PLANNING THE INTERREGIONAL HIGHWAY SYSTEM

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SYNOPSIS

Interregional highways have been built in this country from its earliest days Their character and extent have always been limited by available funds, which, in turn, have depended upon the economic importance of the mode of transport that has used them

The present need of a balanced interregional system of free highways to serve the respective needs of the regions traversed as well as the needs for longer interregional movements is apparent. This system should mainly be made up of the most direct routes between the major centers of population and the belts of heaviest population.

A tentatively defined interregional system is located and the needs of the system are discussed. Design standards are given and cost estimates on both a long term program and an emergency program are quoted. The distribution of the system in geographic regions is analyzed and preliminary indications of the use, cost of operating, and the earning capacity of the system are developed.

HISTORICAL

The concept of an interregional highway system is no startling innovation to the highway builders of this country. We have, as a nation, been dreaming of it and building it since the first settlers landed on our shores.

From the ethnological standpoint, the direction of settlement had a great deal to do with the determination of the location of the overland routes. For example, if there is truth in the hypothesis that the American Indians are descended from Asiatic races, we would expect them, after crossing the Bering Strait, to have spread over the North American Continent by means of the labyrinth of trails connecting the watering places, feeding grounds, and salt licks of their animal antecedents.

After Hernando Cortes established his headquarters in Mexico City in 1519, the Spaniards began to press northward along the mountainous backbone of the continent, in search of the fabulous wealth of the Seven Cities of Cibola and the mystic Straits of Anian which were believed to provide a direct water route from the Old World to China and the Indies. The direction of the first explorations of the Spanish *conquistadores* established routes of travel connecting Mexico City northward with Santa Fe, which was established about 1605. Later in the early part of the eighteenth century a route was established northeasterly across Texas along El Camino Real which connected by land and water with the branch of the old Spanish road leading westward across the Florida peninsula from St. Augustine, which was founded in 1565 A northwestward Spanish route was projected up the Pacific Coast by the *padres* through Los Angeles, Santa Barbara, and San Francisco to Sonoma about the time of our War of the American Revolution. Another direction of travel was established in the latter part of the seventeenth century when Marquette, Joliet, LaSalle and other French explorers began their trips southward along the Mississippi River from New France (Canada).

In 1607 with the founding of Jamestown, Virginia, by the London Company, and the landing of the Pilgrim Fathers at Plymouth in New England in 1620, began the settlements which established and determined the direction of emigration principally westward from the Atlantic to the Pacific Coasts. The pioneer settlements during the period of English colonial development occupied a narrow strip of land about 150 miles wide, bordered on the east by the Atlantic Ocean and on the west by the Appalachian Mountains. From this substantial palm of settlement the first finger of emigration was pointed westward, in 1774, over the route of the Wilderness Road blazed by Daniel Boone to the unknown land of Kentucky beyond the mountains In 1784 there were about 30,000 people in the Kentucky region separated by almost impenetrable mountains from the ports along the Atlantic Coast. Unless adequate routes of communication were provided these people would turn toward the Mississippi River for an outlet and establish connections with the Spanish settlements in the Southwest. "The Western settlers," said General Washington, "stand as it were on a pivot. The touch of a feather would turn them any way." Thus, the far-seeing patriot began to renew his plans for a westward water connection between the Potomac and Ohio Rivers This project was superseded when the Federal Government tapped the territory northwest of the Ohio River by the construction of the Cumberland Road or National Pike on which work was begun in 1806.

