UTILIZATION OF THE PLANNING SURVEY

Paper presented by H. S. Fairbank, Chief, Division of Information, U. S. Bureau of Public Roads, at the conference on Highway Engineering and Highway Safety, Ann Arbor, Michigan, February 15, 1938

- - - - -

It is now about two years since, in most of the States, the work of the State-wide highway planning surveys was begun. Michigan began a little earlier, has maintained her lead, and is now nearer than most of her Sister States to the time when she may begin to apply the results of her studies to the solution of her own highway problems.

In the first year the task was one of observation, recording, and inquiry in the field. In the second the scene of operations shifted to the office; and there for some time since a great deal of painstaking work has been in progress, the purpose of which has been to array the voluminous data gathered in the field in such orderly and related groups as would permit their study and analysis. Draftsmen have been at work transcribing inventory notes onto so-called straight-line diagrams, and compiling maps. Coders and punchers have been busy translating words and figures on thousands of field reports into round holes punched in columned cards, which later have been fed into tabulating machines, to come out as row upon row of statistics. There has been much talk among these office workers of such matters as the suitability of symbols and the size and adequacy of samples; and there has been debate about such things as traffic patterns and expansion factors. The debate has been very serious; the talk has been very technical; the statistics have been very -- statistical.

But, what has there been, what will there be, of tangible, practical, useful result, issuing from all this earnest work, this talk and debate, and these statistics? That is a question we are beginning to hear with some insistence. It is a reasonable question; and it is the question that this paper will attempt to answer, illustrating the answer, wherever possible, by means of fragmentary results thus far gleaned from the surveys in a number of States.

It is reasonable to suppose that many of those who inquire for results have in mind such results as are customarily set down in printed reports. The end of all surveys is expected to be a REPORT. It generally is the end. The report goes on the shelf. The survey is finished; forgotten; and no one is the better or the worse for it.

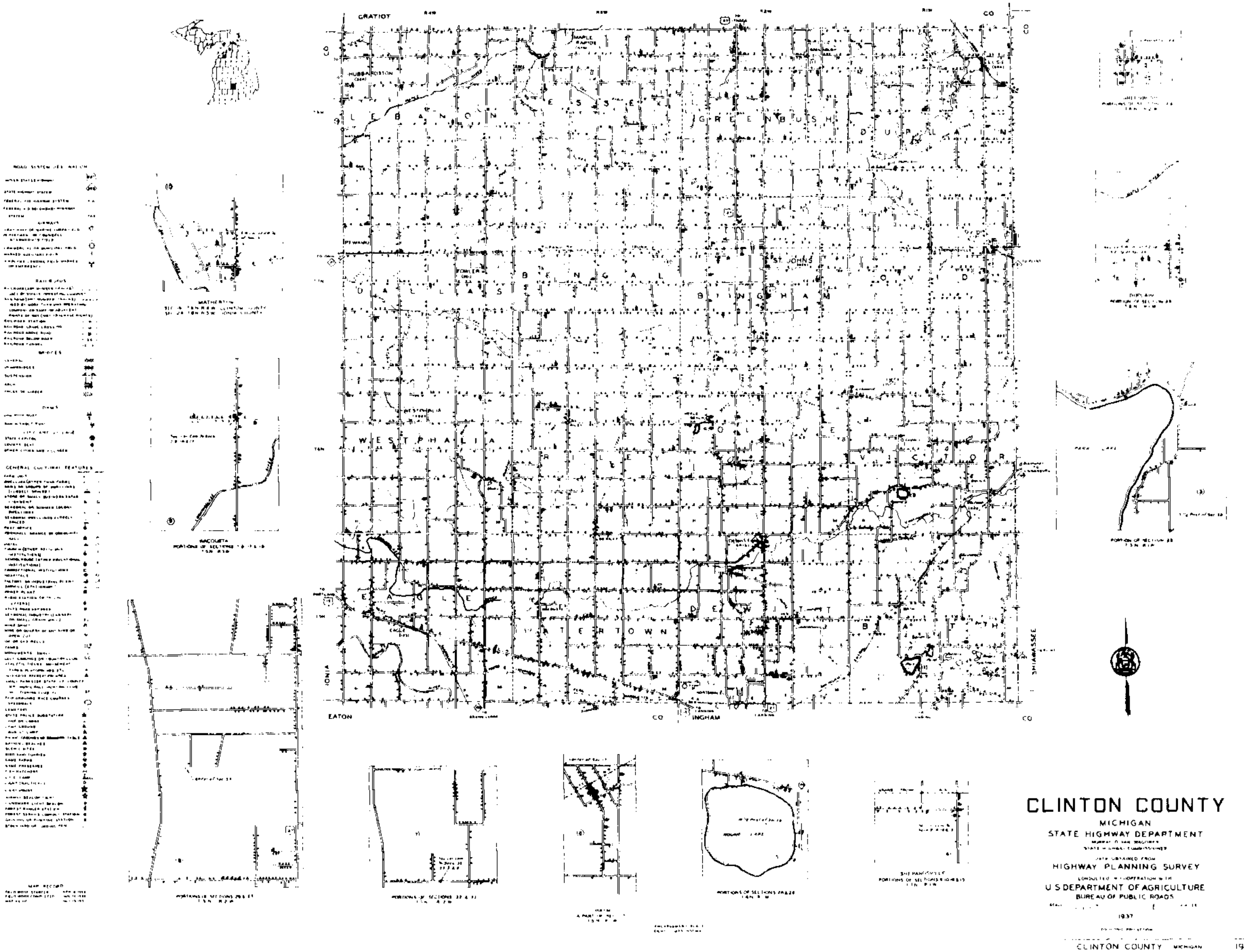
It is regarded, therefore, as a rather fortunate circumstance that much that is exceedingly useful in the results of the highway planning surveys will not have to attain that usefulness through the medium of a report. So much, at least, we may hope will escape the oblivion that seems to engulf whatever enters between the covers of an official report.

Among the extremely useful results of the surveys, that will thus attain their usefulness without aid of a report, are the several kinds of maps that are now fast issuing from them. In the States in which the surveys are in progress there are 2,617 counties. On January 31st, the reports from these States show that the base maps, which result from the surveys' inventories, had been completed for 1,027 of those counties, and hundreds more were on the drafting boards in various stages of completion.

On these base maps is shown every mile of rural public road, and, so far as the inventory parties could discover them, every farmhouse and other residence, every church, and school, and store, and mill, and mine, and every other place of whatever description, in rural area, that is an origin or a destination of the traffic that moves over the roads. On them is shown, also, every mile of railroad, every navigable and actually navigated stream, every railroad station, every airport, every public wharf, every city and town and village, however large or small. Figure 1 shows one of these maps of a county in Michigan.

Remember that, of the great majority of these counties, there existed before the planning surveys were begun no adequate maps whatever. Remember that, before the surveys, there was in many of them no proper idea even of the extent of the public road system. Then envision the vast atlas soon to be filled with thousands of these new and accurate maps of every county of every State in which the planning surveys have been conducted, all drawn with uniform conventions and appropriately uniform large scale, and you will have a fair conception of one result of the planning surveys that it will not be necessary - that it will not be possible to present for use through the medium of a report.

From the base maps, upon which, as will be observed, all roads appear as open bands, several other series of maps will be produced by the simple process of overlaying various other conventions, mostly within the open road bands of the base. Each of these series will be designed to display a particular class of information. Perhaps the most generally useful series will be the Highway and Transportation Maps. The principal purpose of this series will be to show the existing surface condition of all the roads. To this end the open bands



GRATIOT
CO
HUBBARDSTON
MAPLE RAPIDS
LEBANON
ESSEX
GREENBUSH
DUPLAIN
ST JOHNS
FOWLER
DALLAS
BENGAL
BINGHAM
OVID
WESTPHALIA
RILEY
OLIVE
VICTOR
EAGLE
WATERTOWN
DEWITT
BATH
IONIA
EATON
INGHAM
SHIAWASSEE
MATHERTON
WACOUSTA
DUPLAIN
SHEPARDSVILLE
PARK LAKE
CLINTON COUNTY
MICHIGAN
STATE HIGHWAY DEPARTMENT
HIGHWAY PLANNING SURVEY
U S DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS
1937
CLINTON COUNTY MICHIGAN
19

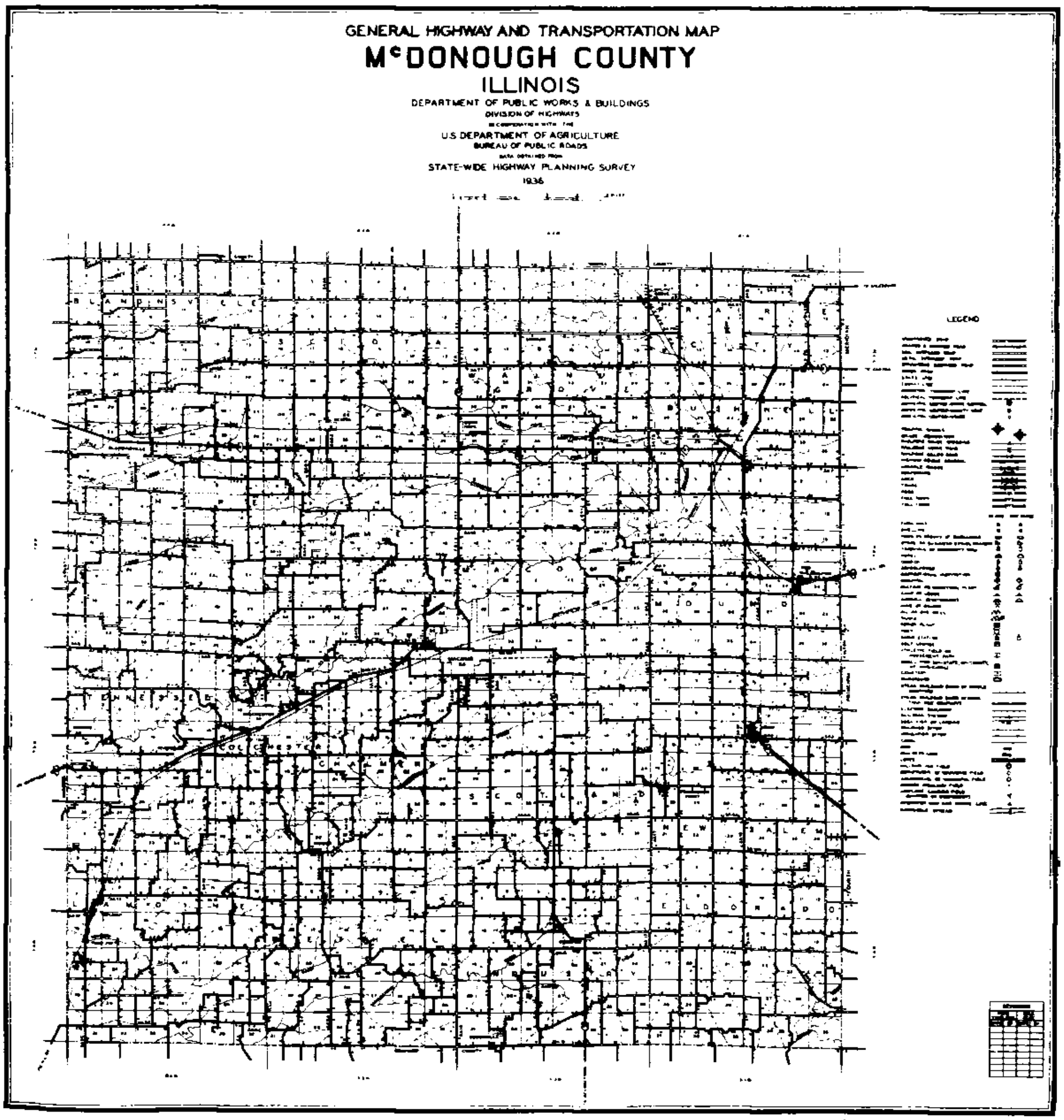
FIGURE 1

of the base maps will be filled, in the maps of this series, with standard symbols appropriately representing on each section of road the type of its surface. Figure 2 shows a typical map of this series, representing an Illinois County.

Another series, made from the same bases, will distinguish and show the state of improvement of the roads that form the rural free delivery mail routes, and other series will show respectively the roads that are used as routes by common carrier busses and trucks and by school busses, and the condition of these several kinds of routes. And, finally, a special series will show by symbols overlaid upon the surface type symbols the relative volume of traffic served by every mile of the rural roads. Figure 3 represents a preliminary sample map of this series.

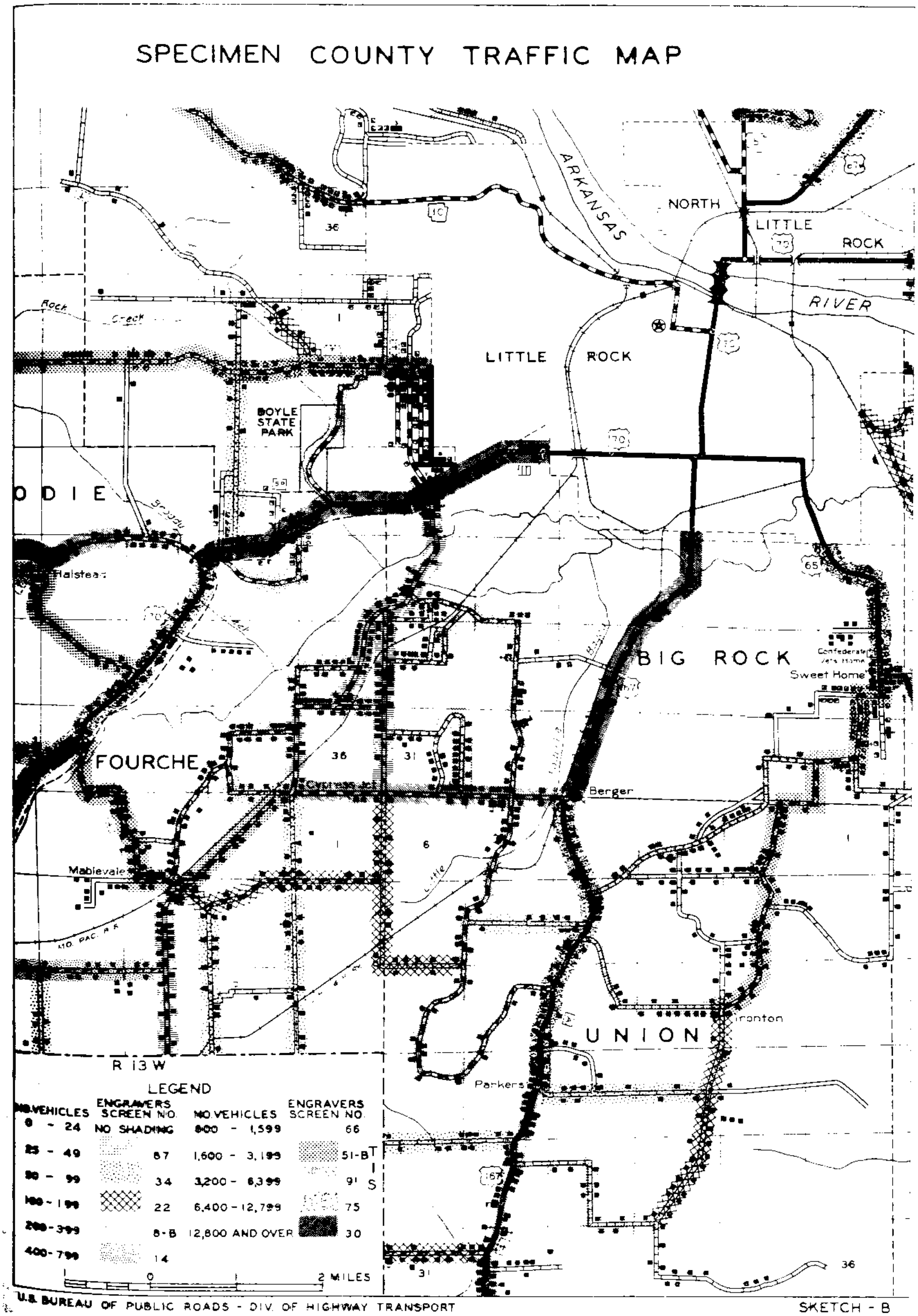
This is a new kind of traffic map, differing from the more familiar kind in the fact that the traffic volume is represented by the overlaid shaded bands of uniform width but varying pattern, instead of by bands of varying width proportional to the varying volume. The difference is an essential one. Traffic maps of the customary form have dealt with main highways only. These new county maps will represent the traffic on all rural roads; and, even on their large scale there is not room enough in the interstices of the closely woven net to squeeze the wide bands that would be needed to depict the heavier volumes of traffic. It is believed, however, that the new symbolically shaded bands will represent the traffic conditions almost as clearly; and they will have one advantage that has generally been lacking in traffic maps, that is, they will show the traffic volume in relation to the existing types of road surfaces, the state of road-bordering culture, and other significant conditions.

