | 100 | 2.82 |
| 1950 | 19,627 | 102.8 | 19,100 | 194 | 4,620 | 166 | 2.42 |
| 1951 | 22,726 | 111.0 | 20,500 | 209 | 4,927 | 177 | 2.40 |
| 1952 | 25,089 | 113.5 | 22,100 | 225 | 5,154 | 186 | 2.33 |
| 1953 | 26,642 | 114.4 | 23,300 | 237 | 5,504 | 198 | 2.36 |
| 1954 | 27,148 | 114.8 | 23,700 | 241 | 5,699 | 206 | 2.40 |
| 1955 | 29,438 | 114.5 | 25,700 | 262 | 6,189 | 223 | 2.41 |
| | | | Illinois | | | | |
| 1929 | 7,280 | 73.3 | 9,920 | 100 | 1,615 | 84 | 1.63 |
| 1940 | 5,964 | 59.9 | 9,930 | 100 | 1,926 | 100 | 1.94 |
| 1950 | 15,984 | 102.8 | 15,600 | 157 | 2,651 | 138 | 1.70 |
| 1951 | 17,777 | 111.0 | 16,000 | 161 | 2,790 | 144 | 1.74 |
| 1952 | 18,579 | 113.5 | 16,400 | 165 | 2,848 | 148 | 1.74 |
| 1953 | 19,669 | 114.4 | 17,200 | 173 | 2,959 | 153 | 1.72 |
| 1954 | 19,786 | 114.8 | 17,300 | 175 | 3,088 | 160 | 1.77 |
| 1955 | 20,988 | 114.5 | 18,350 | 185 | 3,268 | 170 | 1.78 |
| | | | Mississippi | | | | |
| 1929 | 570 | 73.3 | 780 | 99 | 250 | 97 | 3.21 |
| 1940 | 474 | 59.9 | 790 | 100 | 259 | 100 | 3.28 |
| 1950 | 1,590 | 102.8 | 1,550 | 196 | 484 | 187 | 3.12 |
| 1951 | 1,740 | 111.0 | 1,570 | 199 | 510 | 197 | 3.25 |
| 1952 | 1,862 | 113.5 | 1,640 | 207 | 524 | 202 | 3.20 |
| 1953 | 1,889 | 114.4 | 1,650 | 209 | 556 | 214 | 3.37 |
| 1954 | 1,811 | 114.8 | 1,580 | 200 | 585 | 226 | 3.70 |
| 1955 | 2,018 | 114.5 | 1,760 | 223 | 637 | 246 | 3.62 |
| | | | West Virginia | | | | |
| 1929 | 794 | 73.3 | 1,080 | 83 | 269 | 89 | 2.49 |
| 1940 | 777 | 59.9 | 1,295 | 100 | 303 | 100 | 2.34 |
| 1950 | 2,203 | 102.8 | 2,140 | 165 | 482 | 159 | 2.25 |
| 1951 | 2,439 | 111.0 | 2,200 | 170 | 490 | 162 | 2.22 |
| 1952 | 2,540 | 113.5 | 2,240 | 173 | 497 | 164 | 2.22 |
| 1953 | 2,547 | 114.4 | 2,230 | 172 | 517 | 170 | 2.31 |
| 1954 | 2,419 | 114.8 | 2,110 | 163 | 513 | 169 | 2.43 |
| 1955 | 2,555 | 114.5 | 2,230 | 172 | 552 | 182 | 2.48 |

[a] In 1947-1949 prices.

TABLE 8

RATES OF GROWTH, SELECTED STATES

| Period of Years | Personal Income. Percentage Increase | Motor Vehicles Percentage Increase |
|---|---|---|
| | California | |
| 1929-1955 | 243 | 216 |
| 1940-1955 | 162 | 123 |
| 1950-1955 | 35 | 34 |
| | Illinois | |
| 1929-1955 | 85 | 102 |
| 1940-1955 | 85 | 70 |
| 1950-1955 | 18 | 23 |
| | Mississippi | |
| 1929-1955 | 125 | 155 |
| 1940-1955 | 123 | 146 |
| 1950-1955 | 14 | 32 |
| | West Virginia | |
| 1929-1955 | 107 | 105 |
| 1940-1955 | 72 | 82 |
| 1950-1955 | 4 | 15 |

TABLE 9

NUMBER OF MOTOR VEHICLES REGISTERED PER $10,000 OF PERSONAL INCOME IN U S & SELECTED STATES[a]

| Year | United States | California | Illinois | Mississippi | West Virginia |
|---|---|---|---|---|---|
| 1929 | 2 3 | 2 6 | 1 6 | 3 2 | 2 5 |
| 1940 | 2.4 | 2 8 | 1 9 | 3 3 | 2 3 |
| 1950 | 2 2 | 2 4 | 1 7 | 3 1 | 2 3 |
| 1955 | 2 4 | 2 4 | 1 8 | 3 6 | 2 5 |

[a] 1947-1949 dollars

1. 0 in 1940 and 1950, and 0. 8 in 1955.

