Factors Influencing Rural Road Mileage

ROBERT S. SCOTT
R.S. Scott Engineering Company, Inc., Alpena, Michigan

●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:

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

A close approximation is:

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

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.

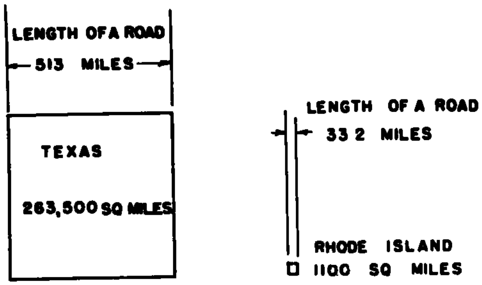


Figure 1.

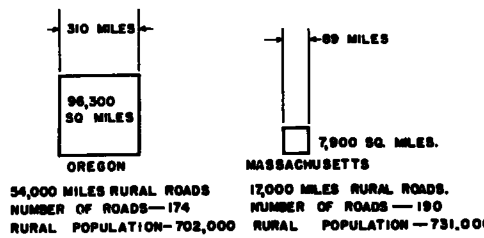


Figure 2.

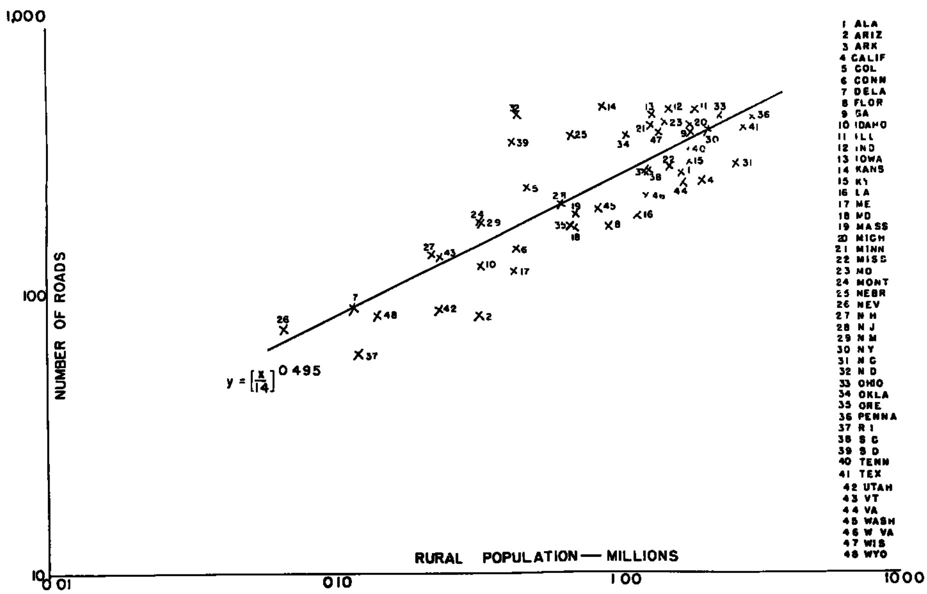


Figure 3. Rural road distribution by states.

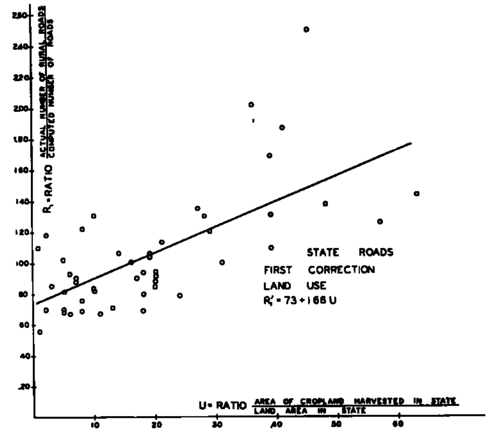


Figure 4.

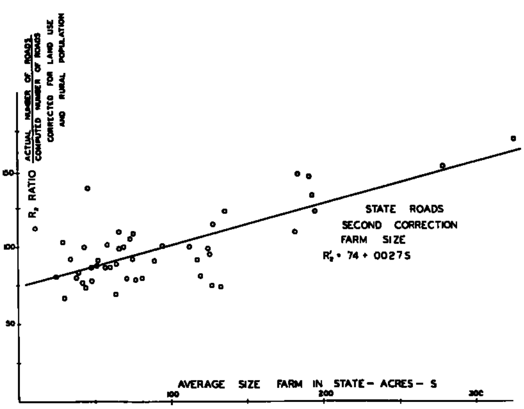


Figure 5.

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

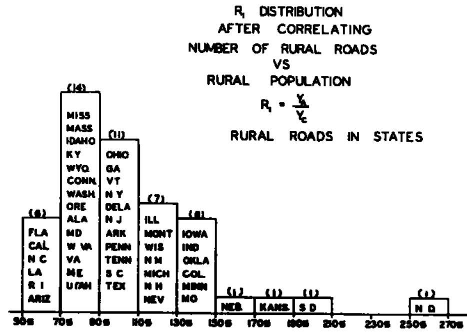


Figure 6.

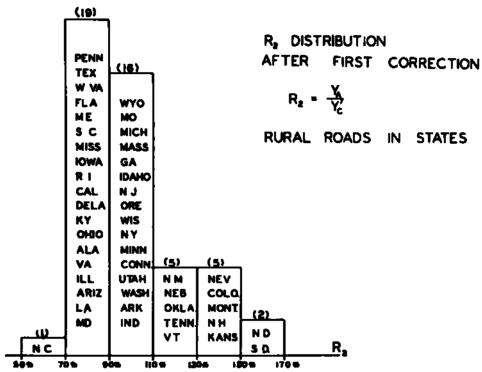


Figure 7.