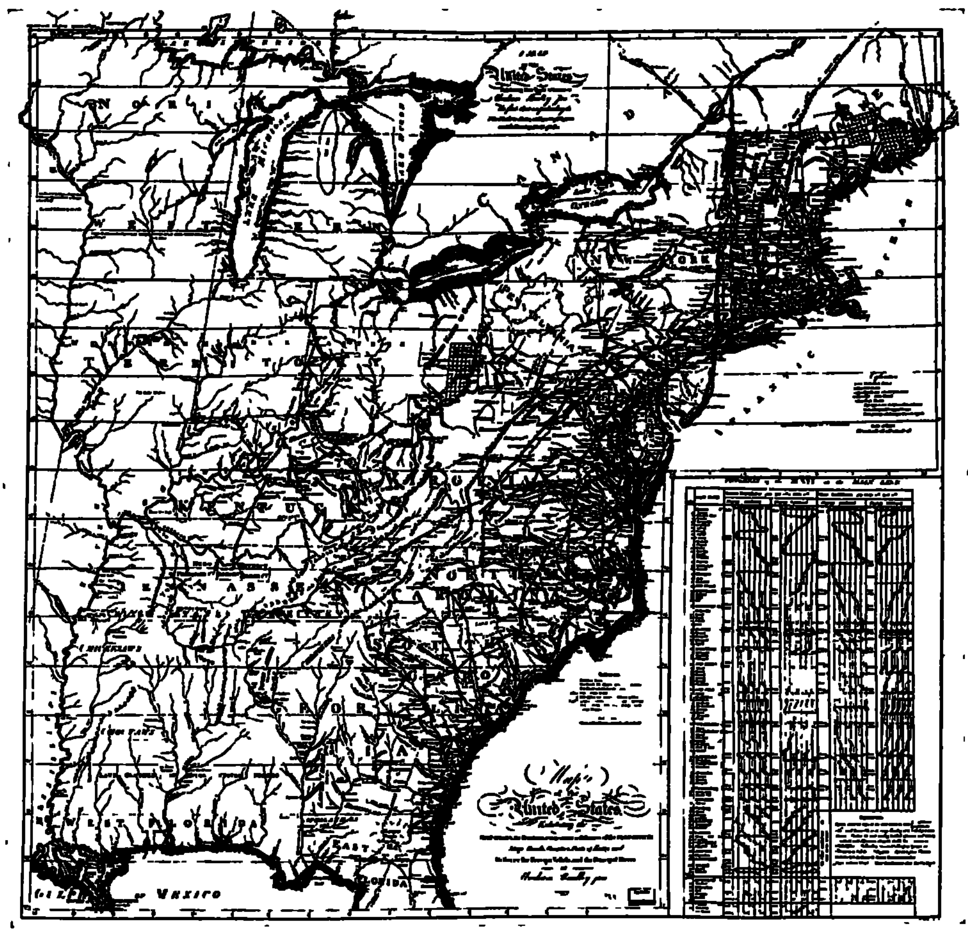


Figure 1. Post and Stage Routes in the United States in 1796

In 1801 the National Government had

established the Natchez Trace from Nashville, Tennessee, to the mouth of the Mississippi River to provide communication with the Southwest and over this land route the flatboatmen returned home to the northern States. In 1821 another finger was projected westward when for the first time commercial intercourse was begun over the Santa Fe Trail between the American frontier at Independence, Missouri, and Santa Fe, then the nearest main settlement in Old Mexico. A generation later a great finger was pointed toward the Pacific Coast when, in 1843, the covered wagons of the "Great Emigration" rumbled to the far Northwest over the Oregon Trail. The discovery of gold in California, in 1848, speeded the extension of other fingers of travel which completed the ties from coast to coast. All of these lines of travel, however, followed closely the routes traversed by aborigines centuries before

In order to visualize the changes that have taken place in our post routes at intervals since the latter part of the eighteenth century, the maps of the times are our best records

Figure 1 is a map (1796) of the post and stage routes in the United States made by Abraham Bradley, Jr., later First Assistant Postmaster General in the Administration of President John Adams. In general, all connected routes are in the seaboard States north of Florida, Knoxville, Tennessee, being the farthest west on the connected routes. There was a midwest net running from Nashville, Tennessee, through Kentucky, Indiana, and along the Ohio-Indiana boundary as far north as the Miami River.

About this time (1790-1820) there was an extraordinary amount of road building, chiefly by private capital, in the form of turnpike companies chartered by the States. They gave the country better

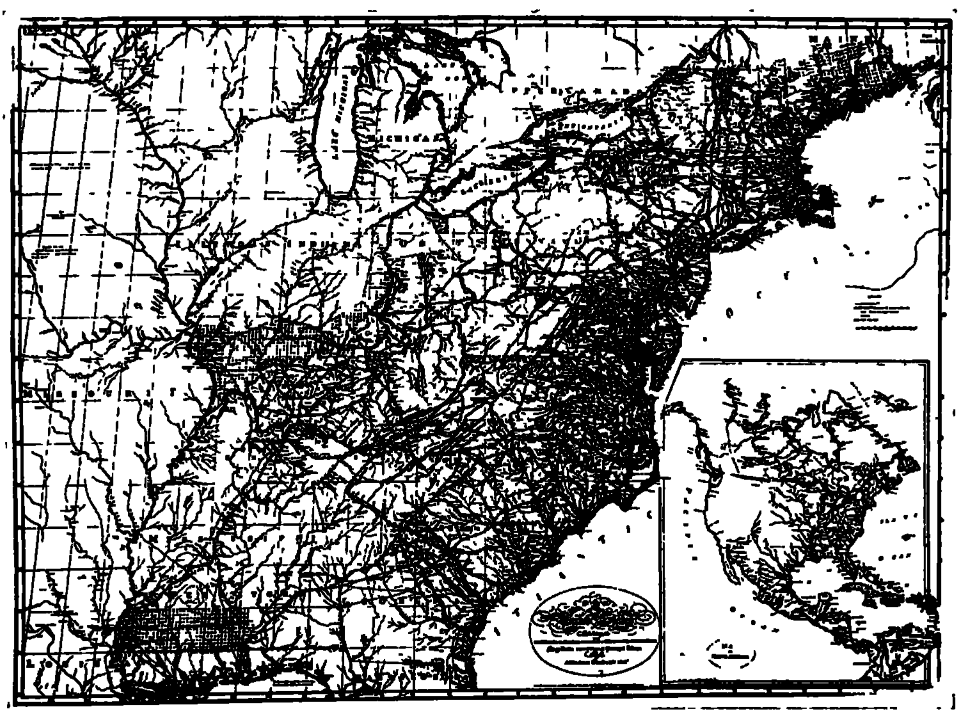


Figure 2. Post and Stage Routes in the United States in 1806

roads, but tolls and other costs prevented the long distance movement of bulky commodities.

By 1802, stage coaches were regularly operated between Boston and Savannah, the trip of 1,200 miles being negotiated at 53 miles per day at a total fare of $70

By 1806, the route network (as shown in Fig 2) had reached the Mississippi River at New Orleans, Vicksburg and St Louis, and to Detroit in Michigan.

commodities 90 percent, and cut the time between New York and Buffalo 60 percent.

By 1837, there were about 1,500 miles of railroad in the eastern part of the United States, and there were 250 steamers on the Mississippi and Ohio Rivers.

Figure 3 shows the wagon roads, railroads and canals in the United States in 1844. The influence of the railroads was still confined to the East The Baltimore