Under the second procedure a state would project its percentage of the national personal income based on the historical trend of that percentage, and then project the number of motor vehicles based on the historical trend of the ratio of motor vehicles to personal income.

A variation of the second procedure would be to substitute for the motor vehicle registrations in a state, the state's percentage share of the national total of motor vehicles computed in the same manner as the percentage share of national personal income. The next step would be to compute the historical ratio of the state's percentage share of total motor vehicles to the state's percentage share of the national personal income.

TABLE 10

TREND IN STATE PERCENTAGES OF NATIONAL PERSONAL INCOME AND MOTOR VEHICLES REGISTERED, SELECTED STATES, SELECTED YEARS

| Year | Percentage of National Personal Income (12) | Percentage of Total Motor Vehicles (11) | Ratio of Motor Vehicles to Personal Income |
|---|---|---|---|
| | California | | |
| 1929 | 6. 4 | 7. 5 | 1. 17 |
| 1940 | 7. 4 | 8. 7 | 1. 17 |
| 1950 | 8. 7 | 9. 4 | 1. 08 |
| 1951 | 9. 0 | 9. 5 | 1. 06 |
| 1952 | 9. 3 | 9. 7 | 1. 04 |
| 1953 | 9. 4 | 9. 8 | 1. 04 |
| 1954 | 9. 5 | 9. 7 | 1. 02 |
| 1955 | 9. 7 | 9. 9 | 1 02 |
| | Illinois | | |
| 1929 | 8. 5 | 6. 1 | 0 72 |
| 1940 | 7. 6 | 6. 0 | 0. 79 |
| 1950 | 7. 1 | 5. 3 | 0 75 |
| 1951 | 7 0 | 5. 3 | 0. 76 |
| 1952 | 6. 9 | 5. 3 | 0. 77 |
| 1953 | 7. 0 | 5. 3 | 0. 76 |
| 1954 | 7. 0 | 5. 3 | 0. 76 |
| 1955 | 6. 9 | 5. 2 | 0 75 |
| | Mississippi | | |
| 1929 | 0. 67 | 0. 94 | 1. 40 |
| 1940 | 0. 60 | 0. 81 | 1 35 |
| 1950 | 0. 71 | 0. 98 | 1. 38 |
| 1951 | 0. 69 | 0. 98 | 1. 42 |
| 1952 | 0. 69 | 0. 98 | 1. 42 |
| 1953 | 0. 67 | 0 99 | 1 47 |
| 1954 | 0. 64 | 1. 00 | 1. 56 |
| 1955 | 0. 67 | 1. 01 | 1. 51 |
| | West Virginia | | |
| 1929 | 0. 93 | 1. 01 | 1. 09 |
| 1940 | 0. 99 | 0. 94 | 0. 95 |
| 1950 | 0. 98 | 0 98 | 1. 00 |
| 1951 | 0. 97 | 0. 95 | 0. 98 |
| 1952 | 0. 94 | 0. 93 | 0 99 |
| 1053 | 0 90 | 0. 92 | 1 02 |
| 1954 | 0. 86 | 0. 88 | 1. 02 |
| 1955 | 0 84 | 0. 88 | 1 05 |

For California this ratio dropped from 1. 17 to 1. 02 between 1929 and 1955, indicating that its percentage of motor vehicles is not growing as rapidly as its percentage of income (Table 10). The Illinois ratio fluctuated around a constant of 0. 75, indicating its percentage of motor vehicles is paralleling its percentage of personal income. The Mississippi ratio increased from 1. 4 in 1929 to 1. 5 in 1955. In West Virginia in recent years the percentage of personal income has been decreasing rapidly and the percentage of motor vehicles only a little less rapidly, indicating the expected deviations from the national averages. In 1950 West Virginia had 0. 98 percent of both personal income and motor vehicles, but by 1955 only 0. 84 percent of personal income and 0. 88 percent of motor vehicles.

To make a projection in accordance with this variation of the second procedure, a state would first project its percentage of the national personal income and then project its percentage of the motor vehicles based on the historical trend of the ratio of its share of motor vehicles to its share of personal income.