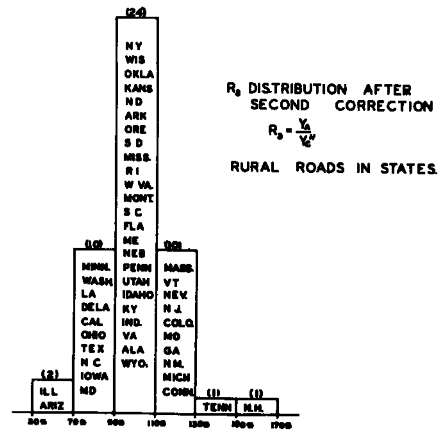


Figure 8.

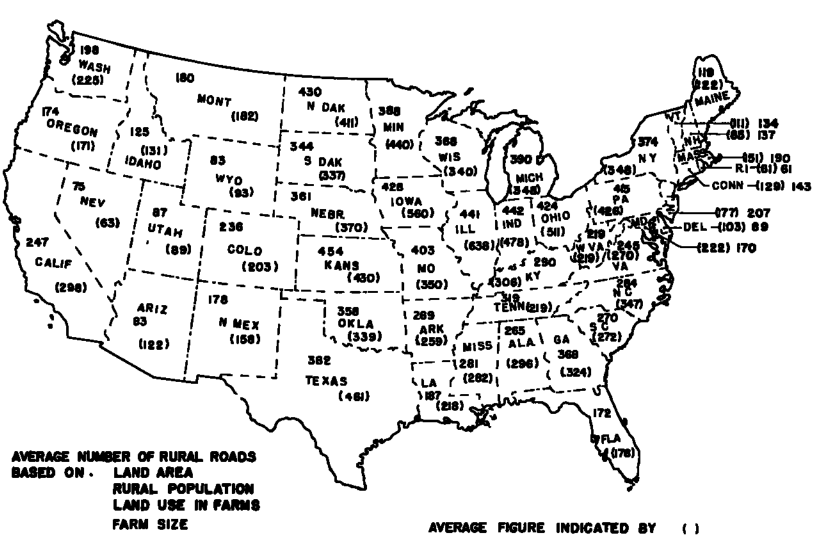


Figure 9. Actual and average number of rural roads in the United States.

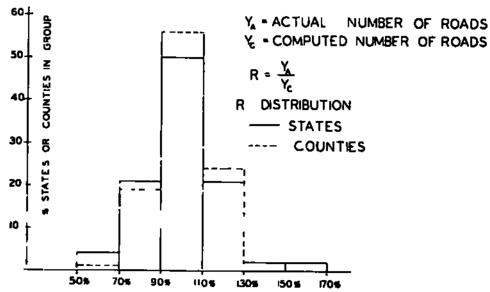


Figure 10.

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.)

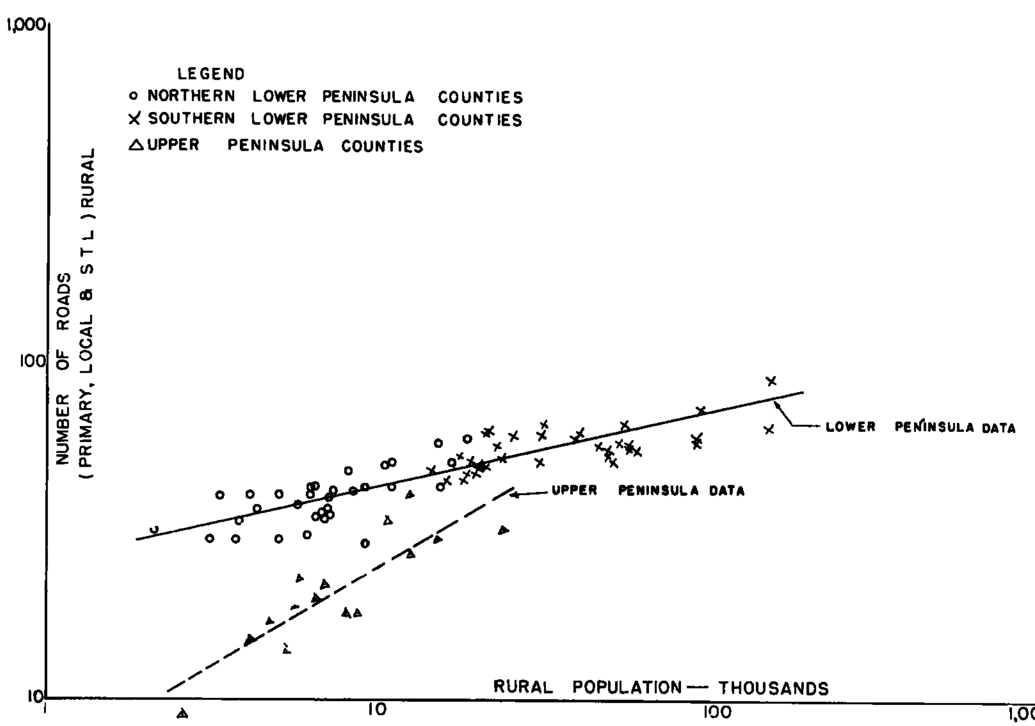


Figure 11. Distribution of rural roads by counties in Michigan.