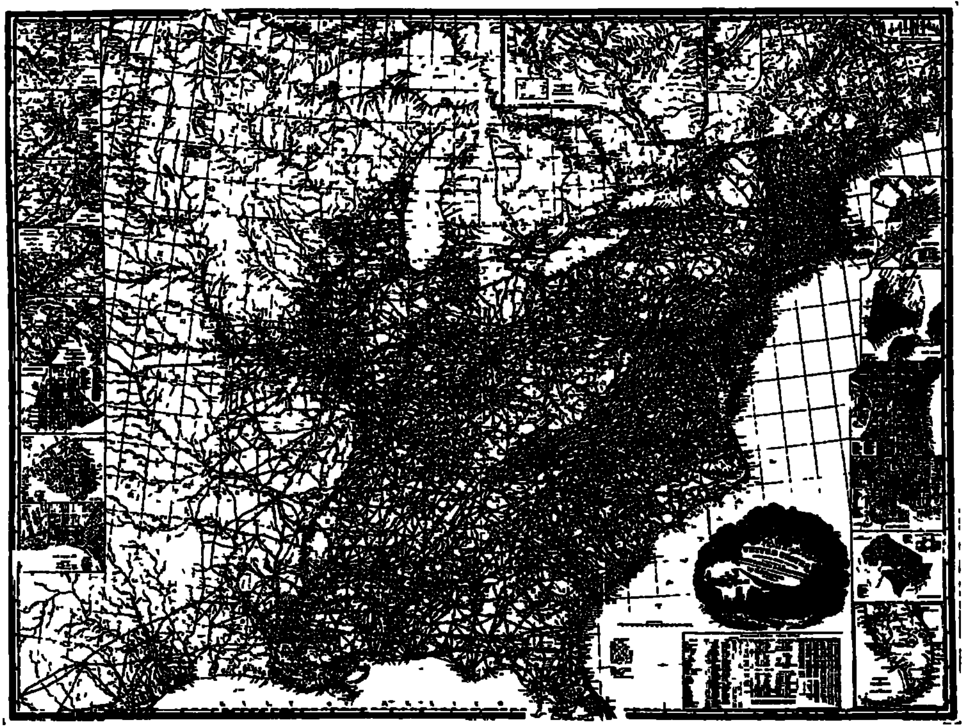


Figure 3. Wagon Roads, Railroads and Canals in the United States in 1844

and Ohio Railroad had reached Cumberland, Maryland, by 1840; the Pennsylvania Railroad did not reach Pittsburgh until 1852; and it was 1853 before the Michigan Central reached Chicago. Therefore, the wagon road system shown in the Midwest and beyond the Mississippi still formed the land transportation network.

In 1806, the National Pike was begun Its construction continued until 1838, when the prospect of lower haulage cost by railroad cast its shadow before, and in conjunction with the panic of 1837 virtually stopped the construction of the Pike

In 1810, we are told, it cost $10 to move a ton of freight from Philadelphia to Pittsburgh, and the construction of the Erie Canal (1817–1825) cut the cost of moving

In 1848, a resolution was offered in Congress for the appointment of a committee to study the construction of a Pacific railway. By 1860, 30,000 miles of railroad had been constructed in this country, and in 1861 telegraphic communications were established across the continent.

Figure 4 is Colton's 1861 map of the United States, and shows the wagon roads to the Pacific Coast.

In 1862, President Lincoln signed a bill creating the Union Pacific and Southern Pacific Railroads, and construction was started the following year.

In May, 1869, the Central and Union Pacific Railroads met at Promontory Point in Utah. By 1883, the Northern Pacific and Southern Pacific reached the coast, to be followed by the Santa Fe in

Figure 4. Colton's 1861 Map of the United States Showing Wagon Roads to the Pacific Coast

1885 Thus between 1830 and 1885, the railroads had supplanted wagon roads for major passenger and freight movements.

In 1873, Selden began his research on internal combustion engines, and in 1880 the League of American Wheelmen was formed. From many complementing forces of this nature our present public owned highway transport system came into being.

In 1887, Olds built a three-wheeled horseless steam carriage and, in 1888, Dunlap repatented the penumatic tire. In 1890, Olds began his experiments on gas-driven vehicles

The first State-aid law for highways was passed in New Jersey in 1891. The United States Office of Road Inquiry of the Department of Agriculture was established in 1893, the first gas carriages were in use during the same year, and major moves were being made to again bring highways into the picture as a modern complement of railroad and waterway transport

In our time the construction of routes that form the basic outline of the interregional system (Fig. 5) has been quickened by the advent of gas driven vehicles whose owners have been farsighted enough to join in reasonable cooperation in financing by public investment the highway plant that is now one of the world's wonders To those who have lived in this era the highway plant has seemed to grow at an uncommonly leisurely pace largely because we are, in the main, a restless, creative people.

Now that the highway network is practically all hard surfaced in order to attain major benefits promptly for both civil and military requirements it seems logical to plan and carry out a program of betterments and new construction on routes carrying large volume of swiftly moving traffic between the country's main population centers. This was probably the impelling reason when the Congress included in the Federal Highway Act of 1938 a provision, Section 13, which directed the Chief of the Bureau of Public Roads to investigate and to report to the Congress on the feasibility of building and operating as toll roads a specified number of superhighways.

The result of the investigation undertaken pursuant to this instruction was published as House Document No 272, 76th Congress, First Session. From the discussion in that report there emerged a general outline of what has been called "a master highway plan for the entire Nation" The consummation of this plan calls for the full cooperation of the Federal and State Governments. The entire program outlined in that report includes the following five points:

"1. The construction of a special, tentatively defined system of direct interregional highways with all necessary connections through and around cities, designed to meet the requirements of the national defense in time of war and the needs of a growing peacetime traffic of longer range

"2. The modernization of the Federal-Aid highway system.

"3 The elimination of hazards at railroad grade crossings.

"4 An improvement of secondary and feeder roads, properly integrated with land use programs

"5 The creation of a Federal Land Authority empowered to acquire, hold, sell, and lease lands needed for public purposes and to acquire and sell excess lands for the purpose of recoupment"

This paper deals with the general problems encountered in a tentative study of the first point together with some remarks on an emergency modernization of the tentatively defined interregional system and the elimination of hazards at the grade crossings on the system

TENTATIVELY DEFINED SYSTEM

The system shown on Figure 5 and tentatively selected after close cooperation with State and Federal agencies includes substantially all of the major inter-