Such maps as all of these, it will not be necessary to explain, will find daily employment in the operations of every highway administrative agency, Federal, State, and local. But apart from their obvious utility in highway work, it is already apparent that they will be widely used for many other purposes. Power companies want them for studies of potential demand. Industrial concerns request them for the charting of sales territories and campaigns. Agricultural specialists will employ them in defining areas of relative soil productivity - a definition basic to the optimum use of the land, which is the agriculturist's objective, but one which is also, and for identical reasons, of interest to the highway planner and builder. Figure 4 is a map of this sort.



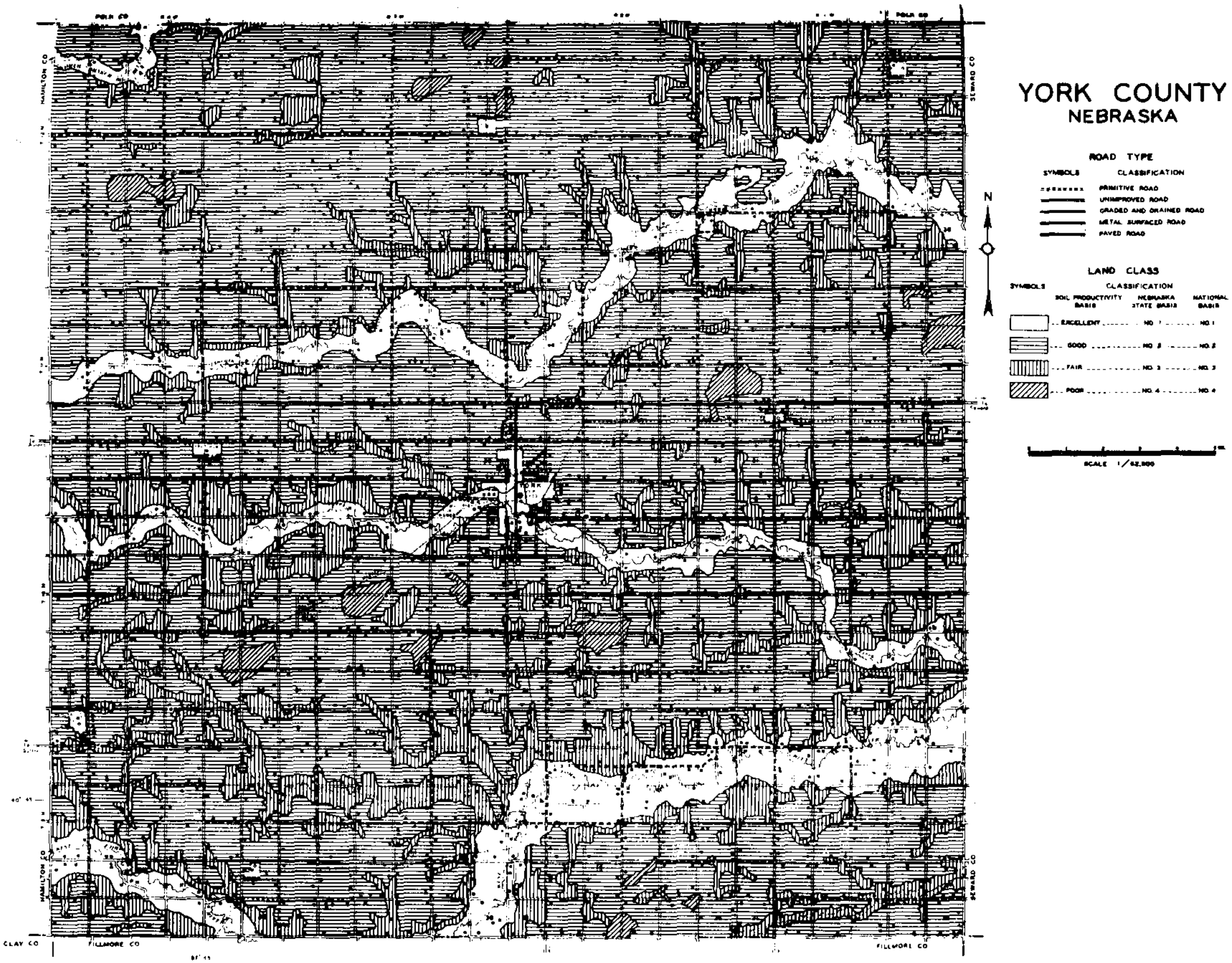
GENERAL HIGHWAY AND TRANSPORTATION MAP
McDONOUGH COUNTY
ILLINOIS
DEPARTMENT OF PUBLIC WORKS & BUILDINGS
DIVISION OF HIGHWAYS
U.S. DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS
STATE-WIDE HIGHWAY PLANNING SURVEY
1936
LEGEND

FIGURE 2



SPECIMEN COUNTY TRAFFIC MAP
ARKANSAS
RIVER
NORTH LITTLE ROCK
LITTLE ROCK
BOYLE STATE PARK
Rock Creek
DIE
Halstead
FOURCHE
BIG ROCK
Confederate Vets Home
Sweet Home
Berger
Mabelvale
MO. PAC. R.R.
UNION
Ironton
Parkers
R 13 W
T 1 S
LEGEND
NO. VEHICLES
ENGRAVERS SCREEN NO.
0 - 24 NO SHADING
25 - 49 87
50 - 99 34
100 - 199 22
200 - 399 8-B
400 - 799 14
800 - 1,599 66
1,600 - 3,199 51-B
3,200 - 6,399 91
6,400 - 12,799 75
12,800 AND OVER 30
0 2 MILES
U.S. BUREAU OF PUBLIC ROADS - DIV. OF HIGHWAY TRANSPORT
SKETCH - B

FIGURE 3


YORK COUNTY
NEBRASKA
ROAD TYPE
SYMBOLS
CLASSIFICATION
PRIMITIVE ROAD
UNIMPROVED ROAD
GRADED AND DRAINED ROAD
METAL SURFACED ROAD
PAVED ROAD
LAND CLASS
SYMBOLS
CLASSIFICATION
SOIL PRODUCTIVITY BASIS
NEBRASKA STATE BASIS
NATIONAL BASIS
EXCELLENT ... NO. 1 ... NO. 1
GOOD ... NO. 2 ... NO. 2
FAIR ... NO. 3 ... NO. 3
POOR ... NO. 4 ... NO. 4
SCALE 1/62,500
N
POLK CO
HAMILTON CO
SEWARD CO
CLAY CO
FILLMORE CO

Without attempting to catalogue all the definite uses of these maps that are now foreseen, mention may be made of one other very important use that will be made of them. Wherever they have been completed in time for use by the enumerators, they will be used as the basis of the Federal Census of 1940, which Census authorities say, will be more complete and more accurate because of their use.

So many, indeed, are the uses that are being found for these remarkable maps that it begins to appear that the highway departments, in producing them, have rendered a service to all sorts of industrial, economic, and social planning comparable to that of the United States Geological Survey, through its topographic maps, to the planning of engineering works. And all these manifold uses, let it be repeated, are additional to the constant employment these maps will have in the everyday work of the Federal, State and County highway departments.

It is in such everyday employment, also, that invaluable use will be found for the so-called straight-line diagrams - another result of the surveys that will have no more than a reference in the printed reports. Figure 5 shows a little more than half of one such diagram as it is being produced by the highway planning survey of Colorado.

On such diagrams as this, most of the States are recording practically all of the significant findings of the survey with reference to each section of the more important highways. On each diagram, the section of road of immediate interest appears as a straight line, divided into 100-foot station intervals. Appropriately placed with reference to these intervals, is shown virtually every fact that has been found about that particular section of highway. The type, and condition, and the dimensions of its surface; the position of all important drainage structures, the location of all significant curvature and grades (significant in their effects upon the movement of vehicles); the places at which sight distance is unduly restricted and the causes of the restrictions; the location of all intersecting roads; the average daily traffic, as determined by the survey; all these facts and others, presently known, are being spread upon these diagrams, where they can be read at a glance. And, henceforth, every significant change that shall occur in each of the road sections will be noted as a correction of the appropriate diagram. Where frost and water damage the road's structure, where accidents occur or lives are snuffed out, where traffic grows or shrinks, where new facilities replace old, such events, such changes, will be recorded on these diagrammatic record pages, and each such record, adding new significance to the prior recordings, will contribute steadily to the sharpening and the accuracy of administrative judgments, in the formation of which these diagrams will surely be regularly consulted.

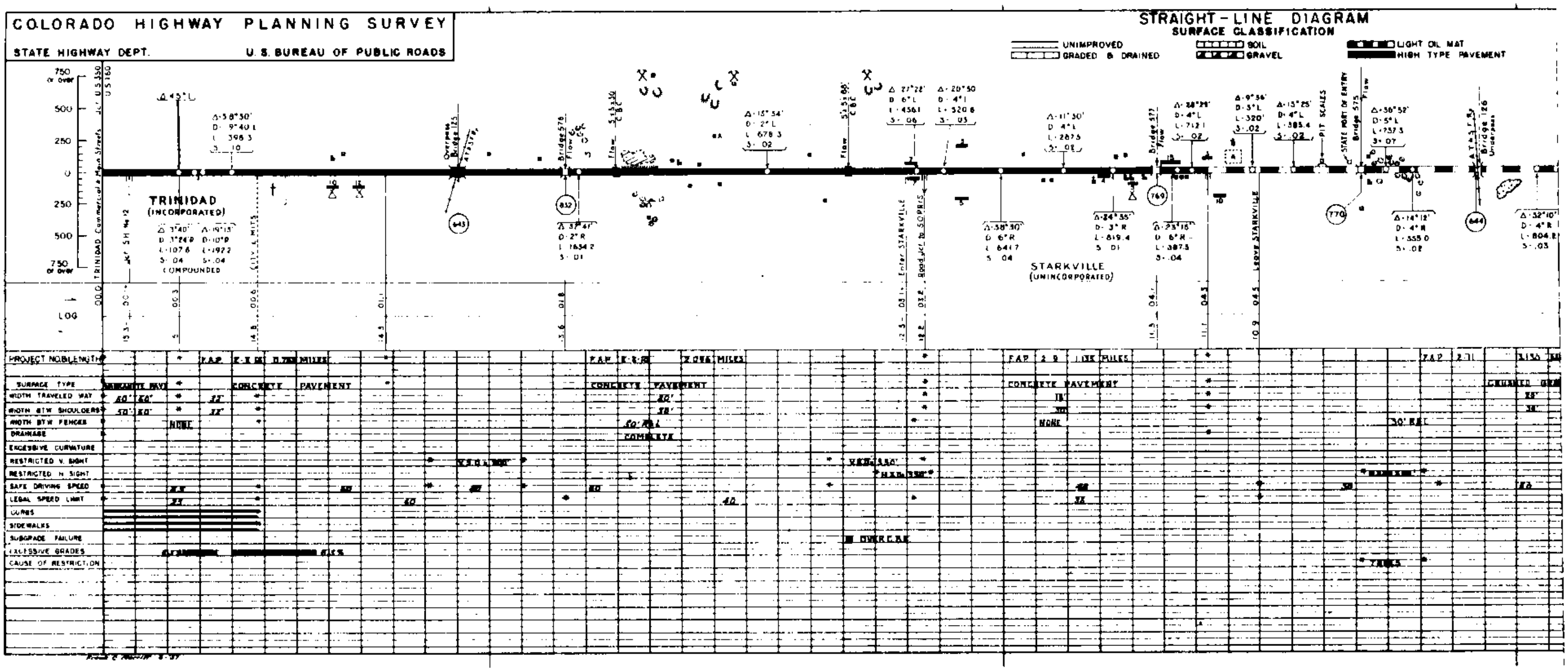

COLORADO HIGHWAY PLANNING SURVEY
STATE HIGHWAY DEPT.
U.S. BUREAU OF PUBLIC ROADS
STRAIGHT-LINE DIAGRAM
SURFACE CLASSIFICATION
UNIMPROVED
GRADED & DRAINED
SOIL
GRAVEL
LIGHT OIL MAT
HIGH TYPE PAVEMENT
TRINIDAD
(INCORPORATED)
STARKVILLE
(UNINCORPORATED)
LOG
PROJECT NO. & LENGTH
SURFACE TYPE
WIDTH TRAVELED WAY
WIDTH BTW SHOULDERS
WIDTH BTW FENCES
DRAINAGE
EXCESSIVE CURVATURE
RESTRICTED V. SIGHT
RESTRICTED H. SIGHT
SAFE DRIVING SPEED
LEGAL SPEED LIMIT
CURBS
SIDEWALKS
SUBGRADE FAILURE
EXCESSIVE GRADES
CAUSE OF RESTRICTION
CONCRETE PAVEMENT
NONE

FIGURE 5

Enlarging upon the reference here to future amendment of the straight-line diagrams, it should be said, with particular reference to all those results of the surveys that are embodied in the maps and other graphic records, that all of them pertain to conditions of the present, and many of them to conditions that will change with the passage of time. It is for the timely discovery and recording of such changes that the Bureau of Public Roads has urged the establishment of a continuing fact-finding function in each State highway department; and it is gratifying to be able to report that its urging has met with almost unanimously favorable response. It is evident that most of the highway departments realize that comparatively slight effort, continuously put forth, will preserve and steadily enhance the present high value of the records that have been made by the surveys - a value that will soon be utterly lost if this small additional labor of maintenance is denied.

Thus far this discussion has dealt with results of the surveys that do not have to be widely published to come into exceedingly valuable use. Such results yield their principal benefits only as they are employed in the everyday operations of the highway administrative agencies, and they remain useful only as they are continually modified in accordance with the changes that continuously occur.

There is another class of results that should be widely publicized, and it is results of this sort that will have an important place in the reports that will be published. Among such results are all those discovered facts that define the general character of highway traffic, that point accurately to the nature and location of its sources, that describe its composition, and indicate the general lines and the extent of its movement. Most of such facts - unlike those we have previously discussed - are relatively immutable. They change slowly, if they change at all.

No sound policy of highway administration can be inconsistent with these facts; and most of the ill-advised proposals that are, here and there, and from time to time, put forward, owe their unwisdom to ignorance or misunderstanding on the part of the proponents of this second group of facts. Only through a widespread acceptance and appreciation of them will it be possible to obtain public confirmation of the measures and programs that will be shown by the whole result of the planning surveys to be essential for a proper further development of the highways and of highway transportation.

Following is the substance of some of these facts as revealed, for the most part, by planning survey findings, supplemented at a few points by evidence collected by the Bureau of Public Roads in previous investigations.

Because the familiar U. S. numbers of our principal highways lead on unchanged by intervening State lines to transcontinental termini, and because each of us has himself at times followed those beckoning numbers to far places, it is easy to think of all the busy movement on our highways as a far ranging movement.

From the planning surveys we have obtained for the first time some facts about the amount of the more distant movements for which these proposed highways would be built; and Figure 6 tells the true story.

At the curved line that extends longitudinally through the States of Idaho, Nevada, and Arizona, the width of the trunk of the tentacled band represents the average daily number of all passenger cars passing eastward and westward on trips extending beyond the borders of the three States, on all major east-west highways. The number is 2,532. Two thousand, five hundred, thirty-two passenger cars daily on all major east-west highways, from the Canadian line to the Mexican border, pass points in Idaho, Nevada, and Arizona bound on trips that begin and end beyond the borders of the three States.