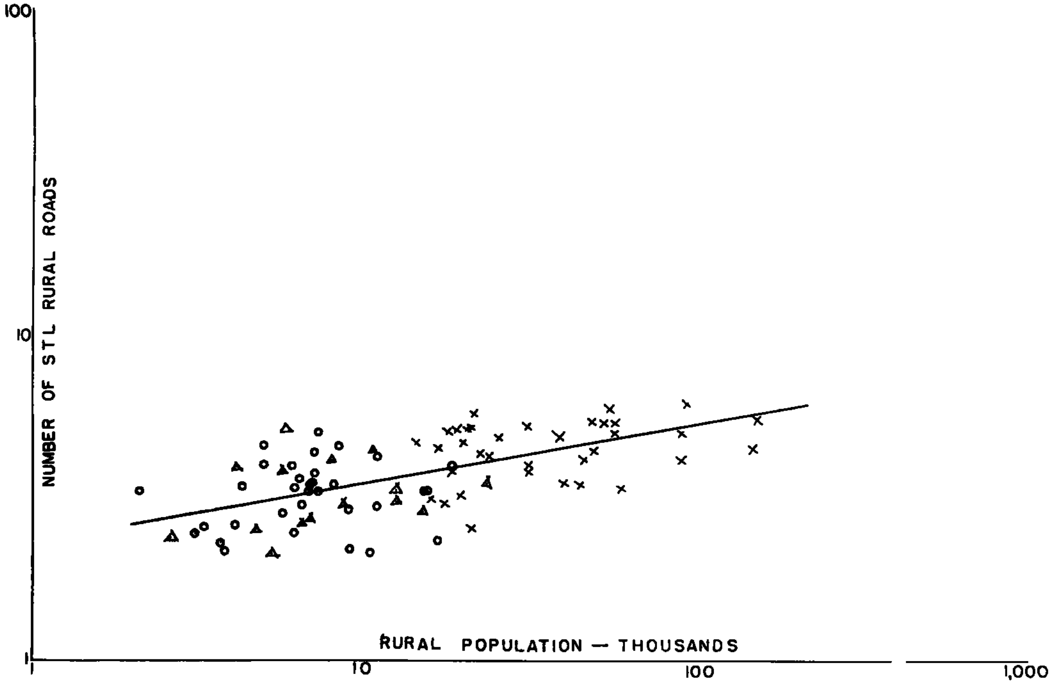


Figure 12. Distribution of rural S.T.L. roads by counties in Michigan.

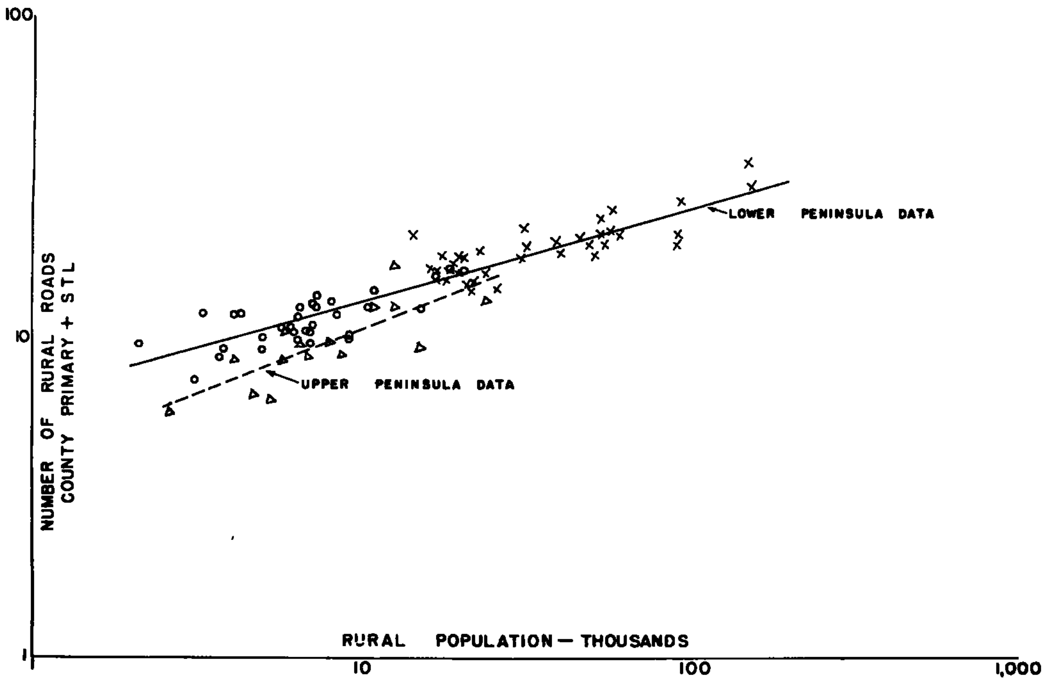


Figure 13. County primary roads in Michigan.

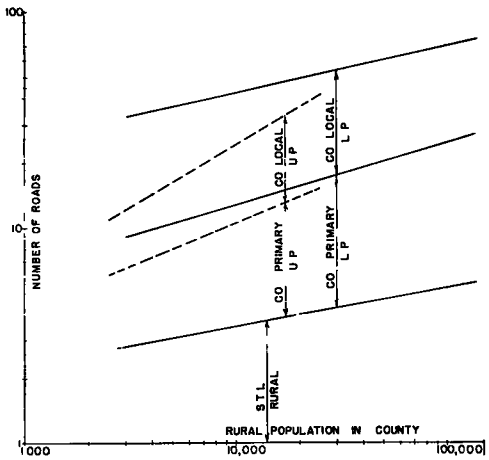


Figure 14. Road distribution in Michigan.