## Third Procedure

The third procedure differs from the first two in that it calls for a forecasting rather than a projecting of a state economic index. To prepare a forecast of personal income, a state would analyze and forecast each of the important segments of the state's economy, taking into account the technological developments and other economic forces which are enhancing or depressing the economic outlook of each segment and of the state as a whole.

For example, growth of petro-chemicals has changed the economic prospects for Texas as well as the Northwest very sharply. The relative exhaustion of new, cheap hydro-electric power sources, in combination with new developments in high-temperature, high-pressure fuel generation of power, is reviving the economic prospects of the coal-bearing areas of the East. Developments in synthetic textiles and chemicals are altering the economic prospects for much of the South and New Jersey.

Forecasting techniques incorporating such economic factors have been developed over the past 20 years, according to Robinson Newcomb, consulting economist. While by no means perfect, such techniques do produce a much more useful estimate of the future than do the simpler projecting devices.

The need for a forecast rather than a projection shows up in the personal income trend in West Virginia. In 1950 that state had 0.98 percent of the national personal income but by 1955 it had only 0.84 percent. A projection of this 5 year downward trend would imply a continuation of the conditions which caused it. This decline in personal income was brought about in large part by the introduction of mechanical loading in the mines and the displacement of about half the miners. Now virtually all the mines are mechanized so personal income should be on the rise again.

## CONCLUSIONS

The conclusions drawn as a result of the exploratory application of the proposed procedures are that economic forecasting has great possibilities and that personal income, the economic index tested, promises to be fully as useful as anticipated. The fact that in the U.S. and in each of the four states analyzed there has been a consistent relation between motor vehicles and personal income over the past 26 years indicates that future trends in motor vehicles can be expected to move with the projected or forecasted trends in personal income.

The use of personal income as a basis for highway forecasting in the states will be facilitated by the publication probably about March 1, 1957, of "Personal Income by States Since 1929, a Supplement to the Survey of Current Business," prepared by the Office of Business Economics of the U.S. Department of Commerce. This is a publication resulting from a re-working of state personal income data to bring them into agreement with national personal income data.

By using the proposed procedures for analyzing and forecasting highway economics can be brought into step with macroeconomics, the newly developed approach to the economics of national growth which is from the aggregate rather than from the component parts.

The results of economic forecasting for highway purposes will prove far more beneficial to highway planning and development than anyone can foresee at this time. It will provide highway planners with a better understanding of the broader economic implications of their highway problems and plans and, at the same time, give important national economic agencies a better understanding of highways by bringing them within their own frame of reference.

## REFERENCES

1. "Potential Economic Growth of the United Stated During the Next Decade," material prepared for the Joint Committee on the Economic Report by the committee staff, Washington, 1954, 83rd Cong., 2nd Session, p. 35.

2. Daly, Rex F., "The Long-Run Demand for Farm Products," Agricultural Economics Research, a Journal of Economic and Statistical Research in the U.S. Department of Agriculture and Cooperating Agencies, Vol. VIII, No. 3, July 1956.

3. Holmes, E.H., "What's Ahead in Traffic Volumes," Proceedings, Institute of Traffic Engineers, 1950. See also E.H. Holmes, "Traffic to Come," paper at National Safety Congress, 1951.

4. The President's Advisory Committee on a National Highway Program, "A Ten-Year National Highway Program," a report to the President, January 1955, p. 8.

5. "1955 Survey of Consumer Finances and Purchases of Durable Goods in 1954," Federal Reserve Bulletin, May 1955.

6. U.S. Department of Labor, Bureau of Labor Statistics, "Family Income, Expenditures and Savings in 1950," Bulletin No. 1097 (Revised) June 1953, p. 19; or see Wilfred Owen, "The Metropolitan Transportation Problem," The Brookings Institution, Washington, 1956, p. 274.

7. U.S. Department of Commerce, Office of Business Economics, "National Income Supplement to the Survey of Current Business, 1954" (Biannual), Government Printing Office, Washington, D.C.

8. Dewhurst, and Associates, "America's Needs and Resources—A New Survey," The Twentieth Century Fund, 1955. See Appendix 4-4, "Consumption Expenditures by Type of Product or Service, 1909-1952," p. 971.

9. Schmidt, Robert E. and Campbell, M. Earl, "Highway Traffic Estimation," The Eno Foundation for Highway Traffic Control, Saugatuck, Connecticut, 1956.

10. "Economic Report to the President" (January 1956).