Now observe where the tentacles go. That shows the places to and from which these 2,532 average passenger cars are bound; and the width of each tentacle represents the number headed toward or coming from each State. Of course, they are all going to or from Washington, Oregon or California. Westward there are no other States. But, see how rapidly that wide band dissevers and attenuates as it extends eastward. At the Mississippi River it has shrunk to a third of its original width. At the eastern seaboard it is a few thin threads. Notice, especially, that 20 cars are shown as moving daily between Florida and the Pacific Coast States. Then turn to Figure 7, which shows the average daily number of all passenger cars bearing license tags of States other than Florida, observed to cross the Florida line, by actual counts made on all the entering highways, and it will be seen that the combined width of the three threads extending into the Pacific Coast States represents 23 vehicles. Counted nearly three thousand miles away, the number of the Florida-West Coast interchange was 20. It is such agreements as this that give confidence in the appropriate accuracy of the survey results. However, in this case the agreement was not quite so close as the figures on the two graphs indicate, because the eastern count omits the number of cars of Florida registration that daily start for or return from the Coast.

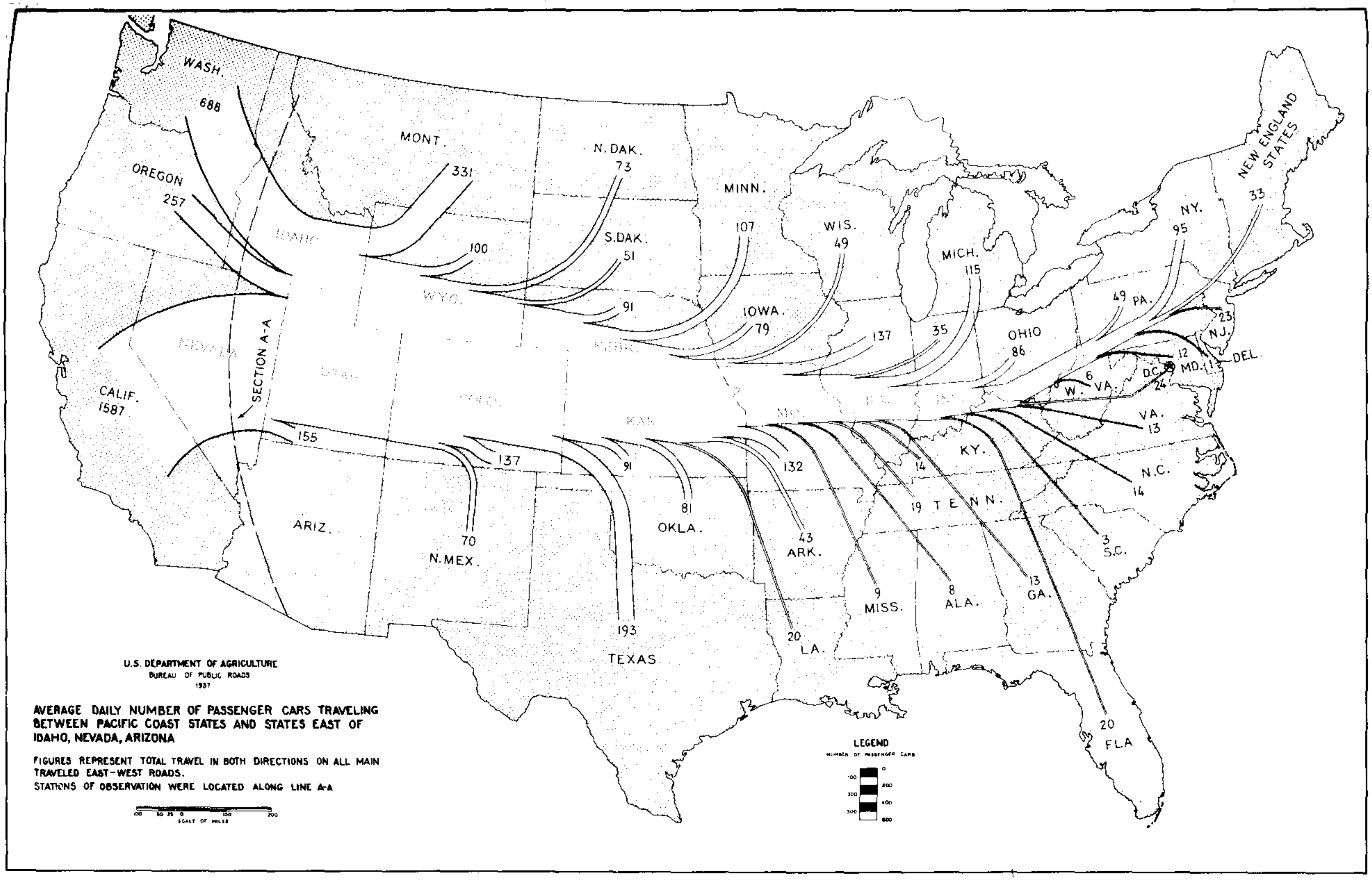
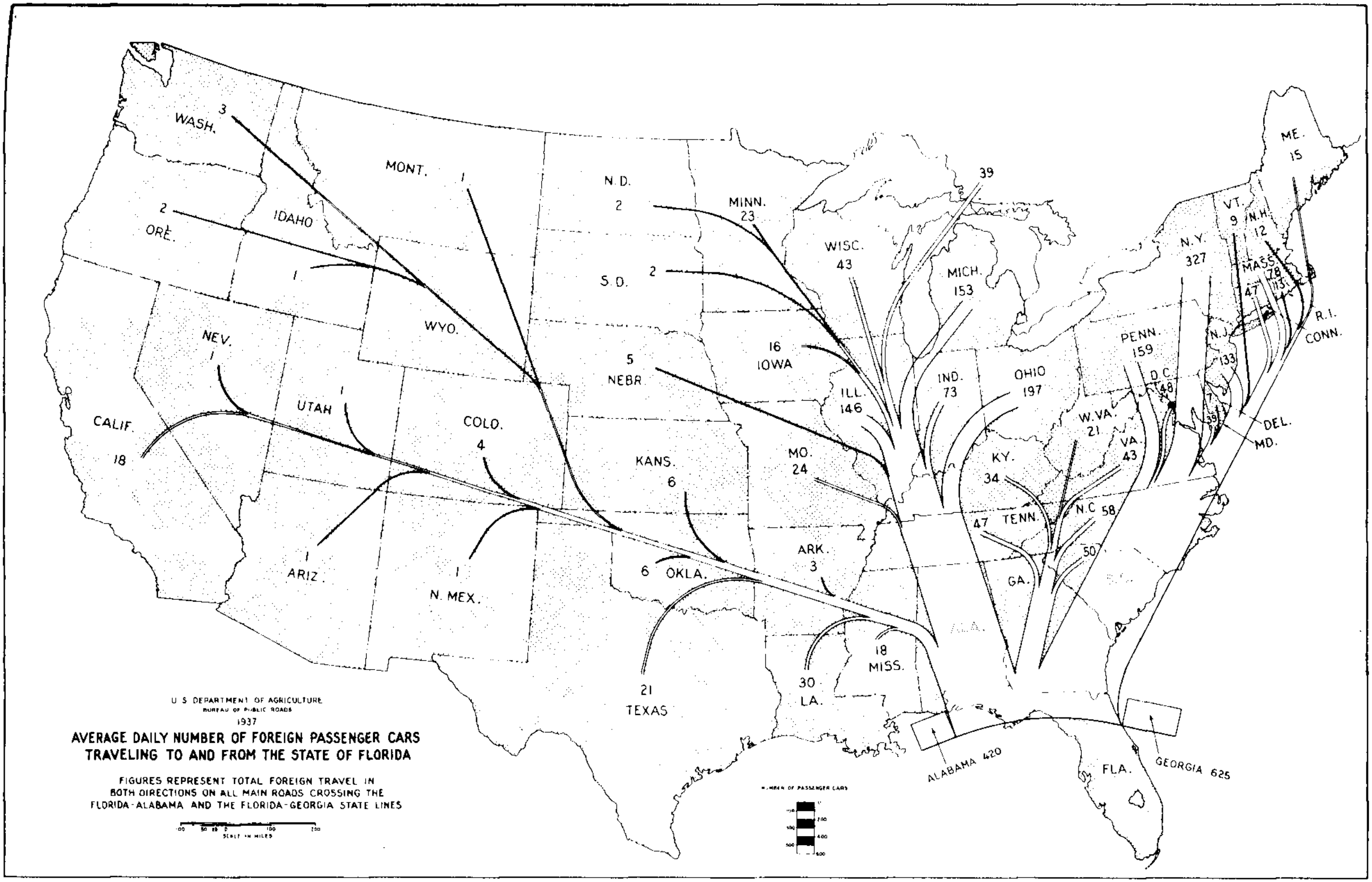

U.S. DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS
1937
AVERAGE DAILY NUMBER OF PASSENGER CARS TRAVELING BETWEEN PACIFIC COAST STATES AND STATES EAST OF IDAHO, NEVADA, ARIZONA
FIGURES REPRESENT TOTAL TRAVEL IN BOTH DIRECTIONS ON ALL MAIN TRAVELED EAST-WEST ROADS.
STATIONS OF OBSERVATION WERE LOCATED ALONG LINE A-A
SCALE OF MILES
LEGEND
NUMBER OF PASSENGER CARS
WASH. 688
OREGON 257
CALIF. 1587
SECTION A-A
MONT. 331
100
N. DAK. 73
S. DAK. 51
91
MINN. 107
WIS. 49
IOWA 79
137
MICH. 115
35
OHIO 86
49 PA.
NY. 95
NEW ENGLAND STATES 33
23 NJ.
12 DEL.
MD. 11
D.C. 24
6 W. VA.
VA. 13
N.C. 14
KY.
14
19 TENN.
3 S.C.
13 GA.
20 FLA
8 ALA.
9 MISS.
43 ARK.
20 LA.
132
81 OKLA.
91
193 TEXAS
137
70 N. MEX.
155
ARIZ.

FIGURE 6



U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS
1937
AVERAGE DAILY NUMBER OF FOREIGN PASSENGER CARS
TRAVELING TO AND FROM THE STATE OF FLORIDA
FIGURES REPRESENT TOTAL FOREIGN TRAVEL IN
BOTH DIRECTIONS ON ALL MAIN ROADS CROSSING THE
FLORIDA-ALABAMA AND THE FLORIDA-GEORGIA STATE LINES
SCALE IN MILES
NUMBER OF PASSENGER CARS
WASH. 3
ORE. 2
IDAHO 1
MONT. 1
WYO.
N.D. 2
S.D. 2
MINN. 23
WISC. 43
MICH. 153
39
NEBR. 5
IOWA 16
ILL. 146
IND. 73
OHIO 197
NEV. 1
UTAH 1
COLO. 4
CALIF. 18
KANS. 6
MO. 24
KY. 34
W. VA. 21
VA. 43
PENN. 159
D.C. 48
N.Y. 327
VT. 9
N.H. 12
ME. 15
MASS. 78
113
47
R.I.
CONN.
N.J. 133
7
39
DEL.
MD.
N.C. 58
50
TENN. 47
GA.
ARK. 3
OKLA. 6
ARIZ. 1
N. MEX. 1
TEXAS 21
LA. 30
MISS. 18
ALA.
FLA.
ALABAMA 420
GEORGIA 625

FIGURE 7

Of such travelers another part of these closely articulated planning surveys - the Florida road-use studies - discovers exactly three; so that the real total as estimated at the eastern end was 26, actually 6 more than the western count, instead of three.

But if, as these graphs appear to show, the actual amount of our transcontinental traffic is insignificant, and the amount of even the half-way movement is small, what do the surveys show to be the actual range of the preponderant highway movement? For the answer to that question, see Figure 8 which combines the road-use findings of 11 States to show the range of frequency of the length of all one-way passenger car trips which extend beyond the limits of cities and towns in those States.

The shaded portions of the bands cover the ranges between the maximum and minimum percentages of the total traffic that compose the various trip-length groups. The graph shows that in one of these 11 States 43.8 percent of all one-way highway trips extending outside of cities were trips of less than 5 miles. In another State the percentage of this shortest class of trips was only 25.7. In all the other States the percentage was somewhere between those limits. Similarly, the limits of the 5-to-10 mile percentages are 30.9 percent maximum, and 23.0 minimum. It is evident that 30 miles is long enough to span the range of the great majority of all trips extending beyond city limits in these States. The percentage of trips over 50 miles in length is extremely small, over 100 miles a bare one or two percent. Remember that these are one-way trips extending beyond city limits. If all the intra-city trips were included these average ranges would be greatly shortened.

Learning from this graph that most highway movements are very short movements indeed - now turn to Figure 9, which gives some further very significant information about the classes of roads on which these movements occur. The facts here represented are averages from road-use studies in 17 States; and altogether they are very representative States.

The graph shows that 58.9 percent of the total annual motor vehicle travel on all roads and streets in these 17 States occurs on the main rural highways and the streets that connect them across cities. Of the balance of the total movement, the greater part - 30.8 percent of the total - occurs on the large mileage of other city streets, the neighborhood streets; and scarcely more than 10 percent of the total occurs on all the secondary and local rural roads, which, in mileage, have eight times the extent of the group of main highways.

RANGE OF FREQUENCY DISTRIBUTION OF THE LENGTH OF ALL **ONE-WAY TRIPS** OF **PASSENGER CARS** WHICH EXTEND **OUTSIDE OF CITIES** IN ELEVEN STATES