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.

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

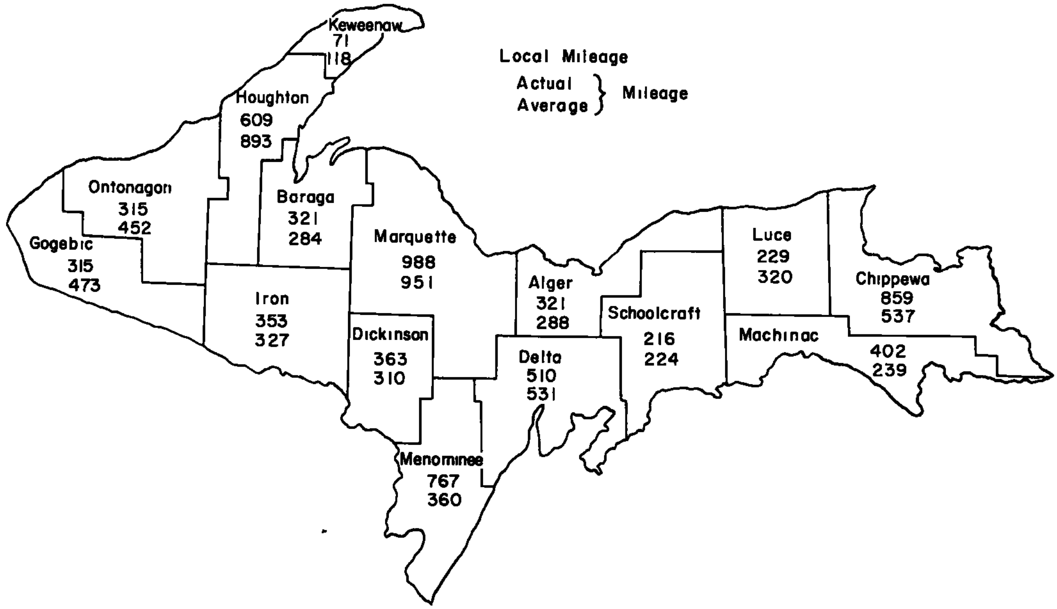
Y''_c = Computed number of roads based on rural population, land use and farm size.

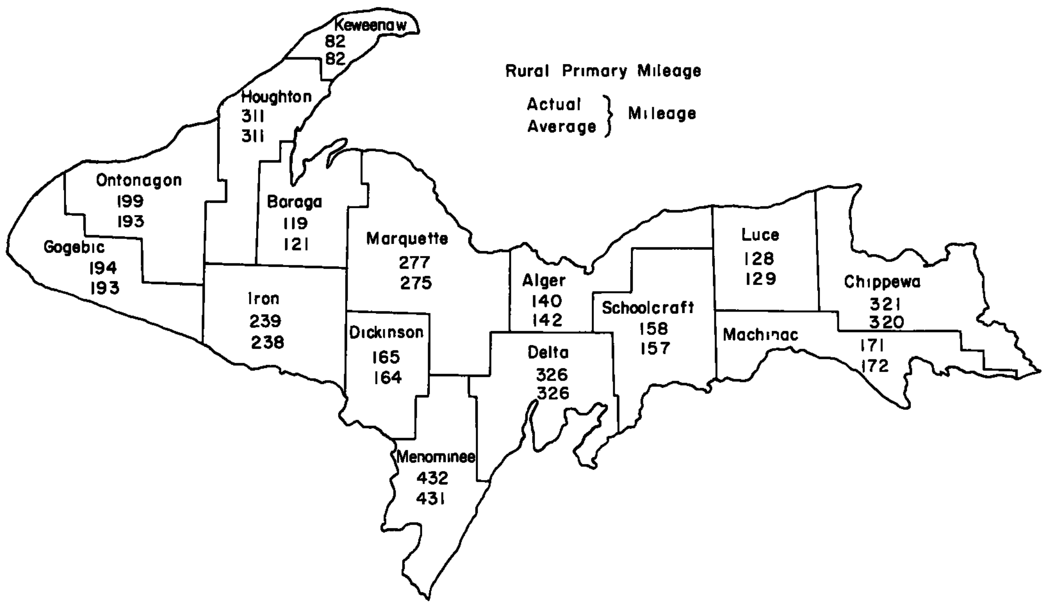
$R_3 = \frac{Y_a}{Y''_c}$; Figure 8.