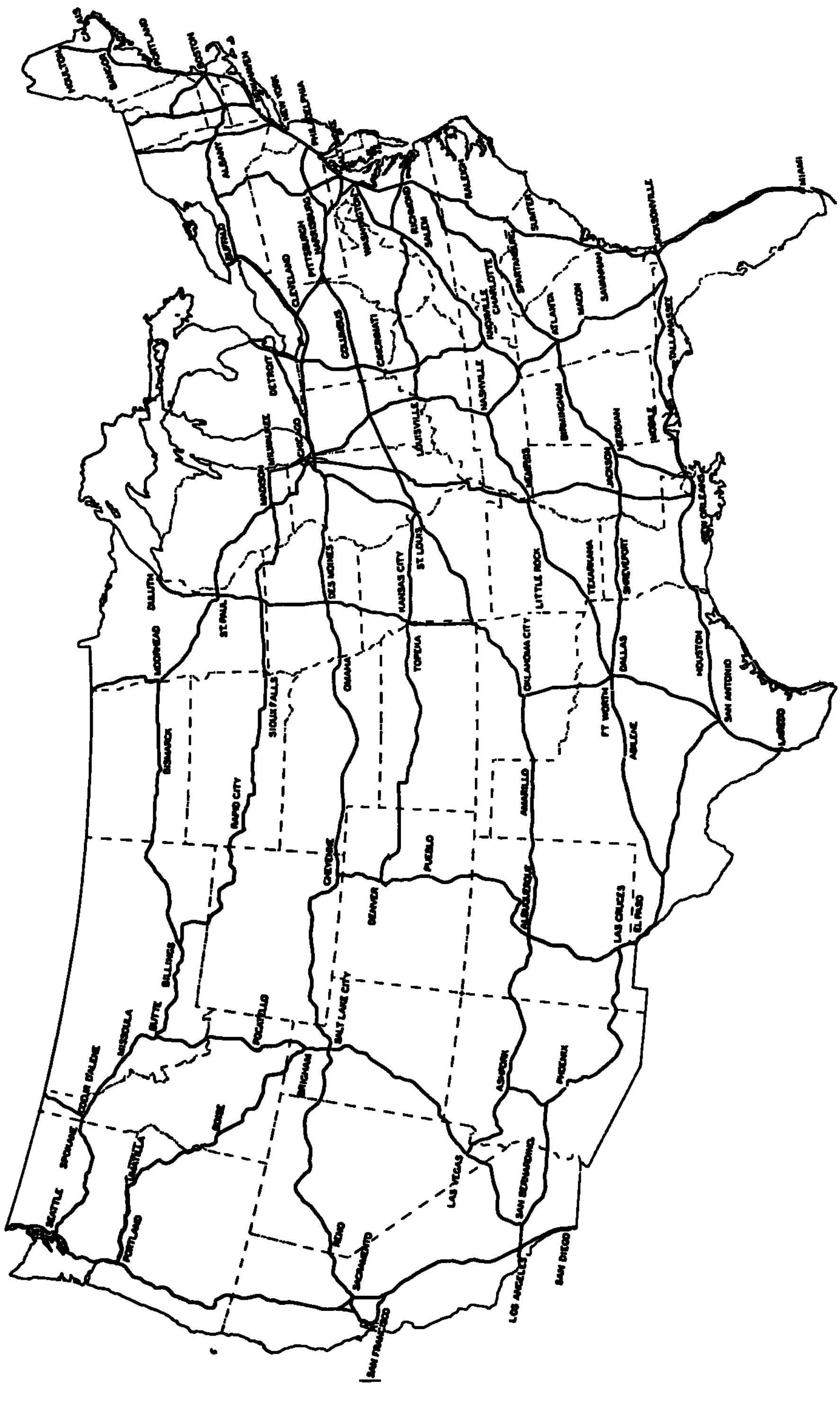


Figure 5. Existing Highways Following the Approximate Alignment of the Tentatively Selected Interregional Highway System

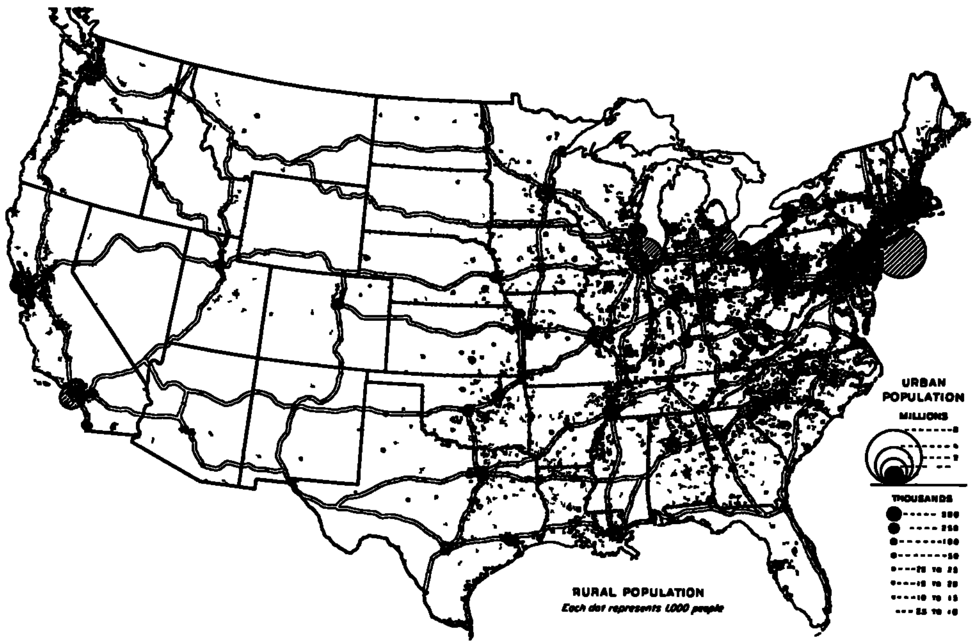


Figure 6. Population Distribution in Relation to the Location of the Tentatively Selected Interregional Highway System

regional lines of travel. The system is 29,330 miles in length, of which 25,554 miles are rural in character and 3,776 miles are in urban territory. Figure 6 shows that it serves substantially all of the major population centers and the belts of the heaviest population.

The traffic maps of the routes to be improved, given in Figures 7 and 8, show them as the most heavily traveled, on the whole, of all the routes in the U. S numbered system Improved as a system of largely limited access free roads, it will attract traffic and generate new activities.

Because of drafting limitations, it is impossible to show how this traffic builds up in cities For this reason the traffic flow has been plotted vertically in profile form and is shown in Figure 9

The existing rural routes most nearly conforming to the direct routes of the interregional system (Figures 10 and 11) now serve almost 11 percent of the total vehicle miles on all rural highways. Although their length represents only about one percent of the total rural highway mileage of the country it is estimated that the completed system would unquestionably accommodate at least 12.5 percent of the total rural vehicle mileage. By providing ample capacity and up-to-date safety devices the construction of these free roads would effect a material reduction in the highway accident rate.