11. Automobile Manufacturers Association, "Automobile Facts and Figures," 1955 and 1956.

12. U.S. Department of Commerce, "Survey of Current Business," September 1955, July and August 1956.

# Highway Program Evaluations

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Long-range highway program costs in various states, for construction and maintenance to provide adequate highways, are reviewed in relation to travel, population and motor vehicle registration.

Reduction of annual costs to common indices provides opportunity to examine similarities and differences among the states. Indices, even though based on estimates computed by various methods and individuals in different localities, have less variation among states than might be expected.

System costs per vehicle mile are shown to be least on the heavily-traveled principal city systems, even though per-mile construction costs are greatest. Conversely, highest vehicle-mile costs are on lightly-traveled local road systems.

Conversion of total costs to per capita and other indices also makes program data more easily understood and provides a better basis for economic analysis.

● HIGHWAY POLICY, financing, and administration rely more and more on results of comprehensive, long-range highway needs studies. The studies are new tools, developed only within the last 10 years. Their reliability and reasonableness have been carefully reviewed and accepted by legislators and administrators as a basis for action, the most notable being the 1956 Federal-Aid Highway Act.

Congress called for a nationwide study of highway needs in 1954, following several studies of needs of the federal-aid systems previously presented by AASHO. The report, "Needs of the Highway Systems 1955—1984," indicated that an annual average expenditure of $9.9 billion, at 1954 prices, would be required over the next 30 years to develop, improve, and maintain all 3,300,000 miles of roads and streets in the nation. Projected travel in that period would approximate an average of 900 billion vehicle miles annually. Thus, for the first time it was possible to estimate that, at 1954 price levels, about 1.1 cents per vehicle mile would do the job. Values were higher than that amount prior to 1928 and lower since that date, falling to 0.6 cents by 1941, 0.5 cents in 1945, climbing back to 1.0 cents in 1953 and 1.07 cents in 1954 (1, 2).

It has been stated by Wilfred Owen of the Brookings Institution that about 10 percent or less, of the total cost of motor vehicle operation has been expended for highways (3). He suggests that a higher proportion would be beneficial in reducing total operating costs and providing other benefits. If total vehicle costs now range from 8 to 10 cents per vehicle mile, then the future highway needs would approximate only 11 to 14 percent of the total—or a somewhat higher percentage if the improved highways reduce total costs, as expected.

Despite the billions of dollars reported, the validity and conservativeness of the national estimates becomes apparent upon closer examination. Although $9.9 billion per year for 30 years totals $297 billion, the growth of traffic should be able to support the necessary expenditures, especially when other sources of income are also involved, if past relations are any criteria.

Beyond the implicit reasonableness of the data is acceptance of the engineering techniques and methods of measurement developed in the highway needs studies of the last 10 years. In numerous states and before Congress, the presentation of facts and detailed explanation of how they were obtained has acquainted legislators and the public with the engineering approach as a sound basis for decision-making.

Relations have been developed in the highway needs studies which place the total highway problem in proper perspective. Usually for the first time, not only are total requirements evaluated, but cost relations of various systems, governmental responsibilities and classes of work are established. When compared to the past and the estimated future, the data assume proportions that are generally found to be more understandable.

Reduction of annual costs to common indices also provides opportunity to examine and evaluate similarities and differences among the states. The indices, even though based on estimates computed by various methods and different individuals in many localities, have less variation than might be expected.

All indices reported are based on 20-year programs. That is, costs required over a 20-year period for the following purposes are included, except where otherwise indicated:

1. Improvement of currently deficient facilities to standards adequate for 20-year future traffic—commonly known as the backlog of work;
2. Additional needs which will develop during the 20-year period on facilities not included in the first item;
3. Replacements of both preceding items in the period, on the basis of road life statistics;
4. Stop-gap work required to keep currently deficient sections in service until finances permit full standard improvements;
5. Maintenance and operation; and
6. Engineering and administration.

Estimated values of population, motor vehicle registration and travel during the same 20-year period[1] are then related to the program costs, all of which are stated at price levels prevailing in 1954. Data are limited to 14 of the highway needs studies in which the Automotive Safety Foundation has participated and in which sufficient information is readily available to permit development of the relations.

Costs per Mile of Travel

Table 1 summarizes results of the several studies for all roads and streets in the states listed.