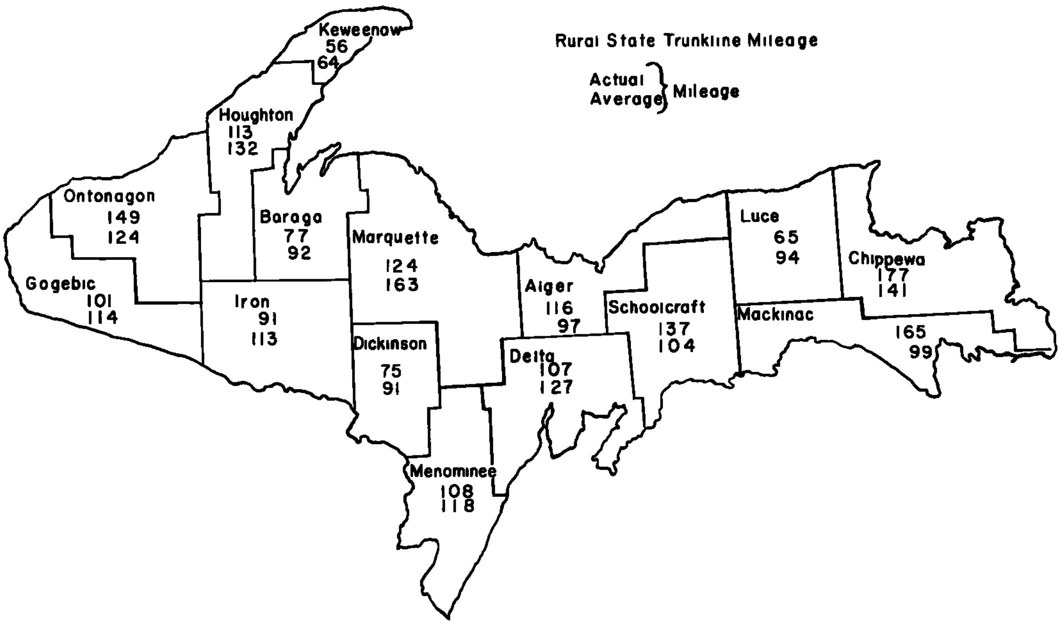
Appendix B

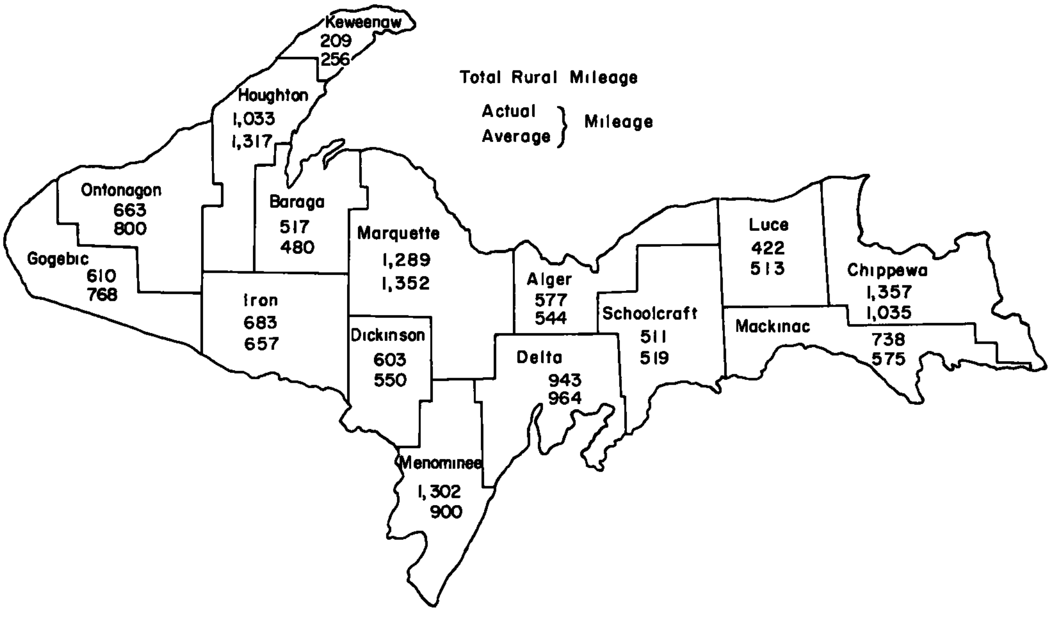
COUNTIES OF MICHIGAN
RURAL PRIMARY MILEAGE