In the data submitted in this paper the direct routes follow the alignment of and incorporate the improvements of the existing highways with deviations from direct routes between population concentrations in limited degree only to accommodate the largest intermediate towns

The routes are assumed to join the facilities that will promote free movement of traffic to and through the center of the cities. At large cities, wherever necessary, limited access belt lines may have to be provided. All small communities are assumed to be bypassed. The two

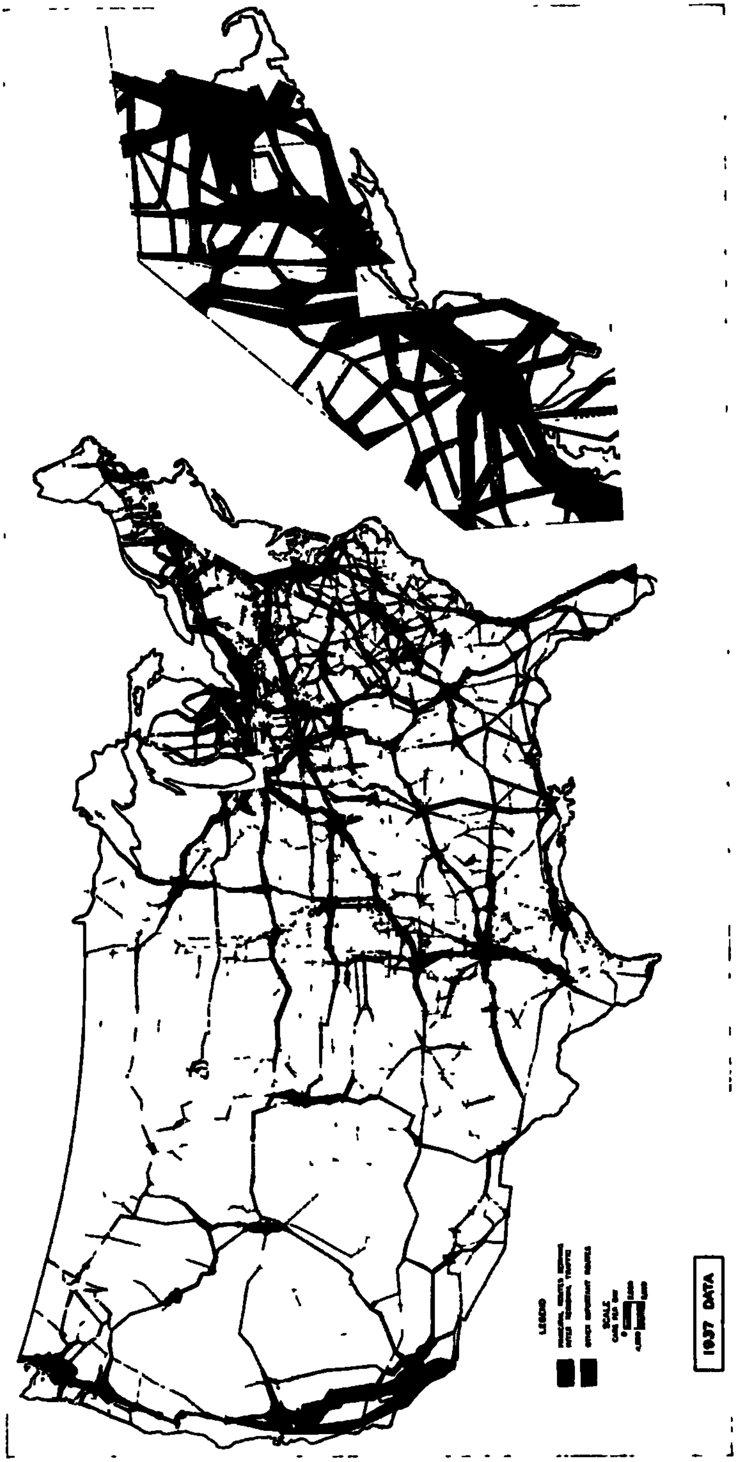


Figure 7. Comparison Between the Average Daily Passenger Car Traffic on the Tentatively Selected Interregional Highway System and That on other Important Routes