TABLE 1

TOTAL HIGHWAY COSTS—ALL ROADS AND STREETS[a]

| Year | State | Cents per Vehicle Mile | Year of Study | State | Cents per Vehicle Mile |
|---|---|---|---|---|---|
| 1948[b] | Kansas | 1.50 | 1949 | Nebraska | 1.45 |
| 1955[b] | Kentucky | 1.24 | 1952 | North Dakota | 1.50 |
| 1954[b] | Louisiana | 1.13 | 1950 | Ohio | 0.95 |
| 1955[b] | Michigan | 1.00 | 1948 | Oregon | 0.93 |
| 1954 | Minnesota | 0.93 | 1955 | Tennessee | 1.07 |
| 1949[b] | Mississippi | 1.18 | 1948 | Washington | 0.91[c] |
| 1956[b] | Montana | 2.10 | 1954 | West Virginia | 1.33[c] |

[a]20-year program at 1954 prices.
[b]Includes interstate freeway system; [c]excludes local streets.

The unweighted average of the 14 states is 1.23 cents per mile of travel, and the median is about 1.15 cents. If weighted in terms of vehicle miles or program costs, the average would be less since generally the less populous states are shown to have higher costs. It will be noted that the average values are near the total of 1.1 cents for all roads and streets in the nation, as previously described.

For convenience in further analysis, Table 1 is re-arranged in Table 2 in order of cost per vehicle mile, showing also the 1950 state population.

Many variables among the states preclude a completely consistent pattern. For example, Oregon's total population and population density per square mile or per road mile would suggest its position in the higher-cost group. However, both Oregon and

[1] These are computed on a straight-line basis; i.e., present and 20-year future estimates (as presented in the respective studies) are averaged. The curvelinear form of many projections was not taken into account, tending to understate these values and overstate costs to a small degree.

TABLE 2

| Cents per Vehicle Mile | State | 1950 Population | Cents per Vehicle Mile | State | 1950 Population |
|---|---|---|---|---|---|
| 0.91 | Washington | 2,379,000 | 1.18 | Mississippi | 2,179,000 |
| 0.92 | Oregon | 1,521,000 | 1.24 | Kentucky[a] | 2,945,000 |
| 0.93 | Minnesota | 2,982,000 | 1.33 | West Virginia | 2,006,000 |
| 0.95 | Ohio | 7,947,000 | 1.45 | Nebraska | 1,326,000 |
| 1.00 | Michigan[a] | 6,372,000 | 1.50 | Kansas | 1,905,000 |
| 1.07 | Tennessee | 3,292,000 | 1.50 | North Dakota | 620,000 |
| 1.13 | Louisiana | 2,684,000 | 2.10 | Montana[a] | 591,000 |
| 0.99 | Average of 7 states | 3,882,000 | 1.47 | Average of 7 states | 1,653,000 |

[a]Includes interstate freeway system.

Washington are expected to have faster future growth of population and travel than any comparable states, thus reducing the relative cost of a future 20-year program.

Travel growth has considerably exceeded nearly all forecasts. Naturally, if travel exceeds the forecasts with less than a comparable rise in total program costs, then costs per vehicle mile would be less, provided price levels do not increase. Data in Table 2 suggest that those states with currently high volumes of travel, or with relatively rapid increases forecast, actually have lower costs per vehicle mile than other states, despite the greater need for higher cost facilities. In part, that may be due to a relatively better current status of improvement in many of the more populous states, thus reducing the catch-up costs required within the 20-year period.

Only Michigan, Kentucky, and Montana included costs of developing the interstate system, both rural and urban, to the high standards recently adopted by AASHO. All studies, however, planned for such multi-lane highways, expressways, and freeways as were indicated by traffic needs, but not necessarily with such desirable consistency as is now contemplated.

For some of the states previously listed, plus the Province of Ontario, Table 3 shows relations of 20-year program costs per mile of travel on specific classes, or systems, as they were classified in the studies. In most cases, it was assumed that the percentage of total state travel on each system would remain at existing proportions throughout the 20-year period, with travel on each system increasing at the estimated statewide rate.

Table 3 shows that, with only two exceptions, the more heavily traveled systems have lower costs per mile of travel. That is true despite the higher standards and greater costs per mile on the principal routes, as indicated in Table 4. One exception is in Minnesota where urban state highways are shown to cost somewhat more than the unusually low-cost rural highways. That was due, at least in part, to the present excellence of the rural state highway system (whose costs would rise as a result of present interstate standards) and, conversely, the need for a major freeway system in the Twin Cities. The other exception is Oregon, where difficulty in allocating costs and vehicle mileage between rural state highways and county primary roads may account for the apparent discrepancy.