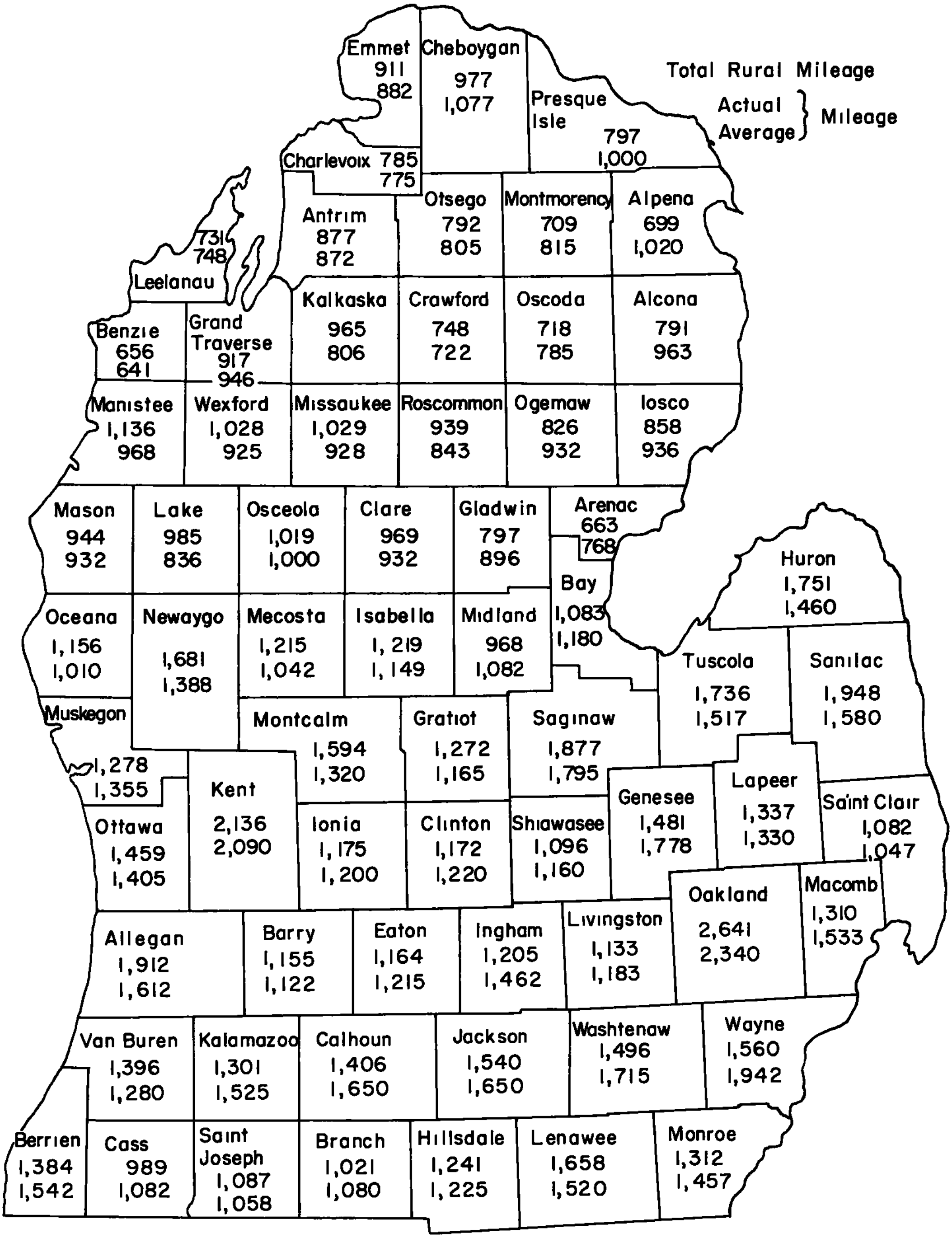
	Actual	Average	%		Actual	Average	%
Alcona	134	168	125	Lake	221	176	80
Alger	140	142	101	Lapeer	299	314	105
Allegan	438	415	95	Leelanau	161	126	78
Alpena	164	227	138	Lenawee	451	348	77
Antrim	183	157	86	Livingston	295	278	94
Arenac	132	154	117	Luce	128	129	101
Baraga	119	121	102	Mackinac	171	172	101
Barry	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				