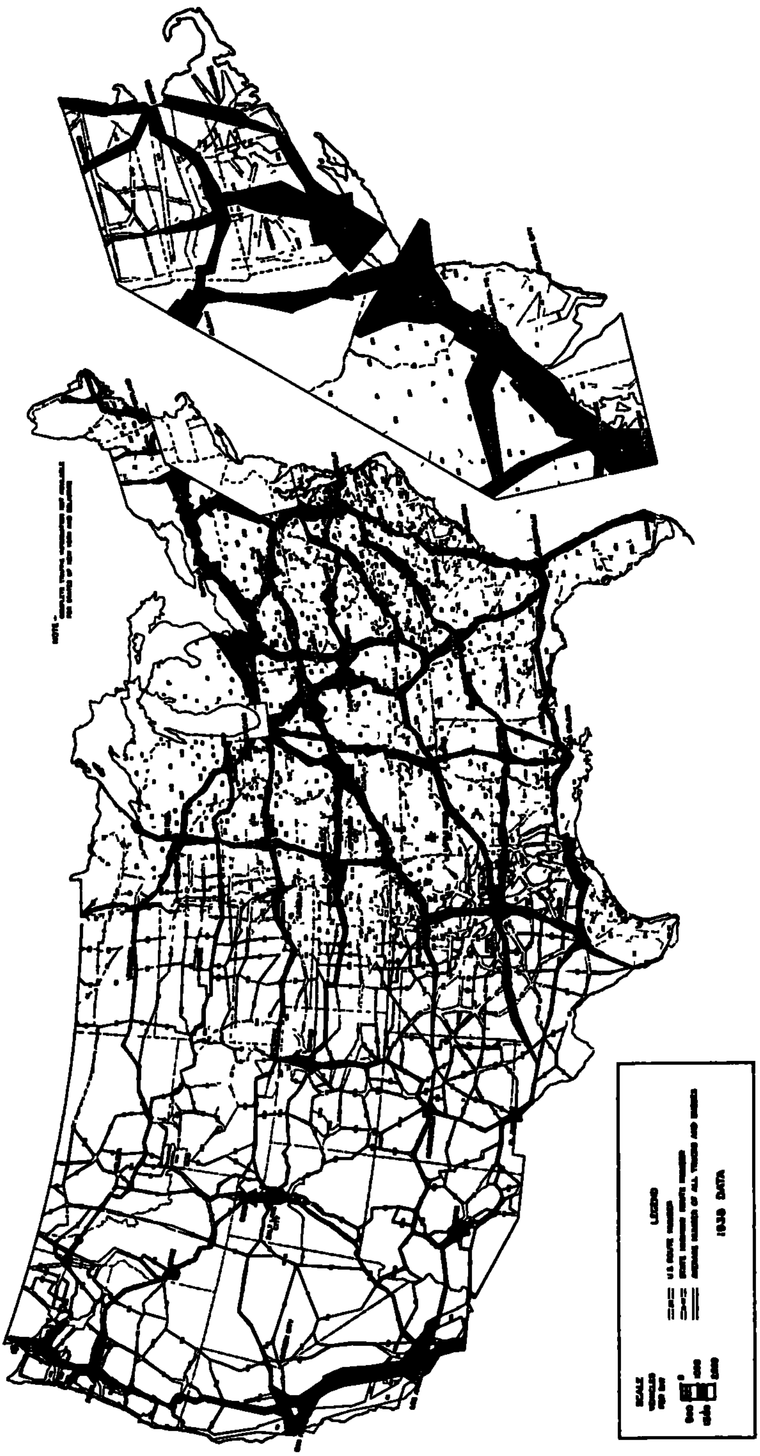


Figure 8. Comparison Between the Average Daily Truck and Bus Traffic on the Tentatively Selected Interregional System and that on Other Important Routes

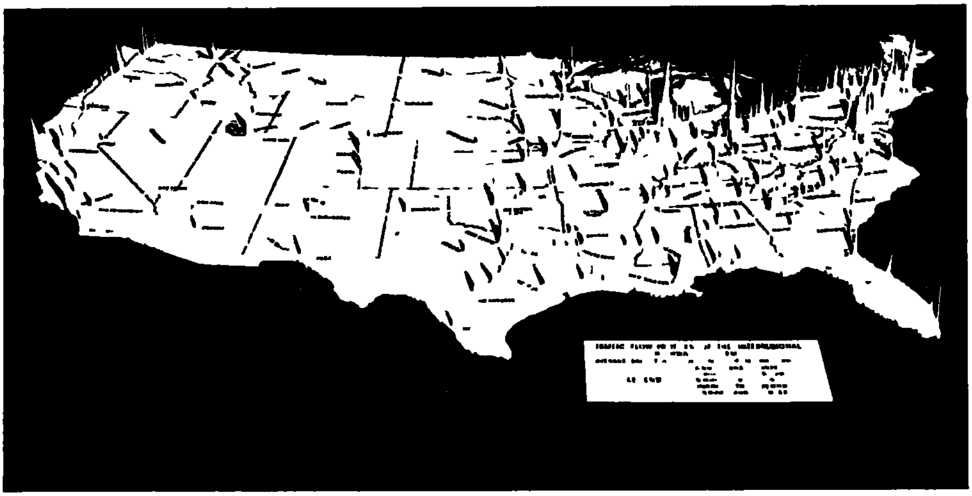


Figure 9. Traffic Flow Profile of the Tentative Interregional Highway System, 1937 Data

conditions cited are premised upon whether the city or town contributes either (1) the larger, or (2), the smaller part of the expected traffic on the route at its boundaries

NEEDS OF THE SYSTEM

In general, the main rural highways of the nation, beyond the immediate vicinity of the cities, are of sufficient capacity to discharge the flow of present traffic

If we accept a slight restriction of absolute freedom of movement, which is to be expected on the rural highways during short periods of maximum hourly traffic volume that occurs in the course of a year, we may consider an average daily volume of 3,000 vehicles as within the reasonably convenient discharge capacity of a 2-lane highway

On this basis, Figure 12 shows the portions of the interregional system now having only two lanes which should be widened Sections now having four or more lanes are also shown in Figure 12 To emphasize the contrast, Figure 13 has been prepared to show only the existing sections having four or more lanes. These data were obtained by analysis of diagrams that will be discussed later. They have been prepared for the entire tentative interregional system, first, between route intersections, and second, as continuous routes between main city termini These diagrams show the main physical and operating characteristics of the entire system. An analysis of these diagrams (Table 1) shows that on the tentative system, 1,230 miles of more than 2-lane width are within 25 miles of the larger municipalities having populations exceeding 100,000, of which 500 miles are 3-lane width and 730 miles are 4-lane width. The traffic data (Table 2) show that to serve traffic in accordance with the 3,000 vehicle premise, 1,770 additional miles of more than 2-lane width should be constructed within 25 miles of the larger municipalities, and 1,230 additional miles should be constructed on the remaining part of the rural interregional system

The traffic standards suggested contemplate the construction of roads greater than two lanes in width when the present