Table 3 also reveals other variables which reflect specific situations in various states:

Urban Primary State Highways. Higher costs in West Virginia reflect difficult construction in mountainous terrain. In North Dakota, fewer vehicle miles relative to needs account for the highest costs listed. The reverse is true in Ohio, but in Mississippi it is believed that estimates of needs were inadequate (Table 4).

Rural Primary State Highways. Two of the highest figures listed (Kansas and North Dakota) reflect large mileages and quite inadequate systems, coupled with relatively light traffic as compared to other more populous states. Again, West Virginia's costs

TABLE 3

TOTAL HIGHWAY COSTS BY SYSTEMS[a]

| State | Primary State Highways Urban (Cents per Vehicle Mile) | Primary State Highways Rural (Cents per Vehicle Mile) | County Primary Roads | Local Roads |
|---|---|---|---|---|
| Kansas | 0.57 | 1.37 | 2.22 | 5.80 |
| Kentucky | 0.84[b] | 0.90[b] | 1.87 | 5.30 |
| Minnesota | 0.81 | 0.60 | 1.56 | 2.40 |
| Mississippi | 0.45 | 0.57 | 2.17 | 3.67 |
| Nebraska | 0.75 | 1.04 | 1.82 | 5.70 |
| North Dakota | 1.02 | 1.34 | 2.00 | 2.10 |
| Ohio | 0.57 | 0.81 | 1.40 | 1.81 |
| Ontario | ---- | 0.88[c] | ---- | ---- |
| Oregon | 0.34 | 1.07[d] | 0.92 | 3.10 |
| Washington | 0.37 | 0.87[d] | 1.33 | 3.02 |
| West Virginia | 0.83 | 1.27 | 2.07 | 4.25 |
| Unweighted Average | 0.66 | 0.97 | 1.74 | 3.72 |

[a]20-year program at 1954 prices, [b]includes interstate freeway system, [c]includes province-wide freeway system, [d]includes secondary state highways.

reflect heavy construction in mountainous terrain. On the other hand, Mississippi's system was well-developed, much of it newly built between 1936 and 1941, and maintenance requirements are less in southern states.

The Ontario system also falls within the general pattern of the states. Needs are considerable, including the development of an extensive freeway system and many other multi-lane facilities along with improved highways in the thinly-populated northern area. Predicted traffic growth, however, is also great, with the result that costs are in line with those elsewhere.

County Primary Roads. There is less spread among the states than for other systems which suggests a greater degree of uniformity in travel and costs. Low-cost states such as Washington, Ohio, and Minnesota possibly reflect the good county engineering which exists there, the easier terrain in the latter two, and more readily available materials.

Kansas has extensive mileage of relatively lightly traveled roads and lacks cheap surfacing materials—both combining to increase costs per mile of travel. Mississippi county roads were in very poor condition, with material also at a premium.

Local Roads. Variations also apply to the local road systems. In addition, the standards applicable to the large mileage in North Dakóta were especially low in keeping with the very light traffic (Table 4). Furthermore, variations may result from greater difficulties in estimating traffic and vehicle miles on these systems. Because of the low percentages of total travel on local roads, a small variation would have a considerable effect on the vehicle-mile cost.

## Annual Costs Per Mile

The total annual costs per mile, including construction, maintenance and administration, for 20-year programs tend to approximate the perpetual cost per mile of owning and operating the road systems—the true annual cost, exclusive of interest. There is considerable variation among the states, since these costs reflect specific standards of construction and maintenance, as well as present degree of improvement, terrain and other factors, without the smoothing influence of predicted vehicle miles of travel (Table 4).

In all cases, urban state highways are highest annual cost-per-mile facilities, and costs of rural systems are graduated downward in accord with function and use. However, costs per vehicle mile are generally in reverse order, indicating the relative value of such high-cost facilities to the motorist.

It should be noted that the "Total" of Table 4 does not include city arterial and local streets, and is too limited a sample to be taken as indicative of values elsewhere than in the listed states. Nevertheless, the data provide valuable comparisons for consideration in other studies.