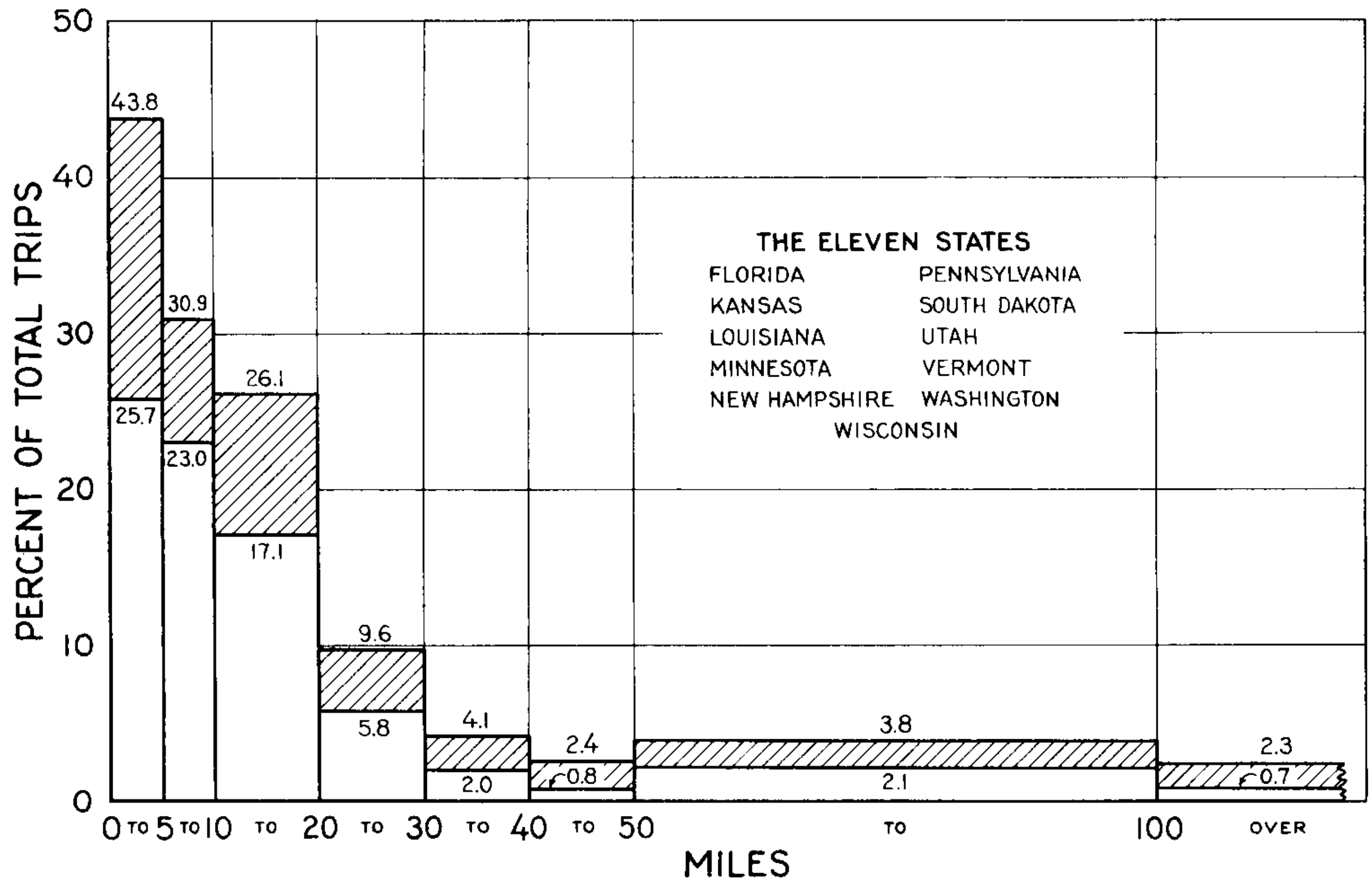
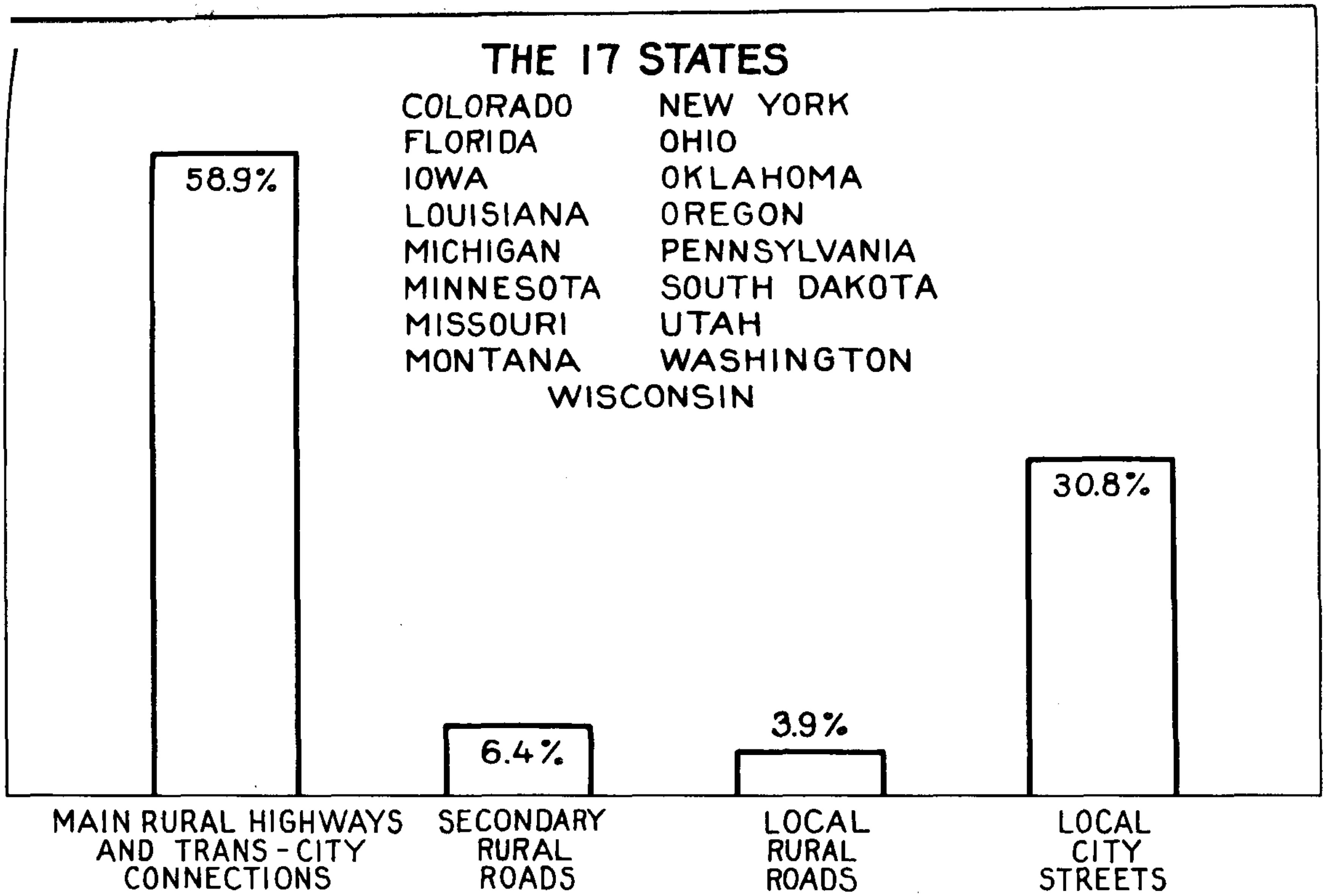


FIGURE 8



DISTRIBUTION OF TOTAL ANNUAL MOTOR VEHICLE TRAVEL IN 17 STATES ACCORDING TO THE CLASSES OF HIGHWAYS BY WHICH IT IS SERVED

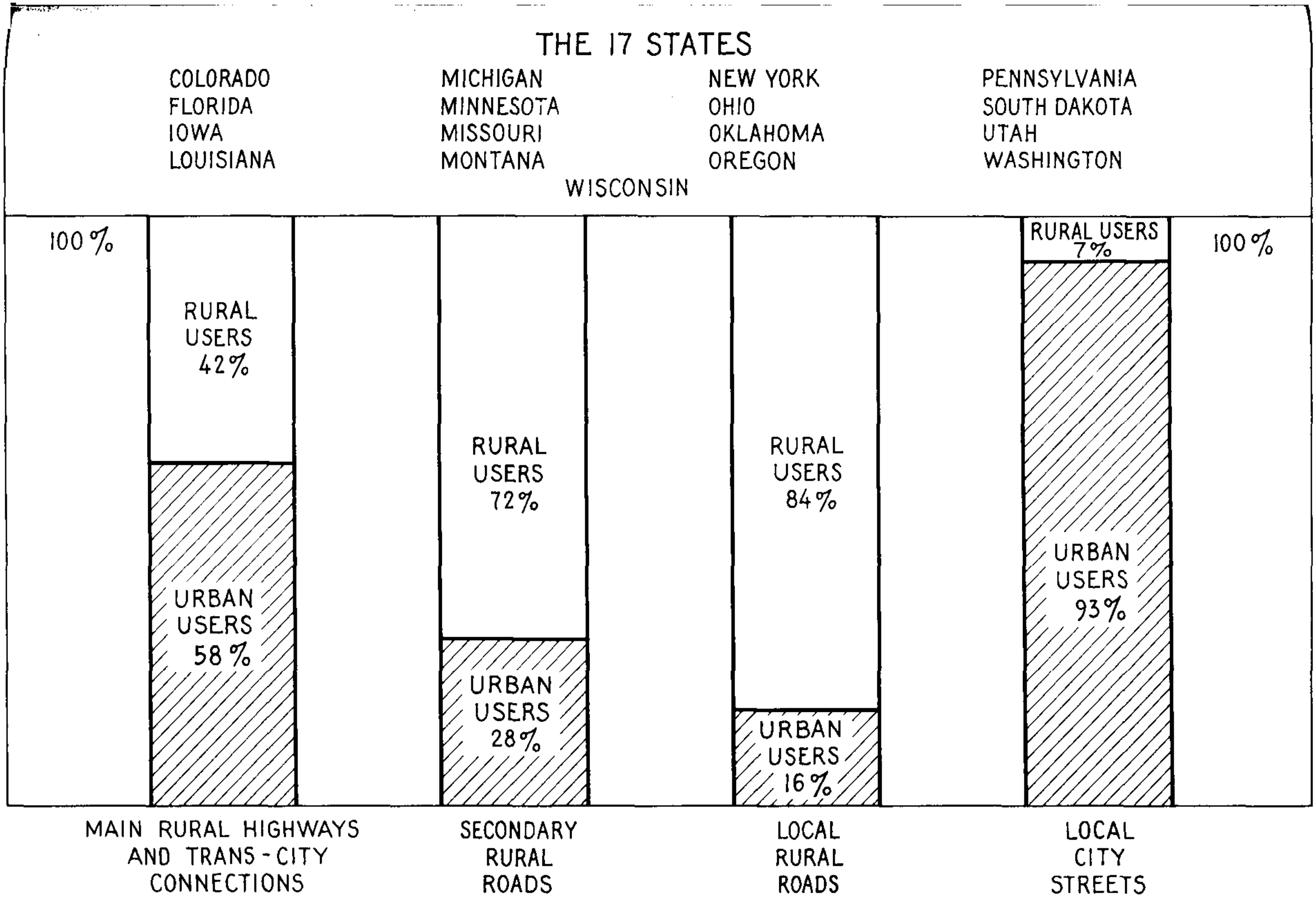
FIGURE 9

We know now, therefore, that the great number of mainly minute movements that make up the sum total of street and highway traffic, in these 17 States at least, occur in largest part on the main rural highways and their transcity connections, that a lesser part occurs on the other city streets, and a least part on the secondary and local rural roads.

Now, who engages in these movements? Are they city people or country people? Are the road users urban or rural? Well, of course, they are both; but the two classes are found in different proportions on the several classes of roads. The facts are shown by Figure 10, which also represents the average findings in the same 17 States. From this graph it will be seen that the main rural highways and their transcity connections are really everybody's highways. Forty-two percent of their use is by rural motor vehicle owners; 58 percent is by urban owners. In these 17 States the population, at the time of the last census, was 38 percent rural, 62 percent urban. That means that country and city people meet on these main arteries in just about the proportion of their relative numbers in the total population. But a glance at the bar representing the other city streets will show a quite different situation. Ninety-three percent of the total use of these streets is by urban vehicles; only 7 percent is by rural vehicles. And, then turn to the local rural road bar at the other extreme, and it will be seen that 84 percent of what has previously been shown to be the small usage of these minor rural roads, is by rural vehicles and only 16 percent by urban vehicles.

These are not merely some more or less interesting statistics. They are vital figures that point some very definite indications as to what we should try to accomplish in our further road building; as to the relative transportation service that may be afforded by improvement of this or that class of roads; as to who will benefit if we do either, and who, being benefited, should pay the cost, and in what proportion.

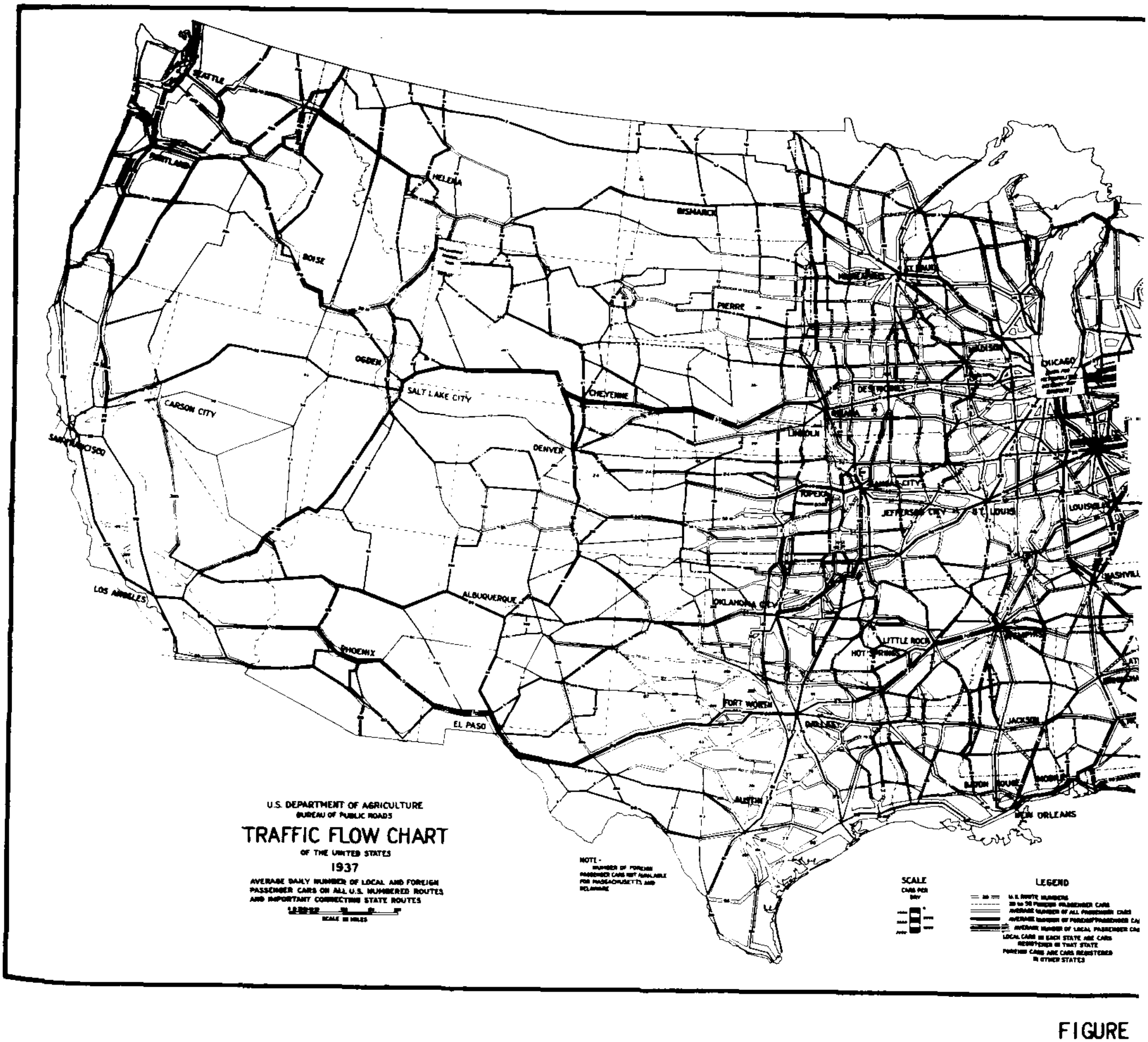
They tell very sharply, for example, that the kind of traffic for which our road system should be designed is a traffic that moves short distances, not long - a traffic that moves in great volume into and out of cities, but dwindles to much smaller proportions as cities are left behind. It is to the relatively short sections of main highways near cities, now dangerously clogged by the local multiplication of short movement, that first attention should be given, as evidenced by the graphs previously presented and by the first traffic map of the United States, presented in Figure 11.



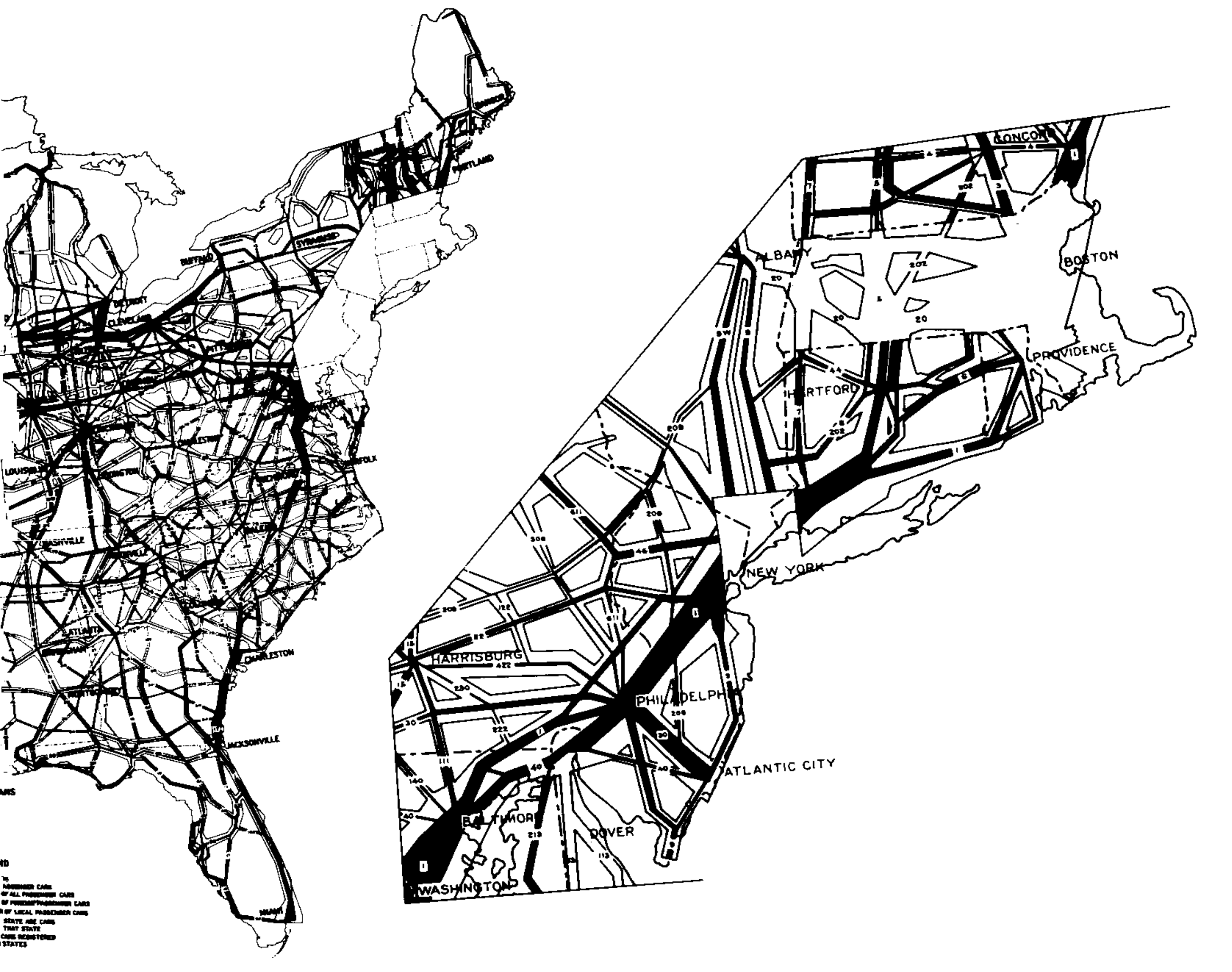
PROPORTIONS OF URBAN AND RURAL USERS OF EACH CLASS OF HIGHWAYS IN 17 STATES

Obviously, for reasons of pure economics, the amount of road user revenue assigned to the main highways or to any other group of highways or streets should not exceed the sum total of vehicular operating savings that is made possible by the improvements provided. But within this limit it is reasonable to assign to any subdivision of the whole highway system, for its improvement, any part of the total available motor vehicle revenue, provided that in doing so a proper return of benefits is assured to each of the two big classes of road users - the urban and the rural users.