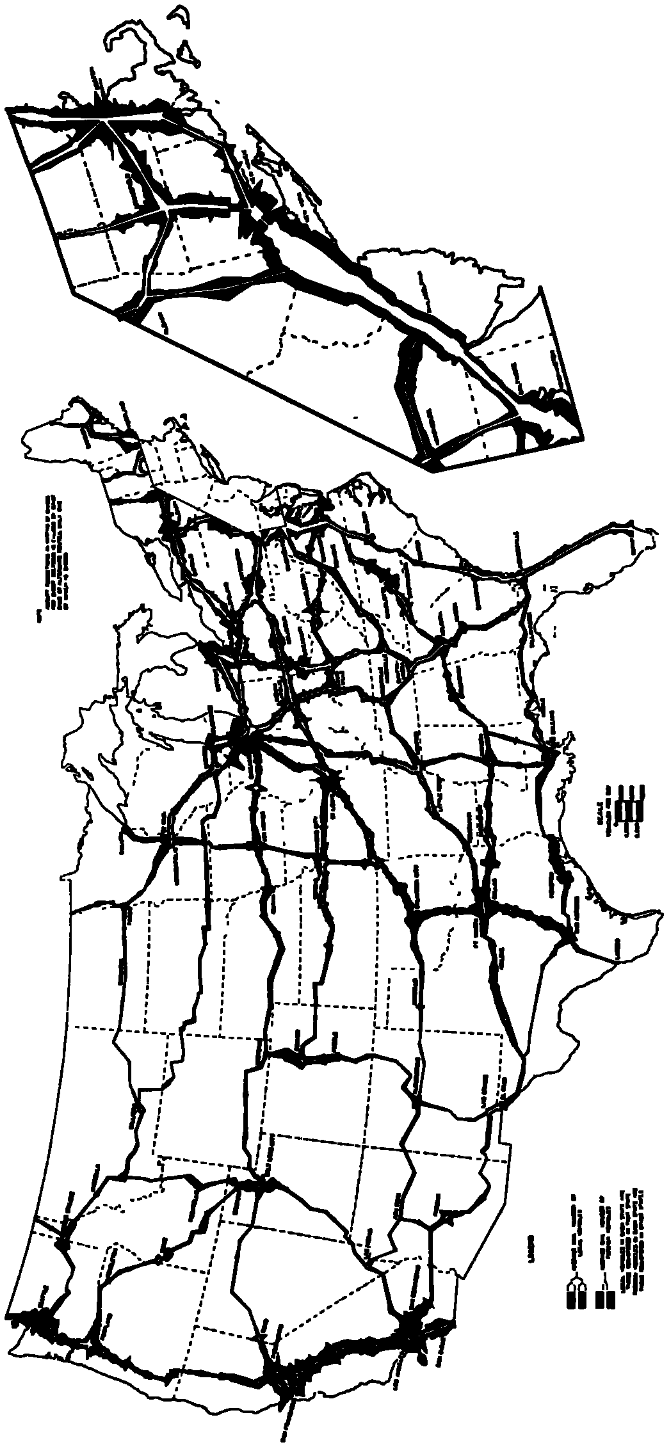


Figure 10. The Average Daily Passenger Car Traffic on the Tentatively Selected Interregional Highway System

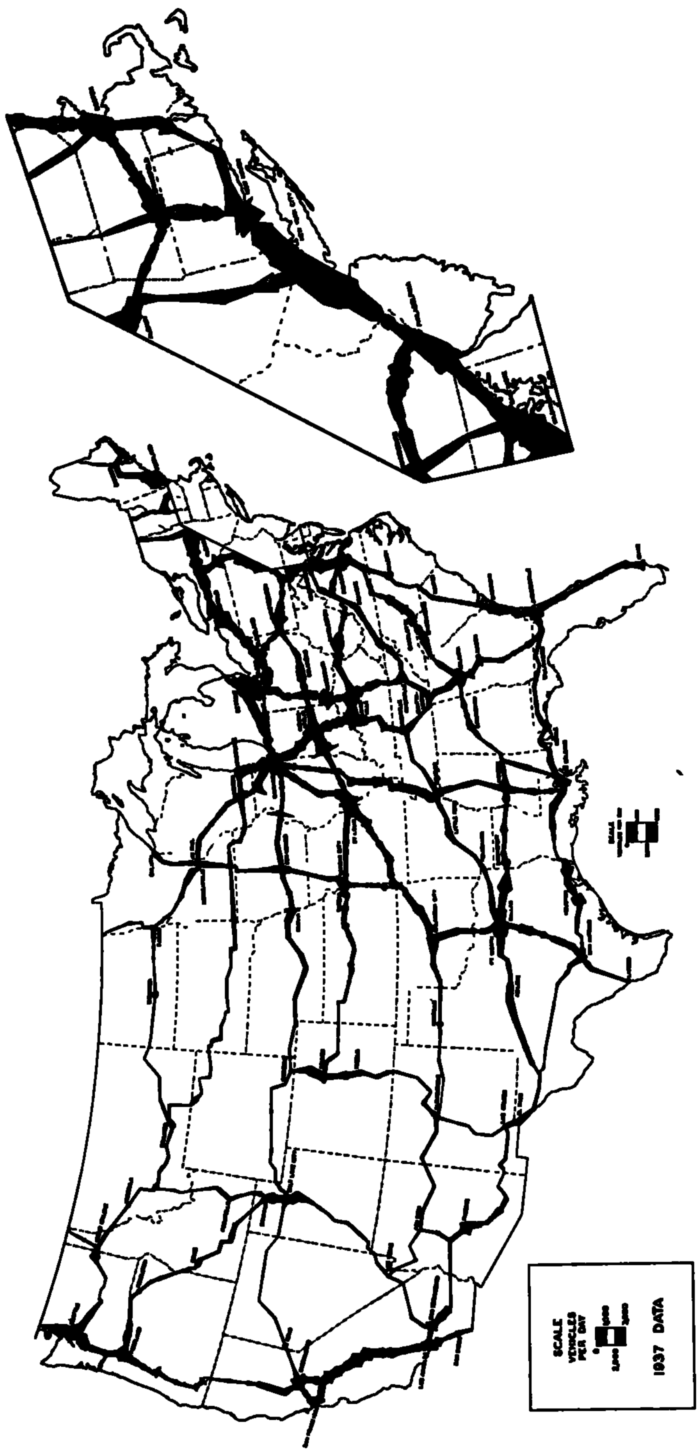


Figure 11. The Average Daily Truck and Bus Traffic on the Tentatively Selected Interregional Highway System

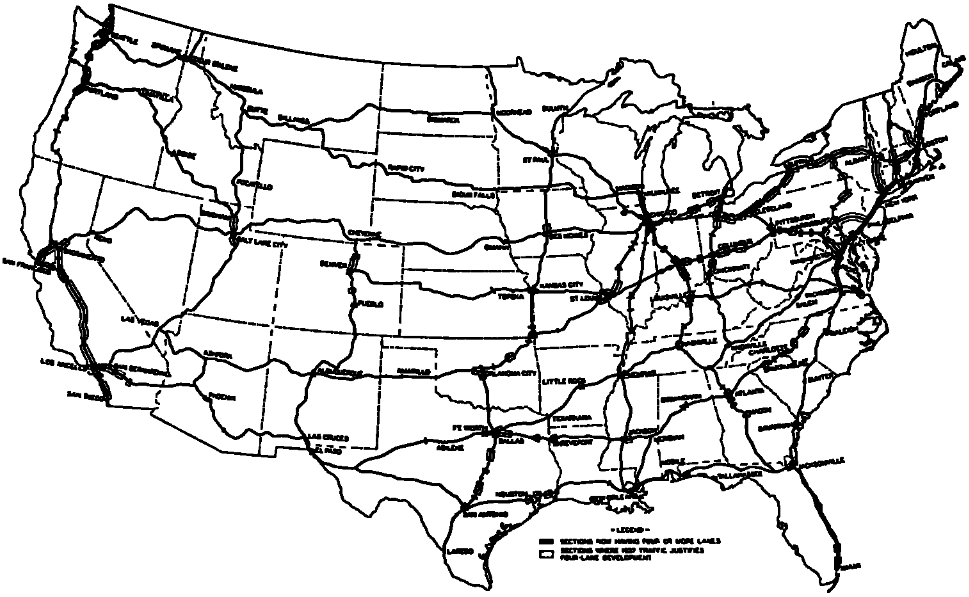


Figure 12. Location of Sections of the Tentatively Selected Interregional Highway System Having Four or More Lanes, and Other Sections Where 1937 Traffic Data Indicate the Need of Improvement to Four-lane Standards.