Some of the reasons for the variations have been noted with respect to Table 3, in which Michigan does not appear because of lack of data with respect to vehicle miles by systems. In Table 4, however, it should be pointed out that Michigan primary

TABLE 4

TOTAL ANNUAL COSTS PER MILE BY SYSTEMS[a]

| State | Urban State Highways | Rural State Highways | Primary County Roads | Local Roads | Weighted Total |
|---|---|---|---|---|---|
| Kansas | $10,100[b] | $ 4,770[b] | $ 810 | $290 | $ 745 |
| Kentucky | 25,600[b] | 10,600[b] | 2,150 | 830 | 2,200 |
| Michigan | (------$18,500[b]----) | | 3,100 | 900 | 3,160 |
| Minnesota | 17,900 | 3,600 | 1,075 | 275 | 1,080 |
| Mississippi | 4,700 | 2,900 | 1,500 | 415 | 940 |
| Nebraska | 10,000 | 3,700 | 950 | 245 | 735 |
| North Dakota | 6,400 | 2,650 | 650 | 130 | 610 |
| Ohio | 22,900 | 6,400 | 1,980 | 610 | 2,250 |
| Ontario | ---- | 12,600 | --- | --- | --- |
| Oregon | 14,300 | 5,280[c] | 1,750 | 410 | 1,560 |
| Washington | 15,000 | 6,200[c] | 1,190 | 445 | 1,500 |
| West Virginia | 21,600 | 11,400 | 2,100 | 730 | 2,620 |
| Unweighted Average | $14,850 | $ 6,380 | $1,570 | $480 | $1,580 |

[a]20-year program at 1954 prices, [b]includes interstate freeway system, [c]includes secondary state highways.

county road programs include considerable multi-lane construction in the vicinity of Detroit and other cities, accounting in part for the indicated cost. Snow removal costs also exceed those of many states.

## Other Indices

Conversion of total program costs to per capita and per-vehicle costs (Table 5) brings the millions or billions involved into more readily understandable form and provides a basis for comparison and evaluation of the costs among states. Population and number of vehicles on which Table 5 is based are average totals as projected for the 20-year programs in the individual states.

The unweighted average annual per capita cost for all 14 states is $46; the annual average cost per vehicle is $116.

Conversion of these costs to any other common base may be of interest; for example, the Michigan cost is the equivalent of 12 cents per day per capita; in West Virginia the cost would average about 40 cents per day for each motor vehicle.

With due regard for variables and with proper adjustment for price changes, such evaluations and comparisons provide a valuable guide in judging the adequacy and validity of needs estimates.

Furthermore, by relating these future estimates to past conditions, the economic feasibility may be clearly indicated. Michigan data showed, for instance, that actual expenditures (without price adjustment) from 1920 to 1931 were at rates averaging about 45 percent higher than the proposed 20-year program per vehicle mile. From 1931 until 1955, expenditures averaged only about 60 percent of those proposed (per vehicle mile), but in 1956, about 87 percent was available. In Kentucky, the state was

TABLE 5

ANNUAL COSTS—ALL ROADS AND STREETS[a]

| State | Average Cost per Capita | Average Cost per Vehicle | State | Average Cost per Capita | Average Cost per Vehicle |
|---|---|---|---|---|---|
| Kansas | $ 58 | $143 | Nebraska | $42 | $113 |
| Kentucky[b] | 44 | 118 | North Dakota | 58 | 117 |
| Louisiana | 41 | 106 | Ohio | 30 | 76 |
| Michigan[b] | 45 | 102 | Oregon | 35 | 89 |
| Minnesota | 42 | 96 | Tennessee | 39 | 102 |
| Mississippi | 28 | 142 | Washington | 32 | 91 |
| Montana | 114 | 188 | West Virginia[c] | 42 | 144 |

[a]20-year program at 1954 prices, [b]includes interstate freeway system, [c]excludes local streets.

spending about 1.1 cents per vehicle mile in 1953-54; the future program was estimated to cost about 1.24 cents.

Highway needs and financing studies have indicated that the future long-range investment requirements are not out of line with past performance when growth factors are accounted for. But acceleration to catch up with deferred work is shown to be the major present problem. Each study should be designed to develop the significant relations that will encourage attainment of adequate highway, road and street systems.

## REFERENCES

1. "Highway Facts," Automotive Safety Foundation (1952).
2. "Highway Statistics," U.S. Department of Commerce, Bureau of Public Roads.
3. Wilfred Owen, "Automotive Transportation," Brookings Institution (1949).

# Perpetual Highway Needs Study

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● ALTHOUGH the necessity of keeping some type of a highway needs study and future program has been apparent at least since the time of the formation of state highway departments, the importance of data in this field has become of increasing significance with the passage of time. With the recent agitation for a more comprehensive program for the improvement of highways at a national level, the necessity for an accurate catalog of future needs has been brought into sharp focus.