How such an apportionment can be made on the basis of the road-use statistics supplied by the planning surveys of each State will be demonstrated by an example using the average statistics of the 17 States previously presented.


U.S. DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS
TRAFFIC FLOW CHART
OF THE UNITED STATES
1937
AVERAGE DAILY NUMBER OF LOCAL AND FOREIGN PASSENGER CARS ON ALL U.S. NUMBERED ROUTES AND IMPORTANT CONNECTING STATE ROUTES
SCALE IN MILES
SEATTLE
PORTLAND
HELENA
BISMARCK
BOISE
PIERRE
OGDEN
SALT LAKE CITY
CHEYENNE
CARSON CITY
SAN FRANCISCO
DENVER
LINCOLN
DES MOINES
MINNEAPOLIS
ST. PAUL
MADISON
CHICAGO
TOPEKA
KANSAS CITY
JEFFERSON CITY
ST. LOUIS
LOUISVILLE
NASHVILLE
LOS ANGELES
ALBUQUERQUE
OKLAHOMA CITY
LITTLE ROCK
HOT SPRINGS
PHOENIX
FORT WORTH
DALLAS
JACKSON
EL PASO
BATON ROUGE
MOBILE
AUSTIN
NEW ORLEANS
NOTE -
SCALE
LEGEND

FIGURE



BOSTON
PROVIDENCE
HARTFORD
NEW YORK
HARRISBURG
ATLANTIC CITY
DOVER
WASHINGTON
JACKSONVILLE
CHARLESTON

FIGURE 11

A RATIONAL METHOD FOR APPORTIONING ROAD-USER TAXES ASSURING ADEQUATE MAINTENANCE AND NEEDED DEVELOPMENT OF STATE-ADMINISTERED HIGHWAYS AND BENEFITS TO URBAN AND RURAL TAXPAYERS IN STRICT PROPORTION TO THE TAX PAYMENTS OF EACH GROUP

Assume that there is a total of \$20,000,000 of Road-User Taxes to be distributed.

Assume further that the Actual Usage of Roads and Streets corresponds to the average usage as found in 17 States:

That is -

Main Highways and Trans-City Arteries	(58.9)	
Local City Streets	serve (30.8)	Percent of the
Secondary and Local Roads	(10.3)	Total Traffic

And -

Use of each System by Urban and Rural Vehicles is divided as follows:

	Percentage of Use by -	
	Urban Vehicles	Rural Vehicles
Main Highways and Trans-City Arteries	58.0	42.0
Local City Streets	93.0	7.0
Secondary and Local Roads	23.5	76.5

Under these conditions, the Travel of Urban Vehicles (and consequently) The Tax Payments of Urban Vehicle Owners

= .58 x 58.9 + .93 x 30.8 + .235 x 10.3

= 65.227 percent of the Total Tax payments

This being true, expenditure of the \$20,000,000 of Road-User Revenue should yield - Benefits to Urban Vehicle Owners = 20,000,000 x .65227

= \$13,045,400

And -

Benefits to Rural Vehicle Owners = 20,000,000 - 13,045,400

= \$6,954,600

Now, since the Main Highways and Trans-City Arteries constitute the most vital and heavily used portion of the whole Street and Highway System and since it is argued that they should be supported by Road-User Taxes solely,

The Amount to be allotted to these most important highways should be equal to the determined needs for their adequate maintenance and desirable development.

Assume that in this way it has been determined that -

The Need of the Main Highways and Trans-City Arteries = \$15,000,000

From an expenditure of \$15,000,000 on the Main Highways and Trans-City Arteries Urban and Rural Vehicle Owners would benefit, in proportion to their relative use of these highways, as follows:

Urban Vehicle Owners .... 15,000,000 x .58 = \$8,700,000

Rural Vehicle Owners .... 15,000,000 x .42 = \$6,300,000

This would leave Balances of Benefits due Urban and Rural Vehicle Owners as follows:

Urban Vehicle Owners .... 13,045,400 - 8,700,000 = \$4,345,400

Rural Vehicle Owners .... 6,954,600 - 6,300,000 = \$ 654,600

These Balances of Benefits due Urban and Rural Vehicle Owners will be supplied by an apportionment of the $5,000,000 available remainder of Road-User Taxes between Local City Streets and Secondary and Local Roads, computed as follows:

Let x = Amount to be apportioned for Local City Streets
y = Amount to be apportioned for Secondary and Local Roads

Then

$$.93x + .235y = 4{,}345{,}400 \;\ldots\ldots\; (1)$$
$$.07x + .765y = 654{,}600 \;\ldots\ldots\; (2)$$

From Equation (2)

$$x = \frac{654{,}600 - .765y}{.07}$$

Substituting in Equation (1)

$$\frac{.93(654{,}600 - .765y)}{.07} + .235y = 4{,}345{,}400$$

From which

y = $438,273 = Apportionment for Secondary and Rural Roads

And

x = 5,000,000 - 438,273 = $4,561,727 = Apportionment for Local City Streets

TEST

The above apportionment, if correct, should yield Total Benefits to
Urban Vehicle Owners = $13,045,400
Rural Vehicle Owners = $ 6,954,600

It actually yields

Benefits to Urban Vehicle Owners
= .58 x 15,000,000 + .93 x 4,561,727 + .235 x 438,273
= $13,045,400 (Check)

Benefits to Rural Vehicle Owners
= .42 x 15,000,000 + .07 x 4,561,727 + .765 x 438,273
= $6,954,600 (Check)

But, although the road-use statistics of the surveys which, mainly, have been employed thus far, may be used, as has been shown, to effect equitable distributions of road-user taxes, they do not tell how large such taxes may properly be, in what amounts they are needed, or how they should be levied upon the various classes of vehicles; nor do they tell anything, specifically, of the kind of improvements required for the adequate service of traffic on the various parts of the highway system, or the cost of such improvements.

For such advice as this we must look to other results of the planning surveys and to certain supplementary investigations already planned or in progress.

As previously suggested, the upper limit of revenue that can properly be exacted of road-users is the sum total of operating savings that accrue to them as the result of all improvements of the highways. For the estimation of such savings the only data at present available are those developed some years ago by the Iowa Engineering Experiment Station. It is realized that these data are inadequate for present use and arrangements are now in progress for new investigations to be conducted by the same agency in cooperation with the Bureau of Public Roads. These investigations will be expedited in order that their results may be made available as promptly as possible for indication of the maximum limit of motor vehicle taxation. Meanwhile, the available data will supply an approximate guide, if full allowance is made for the fact that the point of diminishing returns probably lies well below the maximum limit.

The needed total amount of road-user taxes will depend upon the annual cost of the road investment to be created and upon the amount of revenue that may be expected to accrue from other sources and forms of taxation. The planning surveys were designed to obtain the data necessary for a determination of the probable ultimate extent of the improved road system. It was their purpose to estimate the annual cost of possessing such a system and to indicate the financial means that would be regularly required to meet this continuing cost.

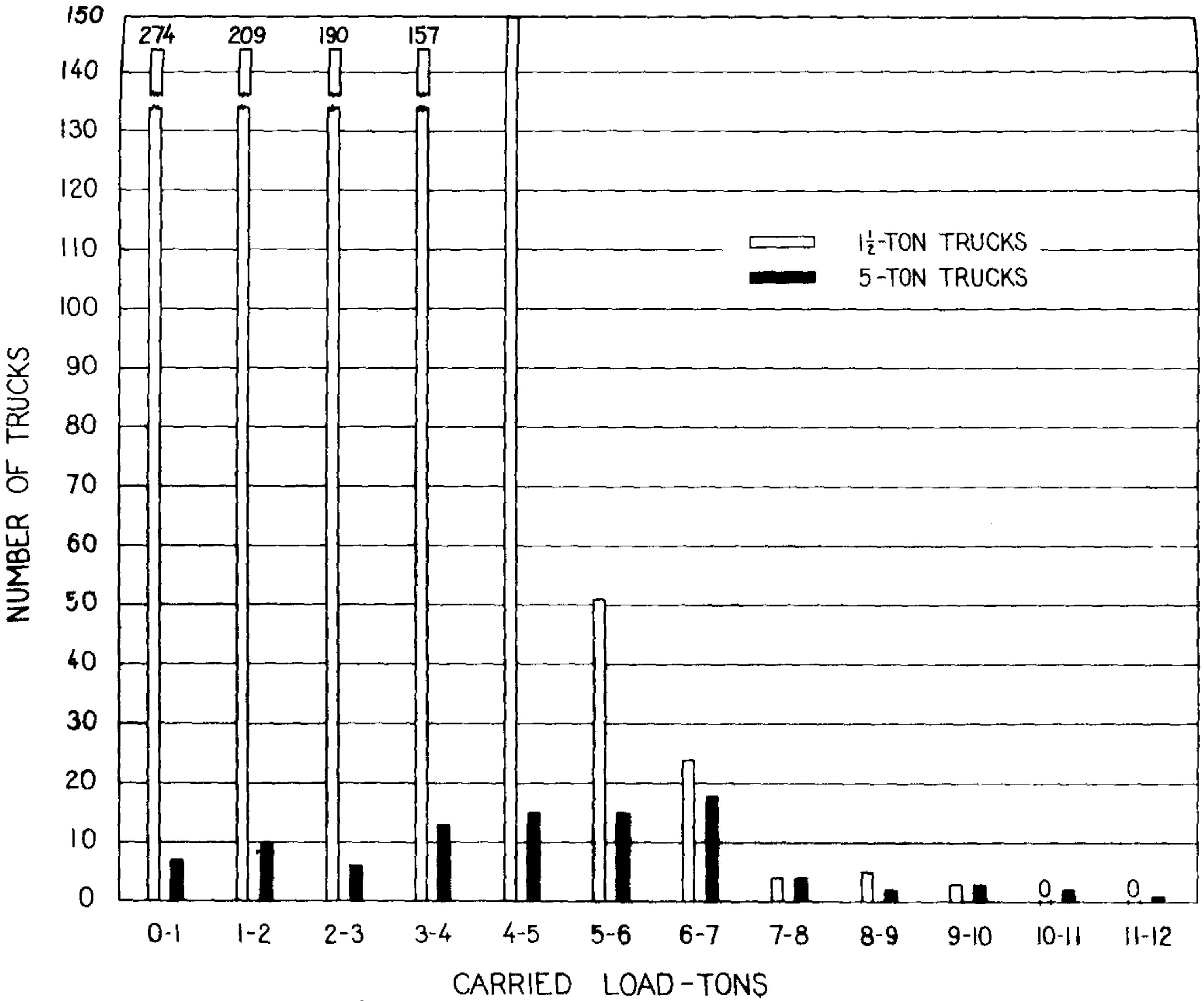
As basis for the reasonable partitionment of costs between motor vehicle and real property taxation the surveys supply a great deal of information indicative of the degrees of road service afforded respectively to general traffic and abutting property.

The determination of road costs will depend upon previous decisions in regard to the general standards of road design necessary for accommodation of the traffic to be served, as defined by the character as well as the number of vehicles; and for such decisions the surveys supply a wealth of information in their various forms of traffic data.

The uses of the traffic volume data are relatively obvious. The purposes of the data that define the character of vehicles are threefold. First, they supply dependable information in regard to the ranges of various vehicle characteristics (including gross loads, wheel loads, tire equipment and over-all dimensions) to be used as the basis for decisions upon regulations to limit such characteristics, which will be consistent with the normal existing practice and such trends as may be revealed. Second, they supply information regarding vehicle characteristics to which the design of the roads must be adapted, both generally and in respect to various classes and sections of the highway system on which the characteristics of the traffic may vary. And third, they indicate the proportionate number of vehicles in use that possess each of several grades of actual characteristics (as distinguished from the often misleading nominal grades), as a basis for the scheduling of tax rates, applicable to such groups, which, when multiplied by the numbers of units involved, will produce from each group a total revenue consistent with the road costs its presence in the traffic entails.

For proper efficiency and economy in the future operation of the system of highway transportation it is obviously necessary that there shall exist such consistent relations between the designed and regulated character of vehicles, the design of the roads and the apportionment of road costs among vehicles, as are here described. That such consistent relations have not existed in the past and do not now exist anywhere, is due in part to an unfortunate discrepancy between the nominal or rated characteristics of vehicles and their actual characteristics, and in part to the lack of the information, much of it now supplied for the first time by the planning surveys that would reveal the want of consistency and indicate the necessary corrective action.

For example, Figure 12 presents some results of the weighing of trucks in Maryland, typical of results obtained generally, which show definitely that the so-called manufacturer's rated capacity of trucks is not indicative of the weight of the loads the trucks will and do actually carry. In this weighing, as will be observed, 3 times as many actual 5-ton loads were found on trucks rated as of 1-1/2 tons capacity as on those rated as of 5 tons capacity.



Trucks of 1½-ton and 5-ton rated capacity classed according to loads carried

FIGURE 12

In Figure 13 a similar lack of appropriate relation is revealed between the maximum over-all widths and the rated capacities of the two classes of vehicles.