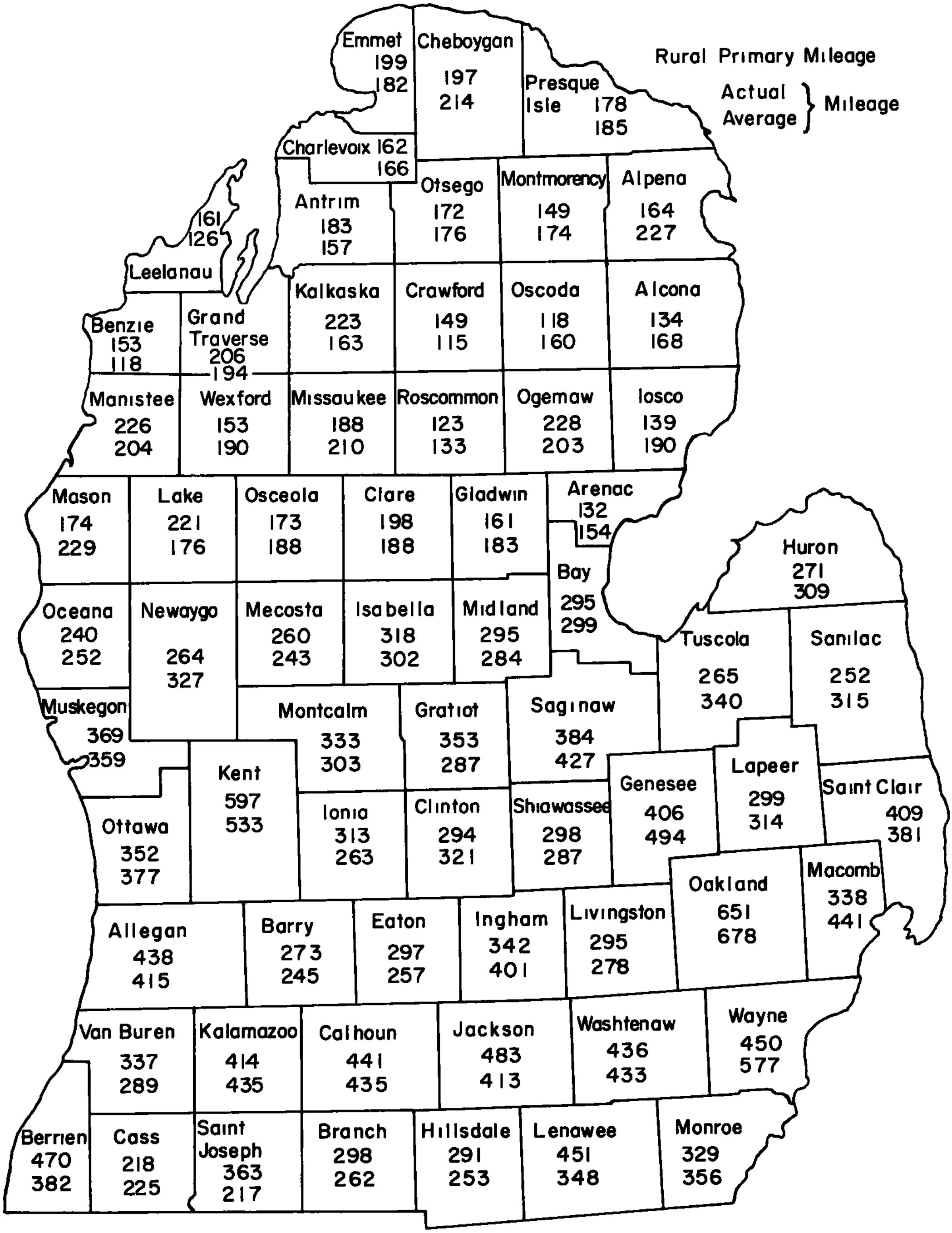

Local Mileage
Actual
Average
Mileage
Keweenaw
71
118
Houghton
609
893
Ontonagon
315
452
Gogebic
315
473
Baraga
321
284
Marquette
988
951
Iron
353
327
Dickinson
363
310
Menominee
767
360
Alger
321
288
Delta
510
531
Schoolcraft
216
224
Luce
229
320
Chippewa
859
537
Machinac
402
239

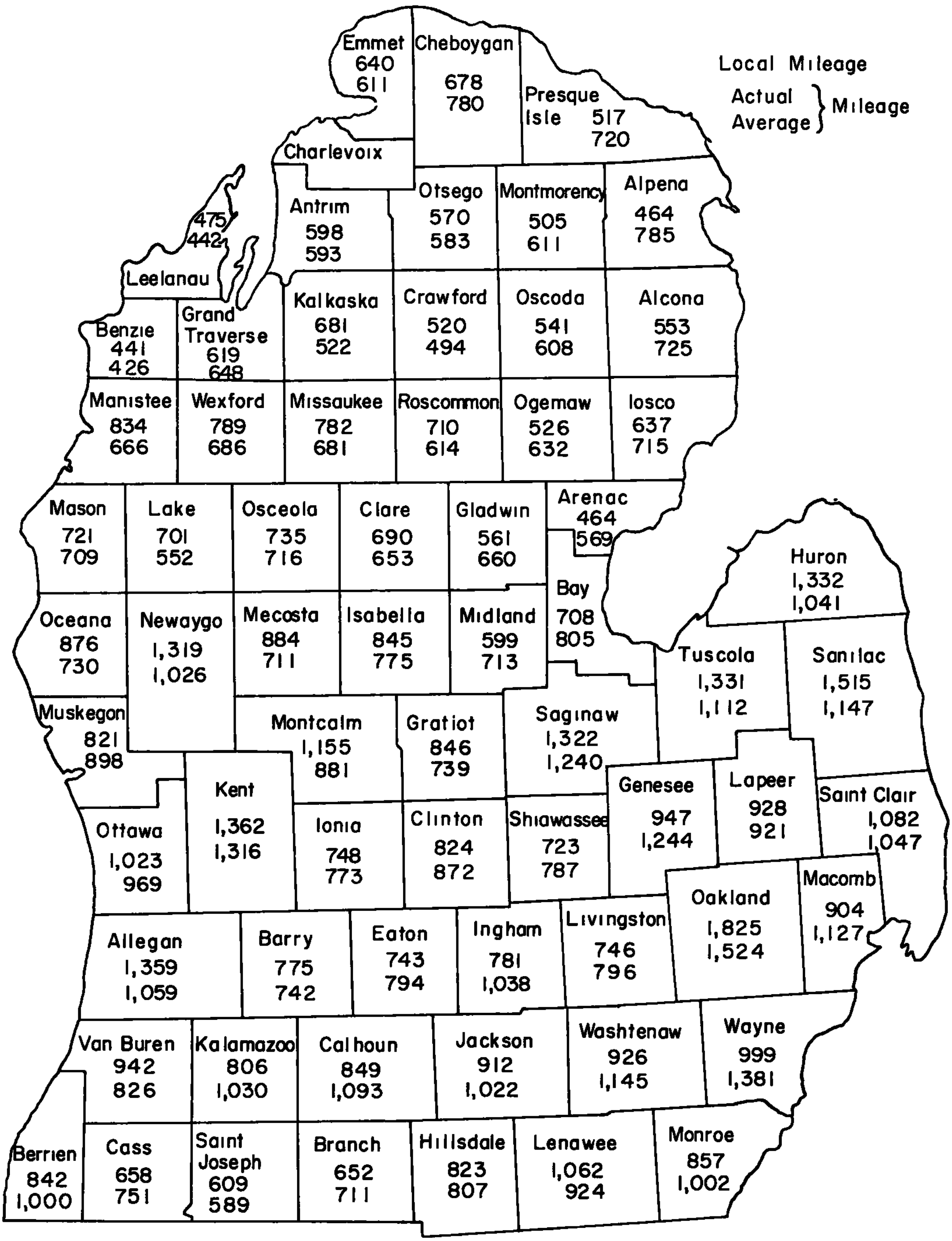

Rural Primary Mileage
Actual
Average
Mileage
Keweenaw
82
82
Houghton
311
311
Ontonagon
199
193
Gogebic
194
193
Baraga
119
121
Marquette
277
275
Iron
239
238
Dickinson
165
164
Menominee
432
431
Alger
140
142
Delta
326
326
Schoolcraft
158
157
Luce
128
129
Chippewa
321
320
Machinac
171
172