The compilation of a needs program is complicated by many factors, one of the principal ones being changing conditions. Roads that were considered adequate 10 or even 5 years ago frequently become inadequate because of changing conditions or new standards such as those adopted for interstate highways. These roads demand an entirely new concept of standards, access control, and other features. In Oregon a future needs program is viewed as a changing inventory which is in a constant state of review and revision so that it may reflect as nearly as possible current needs.

All roads in the state are divided into the rough, general categories of adequate or inadequate. This, of course, entails the analysis of each highway or section of highway in the light of present traffic, anticipated changes in the traffic pattern, and changes in the type of traffic. As an example, frequently an area will be opened to logging and a road that carried a small load of traffic, much of it being passenger or light vehicles, will suddenly be burdened with heavy logging vehicles. This changes the concept of adequacy. All roads in Oregon are reviewed at least once a year applying the yardstick of adequacy.

Probably the largest problem that confronts a department in compiling data on future needs is the problem of cost estimates. The magnitude of this problem can be realized by pointing out that the study encompasses a period of from 10 to 30 years in the future and generally involves but little, if any, information as to possible future revenues.

Cost estimates fall into three categories given in descending order of their accuracy: (1) Jobs on which detailed surveys have been completed giving close estimates of cost if the job is not postponed too long;(2) Jobs on which reconnaissance or other field-type reports have been developed to a point where a reasonable degree of accuracy of estimates is possible; and (3) Estimates on other sections where no field data has been obtained and where estimates are made by the comparative or length-unit cost basis (study of past and present cost figures).

The problem of accurate estimates is complicated in the first type of estimate by changes in geometric standards between the time the survey was made and the job is contracted, addition of facilities (such as additional interchanges) and changes in the unit-cost items of work occasioned by economic considerations.

Similar problems are involved in the second or reconnaissance type of estimate. There is the further complication, however, that detailed surveys frequently indicate costs that exceed those developed from reconnaissance work unless the reconnaissance engineer is extremely careful to make allowances for additional items that inevitably creep into a job when details are finally developed.

The comparative cost type of estimate reflects accuracy of cost only to a degree commensurate with the skill and experience of the estimator. As a further means of assuring reasonable cost estimates, copies of all cost data by highway divisions are submitted to the field on an annual basis for checking and possible revision.

Many western states have seen a rapid rise in population in the last 10 years and the establishment of many new industries which have a direct bearing on the adequacy of highways in areas where these changes have taken place. Also, in most western states the use of trucks has shown an increase in the period since World War II. Both of these factors when applied to existing highways frequently shift them from the adequate to the inadequate column.

Right-of-way costs are handled in somewhat the same manner as are construction costs. More accurate appraisals are bound to follow when better details of location are furnished to the appraisal section.

One of the principal difficulties found in the comparative type estimates is the chronic one of underestimating costs. For some reason, people making this type of a cost estimate are invariably too optimistic and a careful review is necessary if realistic estimates are to be had.

The assembling and cataloging of the data is a difficult, tedious job and is never completed because the program changes in detail from year to year. Cost estimates are carried in two different forms in Oregon. Projects are broken into units of reasonable length with breaks also at division and county lines for ease of use. Projects are segregated by class of highway, division, county and priority. Under the heading "priority," projects are classified on a 1-2-3 basis in the order of their importance to the over-all highway needs of the state, approximately one-third of the total being assigned to each grouping. This is to facilitate the preparation of construction programs commensurate with construction funds or anticipated funds. In this way a catalog is made of the complete future needs program.

The information is placed on straight line charts which are bound in atlases. Copies are furnished to the state highway engineer, his deputy and assistants and interested staff engineers. The straight line charts show in contrasting color cost items of all construction jobs which have been built after 1950. This information gives a quick and ready cost picture which is of great convenience. The state highway engineer, his deputy and assistants keep this atlas in the office and frequently refer to it when considering projects or answering inquiries that come in by letter or telephone. The information is given in the following detail: length of section, number of traffic lanes, cost of grading, surfacing and paving, structures, right-of-way and totals. In certain instances a slightly more detailed breakdown is used to include guard rail, right-of-way fence, or other items of cost. Where these items are substantial they are shown separately; otherwise, they are included in the grading and surfacing costs.

Once the complete catalog of highway needs is compiled it is possible to work out any type of future program by assembling appropriate cost data from the project lists. Summaries were invaluable in compiling statewide cost data for studies such as those undertaken in the summer of 1954 under Section 13: 1954 Federal-Aid Highway Act, Nationwide Highway Finance Study.

The present system in Oregon admittedly has some deficiencies, but it has proven adequate to needs and is the solution to a vexing and chronic problem.

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.

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