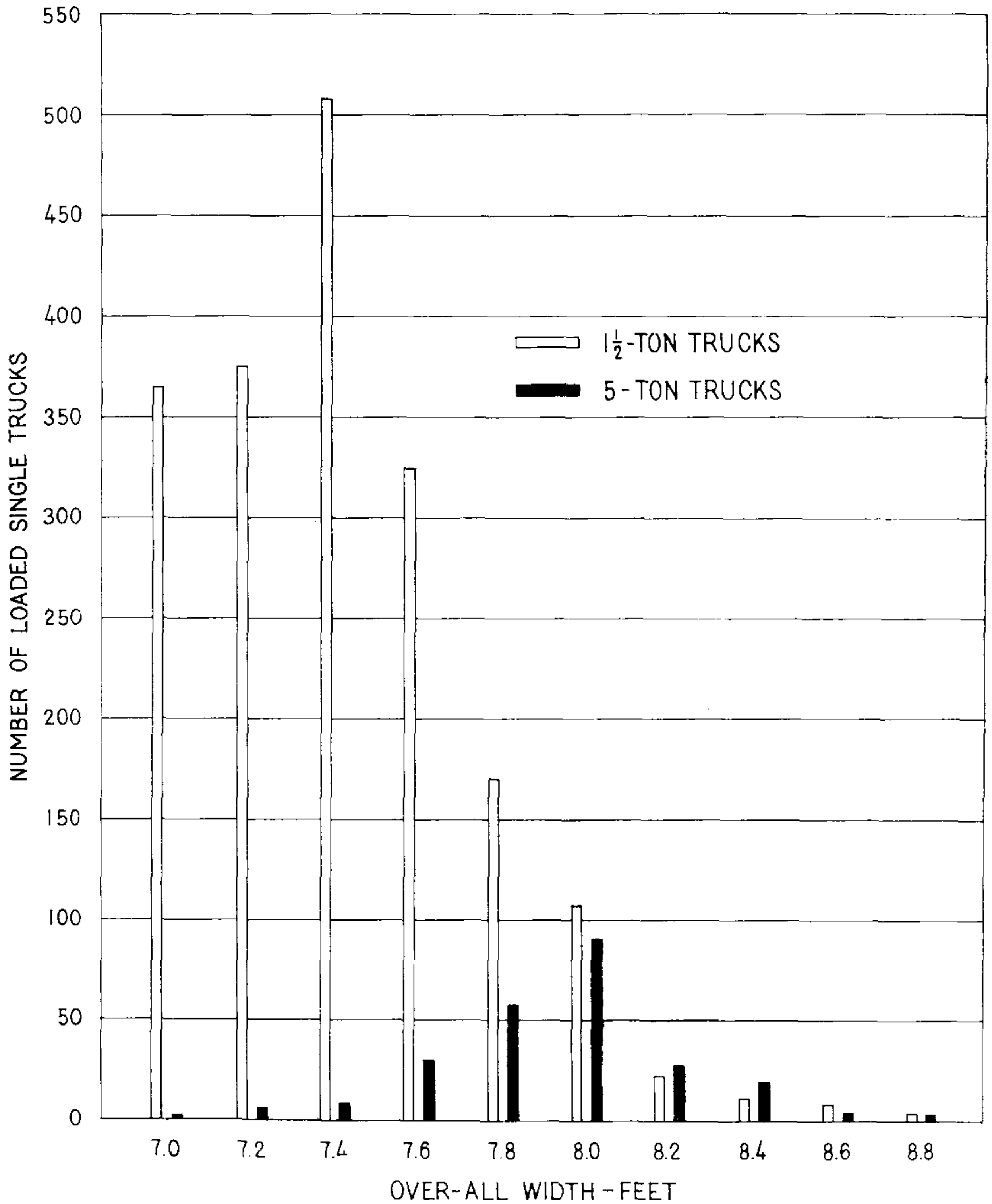
Figure 14 shows how, of more than 4,000 loaded busses tested in one State, nearly one-fourth actually weighed gross, more than the gross weight for which they were licensed and for which their owners had paid a license fee. And it shows, also, how nearly 7 percent of these busses weighed <u>empty</u> more than the loaded gross weight for which they were licensed.

And Figure 15 explains how, in still another State, the existing law permits the extremely illogical result of the heavier loads paying the lighter fees. The law sets a sliding scale of fees which is supposed to exact from the heavier loads a payment that increases in greater ratio than the registered capacity. But, it also provides that a semitrailer shall pay only one-half as much as a truck of the same rated capacity.

The two sides of the diagram relate, one to Private Trucks and Combinations, and the other to For-Hire Trucks and Combinations. It will be necessary to refer only to the left or private truck side to illustrate the point.

Referring, then, to the lower left-hand portion of the diagram it will be seen, by the relative lengths of the light and black bars respectively, that the average loads actually carried on trucks of each rated capacity (as they were weighed on the road) were considerably less than the average loads actually carried by tractor-semitrailer combinations of the same ratings. For example, the average carried load for 4-ton trucks was 3.22 tons; but for 4-ton tractor-trailer combinations it was 6.40 tons, just about twice as much. But, in the matter of payment, the difference was far the other way, as will be seen by comparing the figures inserted within the bars. From these it will be seen, for instance, that for the 4-ton trucks which actually were found, on the average, to carry only 3.22 tons, the license fee exacted was $150; whereas, for the 4-ton combinations, which carried an average of 6.40 tons, the fee required was only $45, equal to the $30 required for a 2-ton tractor and half that sum for a 2-ton semitrailer.

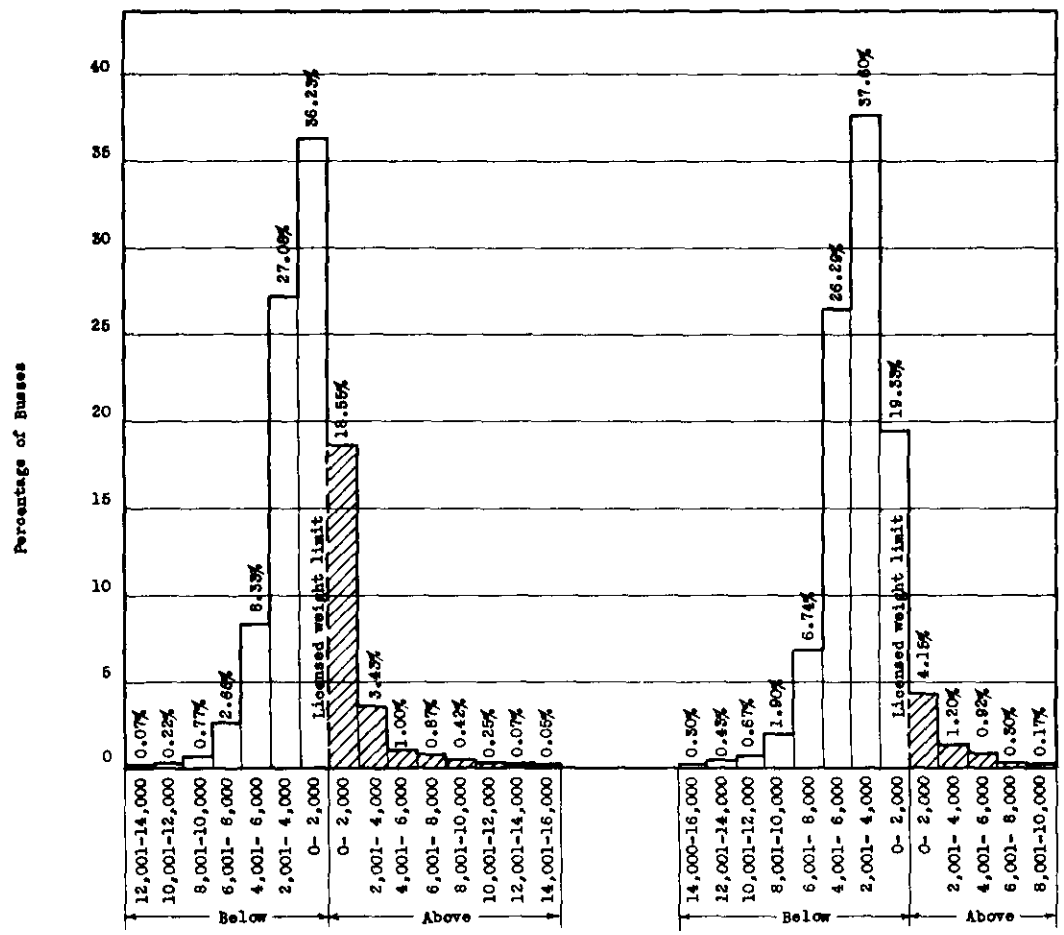
To see the effect of all this on the cost of transportation by the two classes of vehicles, look at the upper left-hand diagrams. There it will be seen that, upon the basis of the legal schedule of fees the 4-ton trucks paid fees of $46.58 per ton of actual carried load and the 4-ton tractor-semitrailer combinations paid $7.03 per



Comparison of numbers of loaded 1½-ton and 5-ton trucks (rated capacity) of various over-all widths

FIGURE 13

BUSSES - COMPARISON OF ACTUAL WEIGHTS WITH LICENSED WEIGHT LIMITS



Pounds below or above licensed weight limit

Distribution of 4002 loaded busses classified as to number of pounds below or above licensed weight limit (Recorded at 108 loadometer stations)

Pounds below or above license· loaded weight limit

Distribution of 4005 busses classified as to number of pounds the empty weight was below or above the licensed loaded weight limit (Recorded at 108 loadometer stations)

FIGURE 14

HIGHWAY PLANNING SURVEY

COMPARISON OF AVERAGE CARRIED LOAD OF SINGLE UNIT TRUCKS AND TRACTOR TRUCKS WITH SEMI-TRAILERS AND COMPARISON OF COST OF LICENSE PER TON AS BASED ON AVERAGE CARRIED LOAD AND 1936 SCHEDULE OF FEES.

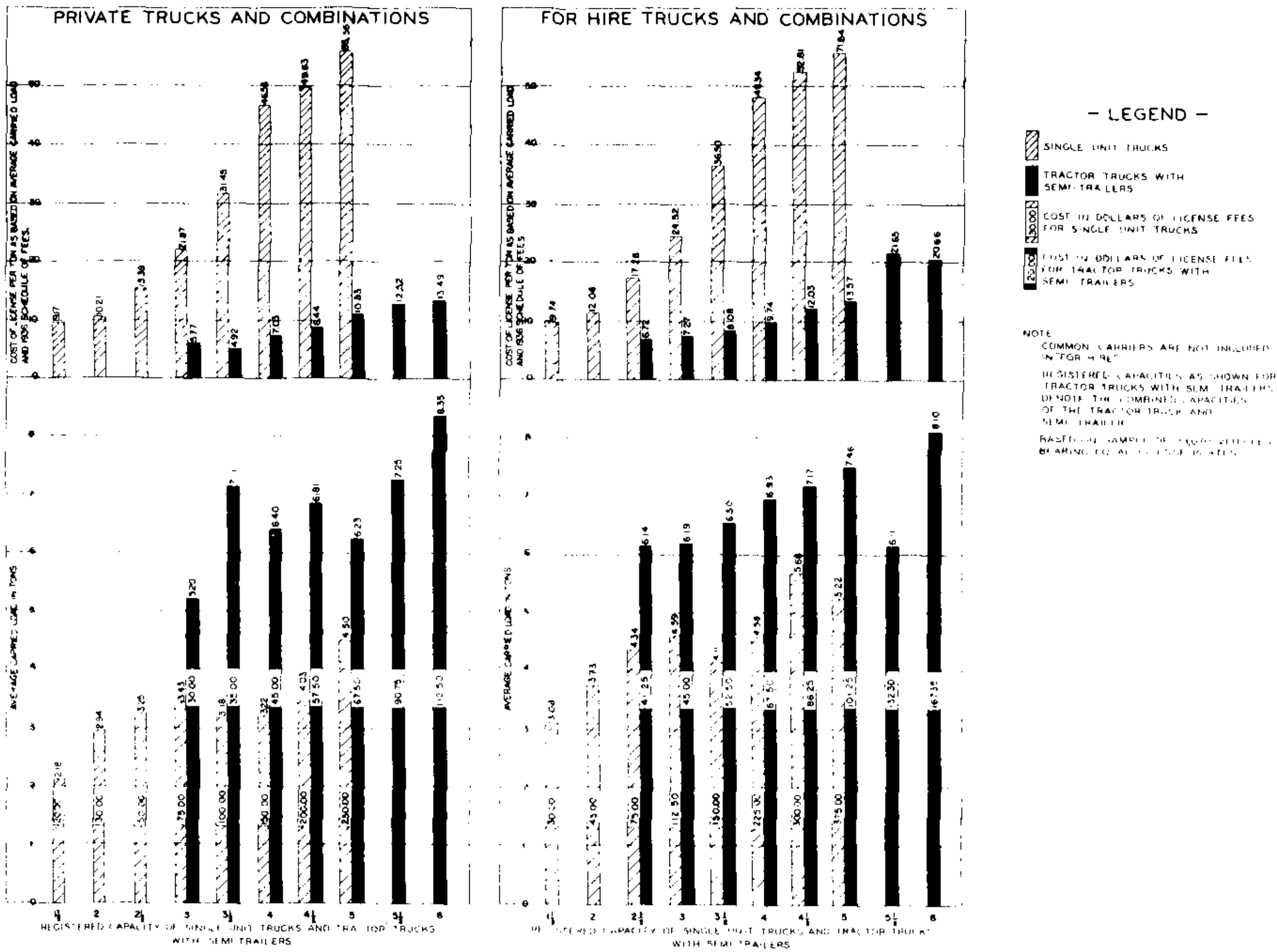


FIGURE 15

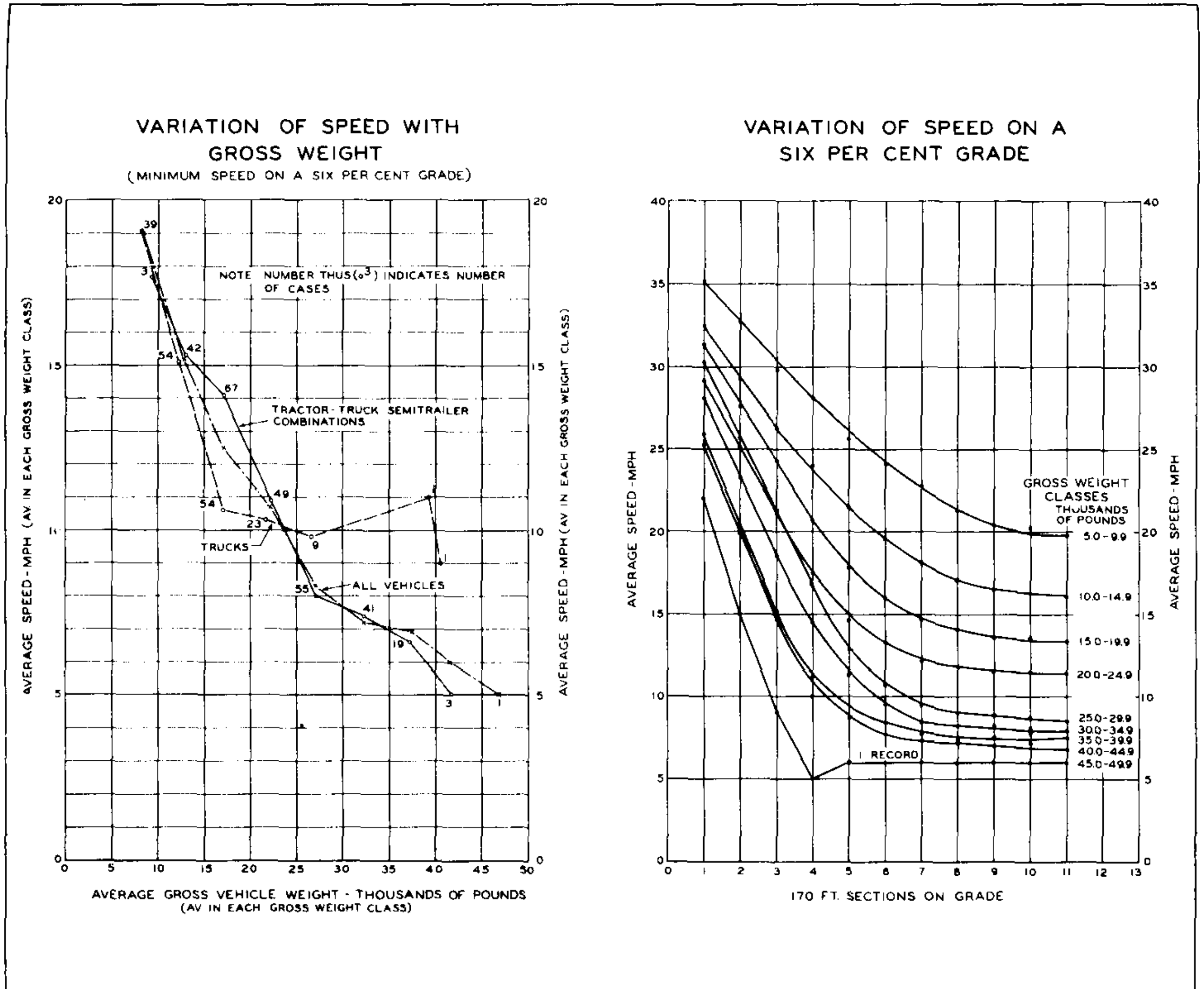
ton actually carried. Here, it would seem, is a conspicuous instance of discrepancy between road service and road payment that need only be revealed, as it has been by the planning survey, to be corrected.