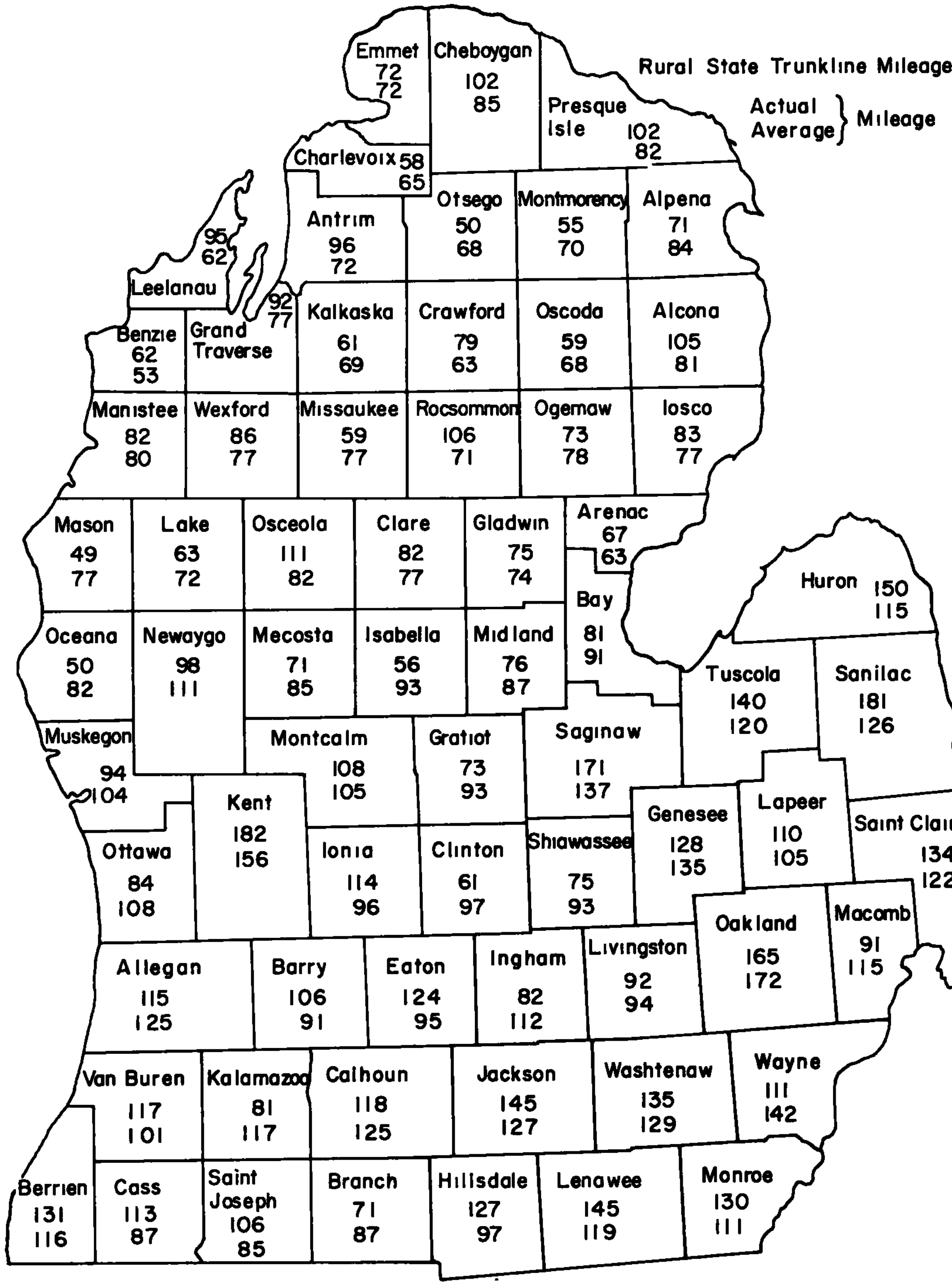

Rural State Trunkline Mileage
Actual
Average
Mileage
Keweenaw
56
64
Houghton
113
132
Ontonagon
149
124
Baraga
77
92
Marquette
124
163
Gogebic
101
114
Iron
91
113
Dickinson
75
91
Alger
116
97
Schoolcraft
137
104
Luce
65
94
Chippewa
177
141
Mackinac
165
99
Delta
107
127
Menominee
108
118


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
Schoolcraft
511
519
Luce
422
513
Chippewa
1,357
1,035
Mackinac
738
575
Delta
943
964
Menominee
1,302
900


Total Rural Mileage
Actual
Average
Mileage
Emmet 911 882
Cheboygan 977 1,077
Presque Isle 797 1,000
Charlevoix 785 775
Leelanau 731 748
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
Oceana 1,156 1,010
Newaygo 1,681 1,388
Mecosta 1,215 1,042
Isabella 1,219 1,149
Midland 968 1,082
Bay 1,083 1,180
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
Leelanau 161 126
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
Kent 597 533
Genesee 406 494
Lapeer 299 314
Saint Clair 409 381
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


Emmet
640
611
Cheboygan
678
780
Presque Isle 517
720
Local Mileage
Actual
Average
Mileage
Charlevoix
475
442
Leelanau
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
Bay
708
805
Oceana
876
730
Newaygo
1,319
1,026
Mecosta
884
711
Isabella
845
775
Midland
599
713
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
Kent
1,362
1,316
Ottawa
1,023
969
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
Kalkaska 61 69
Crawford 79 63
Oscoda 59 68
Alcona 105 81
Benzie 62 53
Grand Traverse
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