But, although the data collected in the planning surveys supply the bulk of the information necessary for establishment of the desirable consistent relation between the design of the roads and the use of them, and payment for them by vehicles, they do not supply a few very essential facts. These missing facts are some that relate to the dynamics of the traffic, as distinguished from its volume, and the weights and dimensions of its units. Highway design, until recently, has paid scant attention to the needs of rapidly moving vehicles. In extenuation it may be said that the movement has not long been so rapid as to require special consideration, and also that in the pioneer phase of road building, from which we have only just emerged, the paramount need of a merely passable road surface prevented attention to what would have been considered excessive refinement of design. So, we may explain the preoccupation of the early road designer with such static economics as the balancing of cuts and fills, his easy acceptance of tortuous alignment, and his long-time scorn of even such simple concession to the movement of vehicles as the superelevation of curves.

This formerly ignored quality of the traffic is recognized today as a condition of major importance, governing the design of the modern highways. The steep grades, sharp curves, and short sight distances present in the existing roads are recognized as defects and, as such, have been definitely located by special inventory processes in order that they may be considered for correction. Such correction will constitute a good part of the work of needed modernization, determining, in large measure, the costs of the work.

But though the defects are apparent, the planning of corrective measures calls for certain precise information concerning the dynamics of traffic flow that the planning surveys do not supply and that is not otherwise available. It is not necessary that this information be sought in every State. Determined anywhere, most of the principles are everywhere applicable, and the Bureau of Public Roads has undertaken to meet the need by special studies, begun last summer, which it expects to complete in the current year.

Among these studies are the investigations of the hill-climbing ability of motor trucks and tractor-trailer combinations, early results of which are shown in Figure 16. The curves on the left show the minimum speed to which trucks and combinations of various gross weights were reduced in climbing a long 6 percent grade. Those on the right show the speed of vehicles of the several weight classes



U.S. BUREAU OF PUBLIC ROADS - DIVISION OF HIGHWAY TRANSPORT

FIGURE 16

as it was reduced by the hill from that at which the ascent was begun to the minimum shown in the other graph. There will be little disagreement with the thought that the speeds to which most of the heavier vehicles were reduced by this grade are such as to create a trouble-provoking condition on a two-lane road, especially if sight distance is greatly restricted.

Alternative corrective measures that suggest themselves for such conditions as this are: (1) reduce the steeper grades; (2) add an outer lane for trucks on the uphill side of the steeper grades; (3) extend sight distances; (4) increase the power and hill-climbing ability of trucks. Achieved by any of these measures the correction will involve a certain cost, the amount of which in any case is likely to be large in the aggregate. The question of choice between the several measures is one which justifies the most careful study, and, it is perhaps unnecessary to say, involves and turns upon the question of who is to pay the cost.

The further tests of this kind that will be made will supply data covering a range of grades and vehicles of various representative weights and makes in new, well maintained, and poor conditions. These data will be generally applicable to the grade conditions recorded by the planning surveys.

Another group of tests, also begun last summer (these in cooperation with the Illinois planning survey staff) aims to answer the important question of the traffic capacity of highways of various widths. Figure 17 presents an early result of these studies that gives convincing evidence of their usefulness.

With the special apparatus developed by the Bureau, it was possible to measure the speed of all vehicles passing through the test section and also record the various time intervals that separated each vehicle from its predecessor and its successor. It should be observed that the total amount of traffic passing in both directions over the two-lane test section during the periods represented in this figure varied from 1,200 to 1,500 vehicles per hour, averaging 1,351.

The diagram shows, for each hourly volume of traffic in one lane, varying from 100 to 1,200, the number of times per hour when the intervals between succeeding vehicles exceeded certain time intervals, the several curves representing the various intervals in seconds, such as 1, 2, 3, 5, and so forth, up to 50.

On each volume ordinate the distance, measured to the ordinate scale, between a 45-degree line and the top curve represents the number of times per hour these separating intervals were

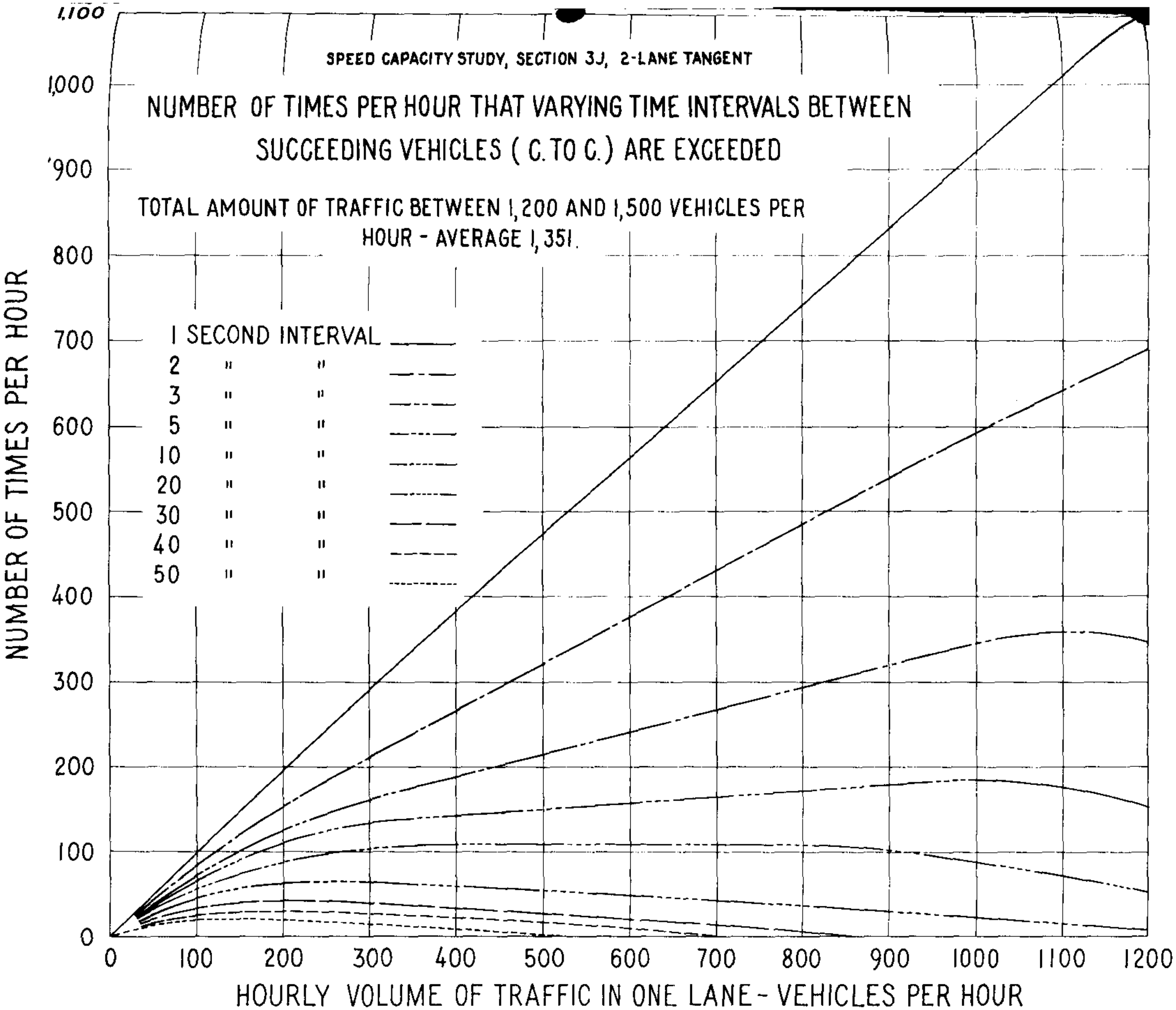

SPEED CAPACITY STUDY, SECTION 3J, 2-LANE TANGENT
NUMBER OF TIMES PER HOUR THAT VARYING TIME INTERVALS BETWEEN SUCCEEDING VEHICLES (C. TO C.) ARE EXCEEDED
TOTAL AMOUNT OF TRAFFIC BETWEEN 1,200 AND 1,500 VEHICLES PER HOUR - AVERAGE 1,351.
1 SECOND INTERVAL
2 " "
3 " "
5 " "
10 " "
20 " "
30 " "
40 " "
50 " "
NUMBER OF TIMES PER HOUR
0
100
200
300
400
500
600
700
800
900
1,000
1,100
HOURLY VOLUME OF TRAFFIC IN ONE LANE - VEHICLES PER HOUR
0
100
200
300
400
500
600
700
800
900
1000
1100
1200

FIGURE 17

less than one second. The space between the one and two-second lines represents the number of times the interval was between one and two seconds in length; and, similarly, the other vertical spaces between curves, measured along the ordinate lines, represent the frequency of occurrence of intervals of other time lengths.

In figurative language, these spaces between the curves represent the number of times per hour when the "holes in the traffic," that is the spaces between vehicles were of various magnitudes, measured in time. Knowing the average speed, it is possible to convert these time intervals into approximate space intervals, and computed in this way, the space interval corresponding to a time interval of 20 seconds was just about 1,000 feet.

Now it is possible to compute from the observed data for each hourly volume of traffic the percentage of the average hour when the "holes in the traffic" moving on the one lane were of less than this 20-second or 1,000 foot length.

For the hourly volume of 100 vehicles this percentage was 10.5; for 1,200 vehicles per hour it was 93.8. That is, with a volume of 1,200 vehicles per lane per hour the "holes in the traffic" were shorter than 1,000 feet for 93.8 percent of the hour.

With 200 vehicles per lane, per hour, the "holes" were shorter than 20 seconds (or 1,000 feet) 18.4 percent of the time. At 400 vehicles per hour the percentage rises to 33.3; at 600 to 48.5.

Let the reader think of such streams of traffic as oncoming in the opposite direction to that in which he is traveling. He wishes to pass a vehicle ahead of him in his own lane, and to do so he must enter the opposite lane in one of those traffic "holes." To complete the maneuver assume that he needs a 20-second or 1,000 foot hole. Then, if the traffic in the other lane has a volume of 200 per hour, according to these test results, a hole of the necessary length would not be available for 18.4 percent of the time.

But the real condition is worse than this; because even when the "holes" themselves are longer than 20 seconds there is always a latter end of such holes which is of shorter duration. If we take this into account, the part of the time when passing requiring a 20-second interval would not be possible rises, for the volume of 200 vehicles per lane, per hour, to 53.4 percent.

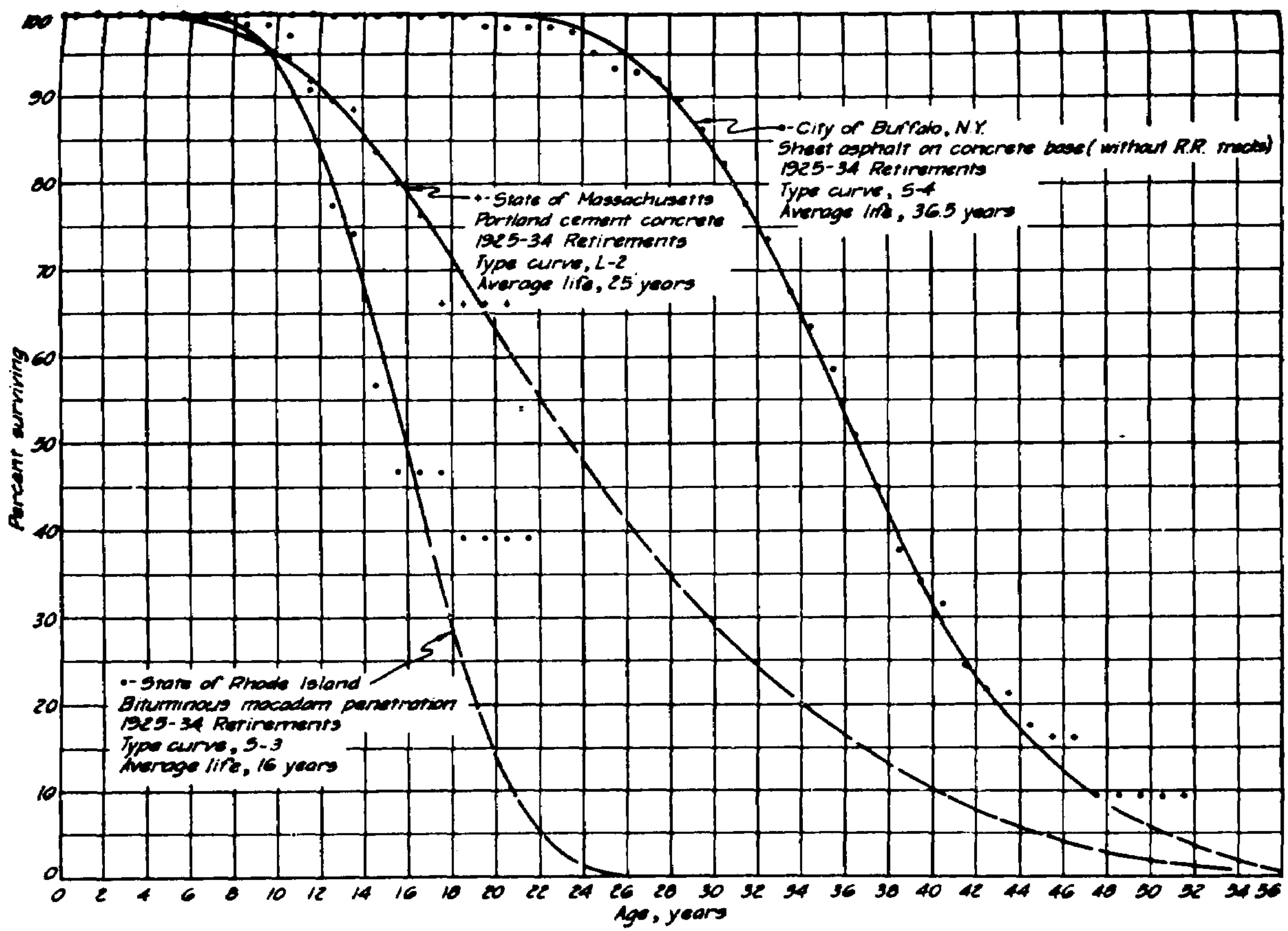
Now, consider that to be useful for passing the availability of a "hole" in the opposite lane must exist coincidentally with the presence of a sight distance sufficient to reveal the existence of the hole, and you will see that the probability of these conditions occurring coincidentally when lane volume is 200 per hour is really not too great.

As 200 vehicles per hour, per lane of balanced traffic, is roughly equivalent to 4,000 vehicles per day, it may be seen that at such a density a two-lane road may be not far from its congestion-free capacity. This approximation is given not as an immediately usable generalization, but rather as the conclusion of a demonstration of the utility and application of the highway capacity studies, from which actually usable generalizations should be shortly forthcoming.

In this necessarily sketchy exposition of some of the uses of the planning surveys, mention will be made of only one more item of valuable information that is being established before concluding with a suggestion of a way in which all items may be synthesized into a general program planning method.

The one item to which brief reference must be made is the information, that is being systematically compiled, that tends to indicate the normal life of various elements of the road structure. Figure 18 shows typical survivor curves for various types of road surface resulting from studies of this sort.

For purposes of further discussion, we shall consider these actual, complete survivor curves for three different types of road surface as representative of three general types of life experience, calling the one nearest to the left Type S-3, the middle one Type L-2, and the one to the right Type S-4. In Figure 19 several variants of the two Types L-2, and S-4 have been reproduced, in each group of which the general characteristics of the several curves are alike. The several curves of each group represent each a different average life, the one in each group furthest to the left an average life of 5 years, the one furthest to the right an average life of 30 years. The diagrams show how these two sets of type curves can be used to forecast the <u>probable</u> average life of two groups of roads of which we have thus far only the stub curves, A and B. Of the groups represented by both curves 20 percent of the original mileage still survives, for group A at the end of 22 years, and for group B at the end of 18 years. The purpose is to estimate what will be the average life of the whole group as it will be revealed when, finally, the last mile of each group is retired from service. As will be observed, this is done by matching the two stub curves against the available systems of type curves. In this way, it is found that Curve A fits Type Curve L-2 for an average life of 17 years; while Curve B fits Type Curve S-4 for an


City of Buffalo, N.Y.
Sheet asphalt on concrete base (without R.R. tracks)
1925-34 Retirements
Type curve, S-4
Average life, 36.5 years
State of Massachusetts
Portland cement concrete
1925-34 Retirements
Type curve, L-2
Average life, 25 years
State of Rhode Island
Bituminous macadam penetration
1925-34 Retirements
Type curve, S-3
Average life, 16 years
Percent surviving
Age, years

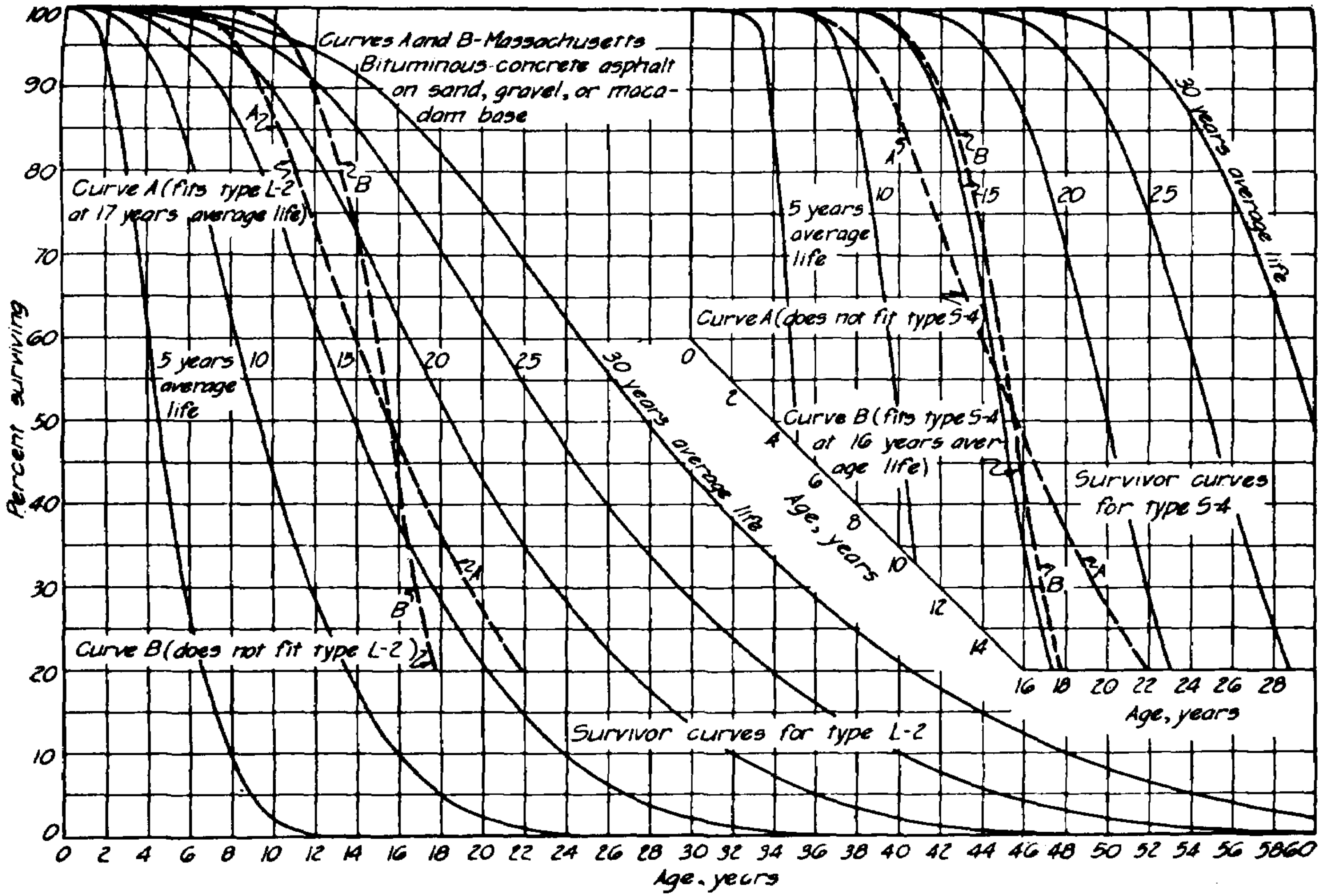

Curves A and B-Massachusetts Bituminous-concrete asphalt on sand, gravel, or macadam base
Curve A (fits type L-2 at 17 years average life)
Curve B (does not fit type L-2)
Curve A (does not fit type S-4)
Curve B (fits type S-4 at 16 years average life)
Survivor curves for type L-2
Survivor curves for type S-4
5 years average life
30 years average life
Percent surviving
Age, years

FIGURE 19

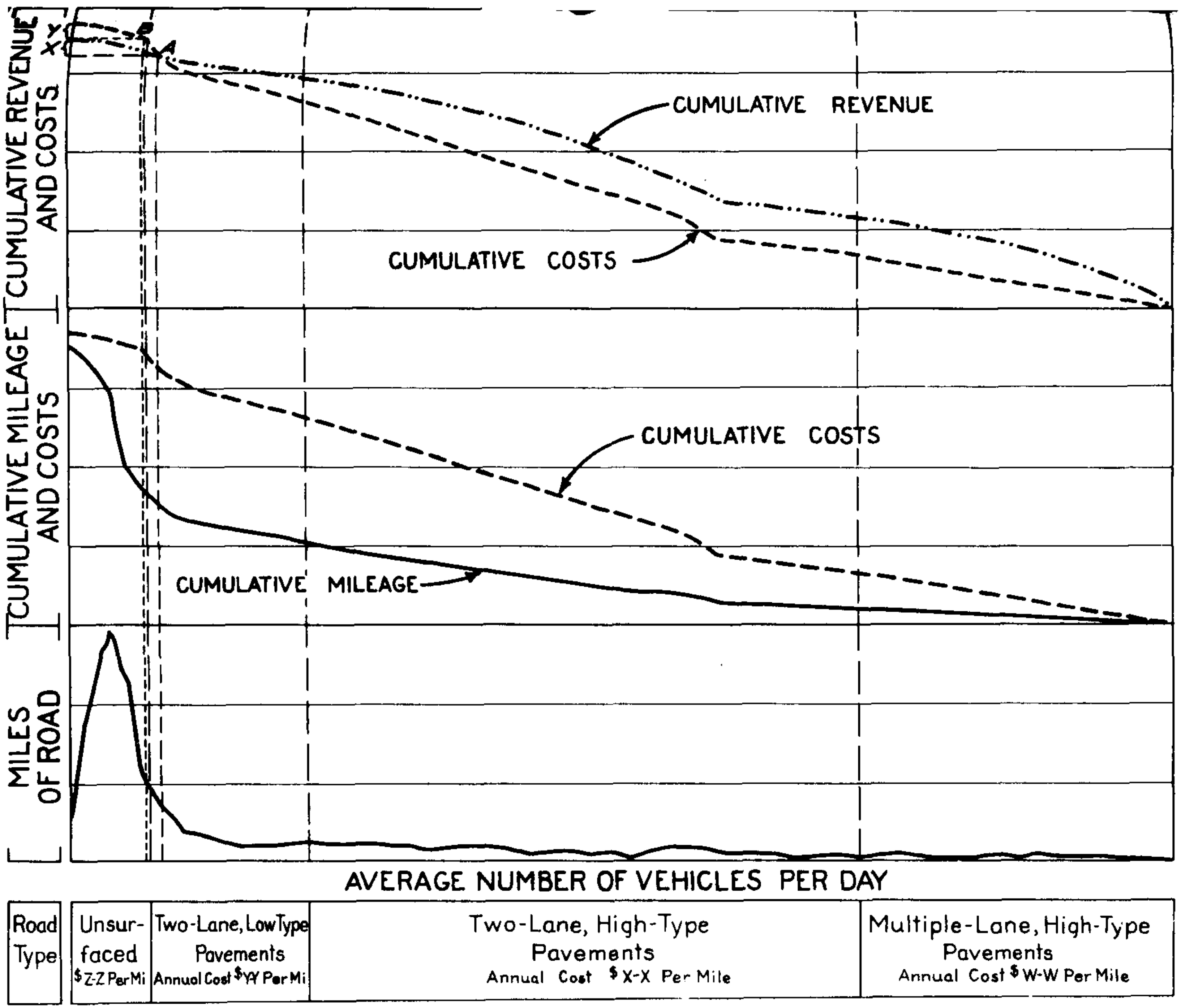
average life of 16 years. We, therefore, estimate that the final average life of the whole group of roads represented by Curve A will be 17 years, and that of the roads represented by Curve B will be 16 years.

Employing such methods as these, it is hoped that the road-life studies of the survey will shortly indicate, at least, what reasonable assumptions may now be made concerning the average life period of various physical elements of the road investment; and, continued, will permit the accuracy of such estimates to be steadily refined. The need of such reasonable assumptions or estimates arises in the determination of annual road costs, a working knowledge of which is essential for planning of the future road program.

A method of approach toward such planning, employing all of the data developed by the planning surveys, is indicated diagrammatically in Figure 20. The curve in the lowest rectangle shows, for any group of highways, the number of miles serving each level of traffic volume. The brackets at the bottom indicate the decisions that must be made concerning the type, width, and average annual cost of the surfaces and other improvements required for classes of these roads serving the several broad ranges of traffic volume. Such decisions will be made upon evidence supplied by all phases of the planning surveys, including the road life and traffic capacity and other special studies, and upon the basis of information supplied by physical researches and experience.

Beginning with the section of greatest traffic volume in the group and accumulating the mileage down the scale of traffic volume gives the Cumulative Mileage Curve of the middle rectangle, and multiplying the ordinates of this curve by the appropriate average annual costs per mile gives the Cumulative Cost Curve.

This Cumulative Cost Curve is repeated in the upper rectangle in order to compare it with what is designated as a Cumulative Revenue Curve, formed by multiplying the accumulated product of miles and volume for each traffic volume increment by the average motor vehicle tax earning of one vehicle-mile. A similar comparison may be made between cumulative costs and cumulative vehicle operating savings by using, as the multiplying factor applied to vehicle-miles, the estimated saving per vehicle-mile afforded by each class of improved road. As previously suggested, such savings may be assumed to represent the absolute limit of motor vehicle taxation, a limit that is probably, however, well beyond the point of diminishing returns.



CUMULATIVE REVENUE AND COSTS
Y
X
B
A
CUMULATIVE REVENUE
CUMULATIVE COSTS
CUMULATIVE MILEAGE AND COSTS
CUMULATIVE COSTS
CUMULATIVE MILEAGE
MILES OF ROAD
AVERAGE NUMBER OF VEHICLES PER DAY
Road Type
Unsur-faced $Z-Z Per Mi
Two-Lane, Low Type Pavements Annual Cost $Y-Y Per Mi
Two-Lane, High-Type Pavements Annual Cost $X-X Per Mile
Multiple-Lane, High-Type Pavements Annual Cost $W-W Per Mile

FIGURE 20

Constructing such a Cumulative Revenue Curve for any assumed total tax rate and comparing it with the curve of Cumulative Cost will show what part of the whole road system could be supported by motor vehicle taxes at the assumed rate.

In the example it will be observed that the cumulative revenues and costs are in balance for the roads of greater traffic volume down to a volume indicated by the intersection of the two curves at A. For all roads of lesser traffic volume the cumulative costs exceed the cumulative revenues; but an additional revenue, in amount x, is accumulated by these lesser roads which may be further applied to the support of additional mileage carrying traffic volumes in excess of that indicated at point B. The additional Cumulative Cost, y, of the remaining mileage, serving less than this traffic volume, is the net excess of cost of the whole system over total revenues, produced at the assumed rate of motor vehicle taxes. To represent the effect of any subsidy extended to such a group of roads, such as a portion of revenue earned by another group of highways or streets, or an appropriation from property taxes, Federal aid, etc., the Cumulative Revenue Curve would be raised uniformly by the amount of the subsidy, and thus would cross the Cumulative Cost Curve further down the scale of traffic volume, if it crossed at all.

The group comprising roads of the greater traffic densities, indicated by any such analysis to be supportable at any assumed rate of vehicle taxation, can be seen upon a map as all those sections of roads having traffic densities above the indicated minimum.

Such a group of roads in one county is suggested in Figure 21 by the solid black lines. As indicated by the dotted black lines, it is probable that any such group of roads would be discontinuous in certain sections. Such gaps, if filled, would necessarily be supported by some form of subsidy, as would any other additions to the system.

By such a process the continuing costs of a group of improved highways can be balanced against the vehicle tax earnings of the same group, supplemented or not, as the case may be, by revenues from other sources. When such a balance of particular highway improvements against particular sums of revenue can be thus specifically described, when definite roads on a map can be shown to be the only roads possible of possession within the income from definite tax sources, then we shall have a road program, rationally developed. The establishment of such a program, as nearly as may be practicable, is the final objective of the highway planning surveys.

COUNTY MAP SHOWING ROADS ECONOMICALLY JUSTIFIED BY COMPARING ANNUAL COSTS AND ANNUAL ROAD USER REVENUES

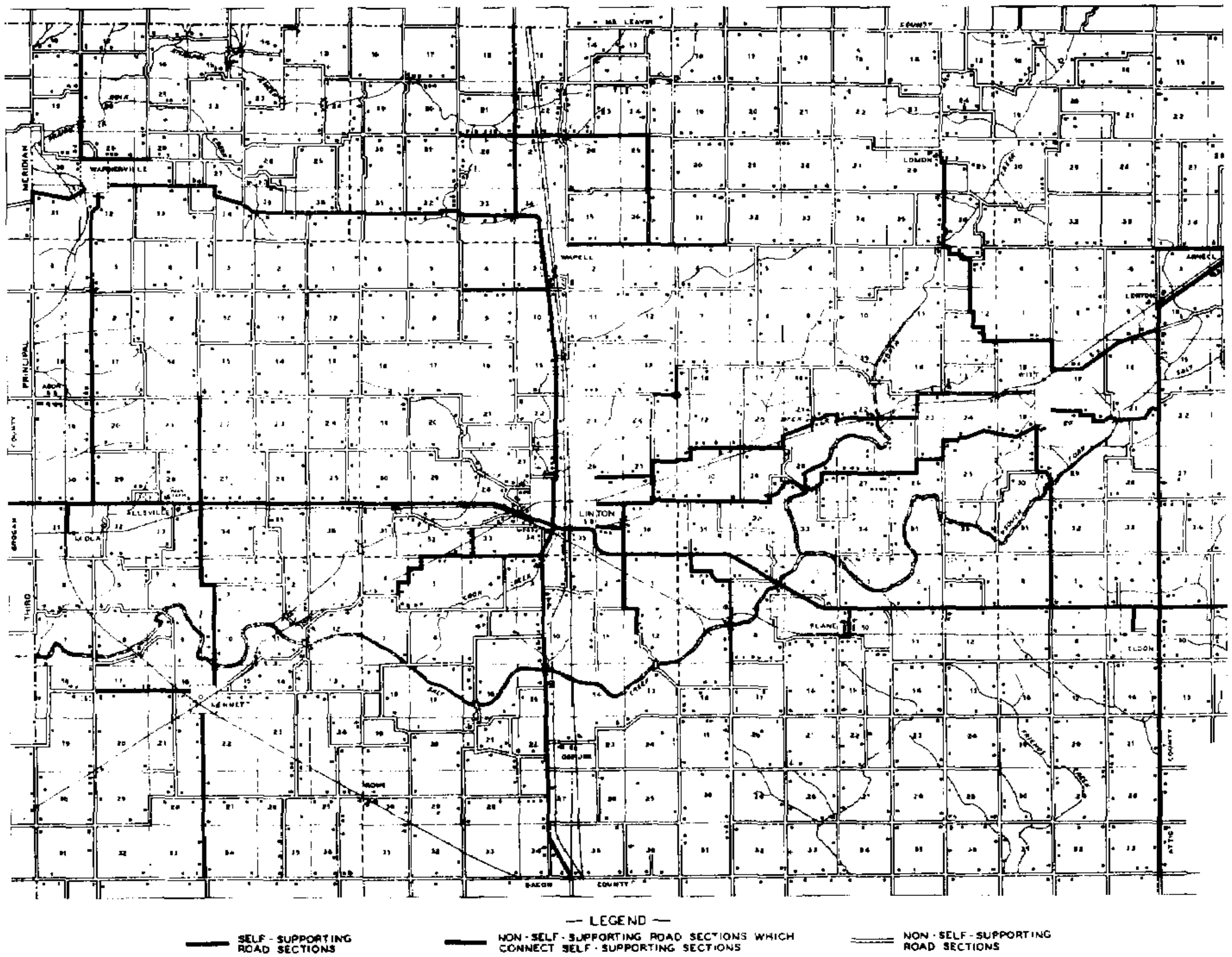


FIGURE 21