Figure 13. Location of Sections of the Tentatively Selected Interregional Highway System Having Four or More Lanes

average daily traffic volume exceeds 3,000 vehicles. For the purpose of this discussion it is assumed that 4-lane divided roads will be built for roads having present average traffic volume of from 3,000 to 10,000 vehicles per day. Should the present average volume exceed 10,000 vehicles per day, it might be that special conditions would require still wider pavements, but such requirements should be determined by the analysis of each case rather than by resort to a general standard.

TABLE 1

PRESENT LENGTHS OF SECTIONS OF THE TENTATIVE INTERREGIONAL HIGHWAY SYSTEM HAVING MORE THAN TWO LANES LOCATED WITHIN 25 MILES OF CITIES OF MORE THAN 100,000 POPULATION

Geographic divisions	Lengths having 3 lanes	Lengths having 4 lanes or more	Total length
	miles	*miles*	*miles*
United States	500	730	1,230
New England	80	90	170
Middle Atlantic	140	130	270
East North Central	80	150	230
West North Central	30	70	100
South Atlantic	70	90	160
East South Central	10	30	40
West South Central	10	60	70
Mountain		10	10
Pacific	80	100	180

By correlating the analysis of the complete records of 89 fixed-type automatic traffic counters, selected from a total of some 500 now in operation, with the analysis of speed and passing distance studies made on 28 sections of 2-lane highway in the States of Virginia, Maryland, Massachusetts, New York, Connecticut, and Illinois, eight sections of 4-lane undivided highway and five sections of 4-lane divided highway in the States of Massachusetts, New York, and Illinois, the following present general resume appears reasonable During certain periods

TABLE 2

A COMPARISON BETWEEN THE LENGTH OF SECTIONS OF THE TENTATIVE INTERREGIONAL HIGHWAY SYSTEM REQUIRING WIDTHS IN EXCESS OF TWO LANES AND THE LENGTH OF THE EXISTING SECTIONS HAVING MORE THAN TWO LANES[1]

Geographic divisions	Length of sections requiring more than 2 lanes		Length of sections in this category now having more than 2 lanes[2]		Length of sections requiring widening	
	Located within 25 miles of cities	Located beyond 25 miles of cities	Located within 25 miles of cities	Located beyond 25 miles of cities	Located within 25 miles of cities	Located beyond 25 miles of cities
United States	2,810	2,120	1,040	890	1,770	1,230
New England	390	180	170	70	220	110
Middle Atlantic	560	450	260	160	300	290
East North Central	540	280	200	100	340	180
West North Central	210	80	40	80	170	
South Atlantic	430	240	150	160	280	80
East South Central	100	30	10		90	30
West South Central	220	190	40	30	180	160
Mountain	90	60	10	40	80	20
Pacific	270	610	160	250	110	360

[1] The determination of need is based on the assumption that routes carrying in excess of 3,000 vehicles per day should be wider than two lanes

[2] Length of sections now having more than two lanes and carrying more than 3,000 vehicles per day

of the year, and particularly on week ends, the daily traffic will far exceed the average On roads with an average daily volume of 3,000 vehicles it may be expected that on one day each year the volume will reach 7,300 vehicles, and that on the ten days of heaviest traffic the daily volume will exceed 5,700 vehicles. This latter figure corresponds to what might be expected on a normal summer Sunday. On the average road carrying an average daily volume of 10,000 vehicles, the maximum daily volume will probably reach 18,500 vehicles, and on the tenth highest day, or the summer Sunday condition, the daily volume may be expected to be 15,000 vehicles. That volumes in this range require special analysis is shown by the fact that on one road, of modern 4-lane divided construction and corresponding to the design proposed for the interregional system, an average traffic of 10,000 vehicles per day would result in a peak day's flow of 24,000 vehicles, and on the ten days of highest traffic volume, the daily flow would exceed 19,000 vehicles Either special conditions surrounding this road induced these larger peaks, or its design permitted a traffic movement more nearly corresponding to the desires of the traveling public. The latter explanation is quite reasonable when it is considered that the peaks on this road are in the same proportion to the average daily flow of 10,000 as they are on the other roads with but 3,000 vehicles per day Undoubtedly congestion, caused by poor alignment, intersections and other restrictive features deters some travel and tends to lengthen the peak periods and thus to lower the peaks.

The significance of these figures is emphasized by translating them to terms of hourly traffic density, and measures of congestion On the average highway carrying an average daily volume of 3,000 vehicles, it may be expected that during one hour of the year the volume will be 750 vehicles, and during the ten hours of heaviest flow the volume will exceed 550 vehicles per hour. As a result of studies on selected average 4-lane roads it is estimated that with an average traffic of 10,000 vehicles per day, the maximum volume in any one hour during the year will be 1,750 vehicles, and for 10 hours the flow will exceed 1,450 vehicles per hour. On the more modern road with its sharper traffic peaks, the hourly volume will reach 2,500 vehicles, and for 10 hours the flow will be 1,800 per hour or more. Since the 4-lane roads will be divided, however, the traffic in each direction will be of greater importance than the total. For an entire day the traffic in either direction will nearly equal that in the other. For individual hours, however, as much as 70 percent may move one way or the other Average roads, with average traffic of 10,000 vehicles per day, thus will carry some 1,200 vehicles in one direction during the heaviest hour, while the road permitting free travel will be required to accommodate 1,750 vehicles in one direction during one hour of the year. With these traffic standards, vehicles will be able to move with very little restriction to speed even during the hour of heaviest flow.

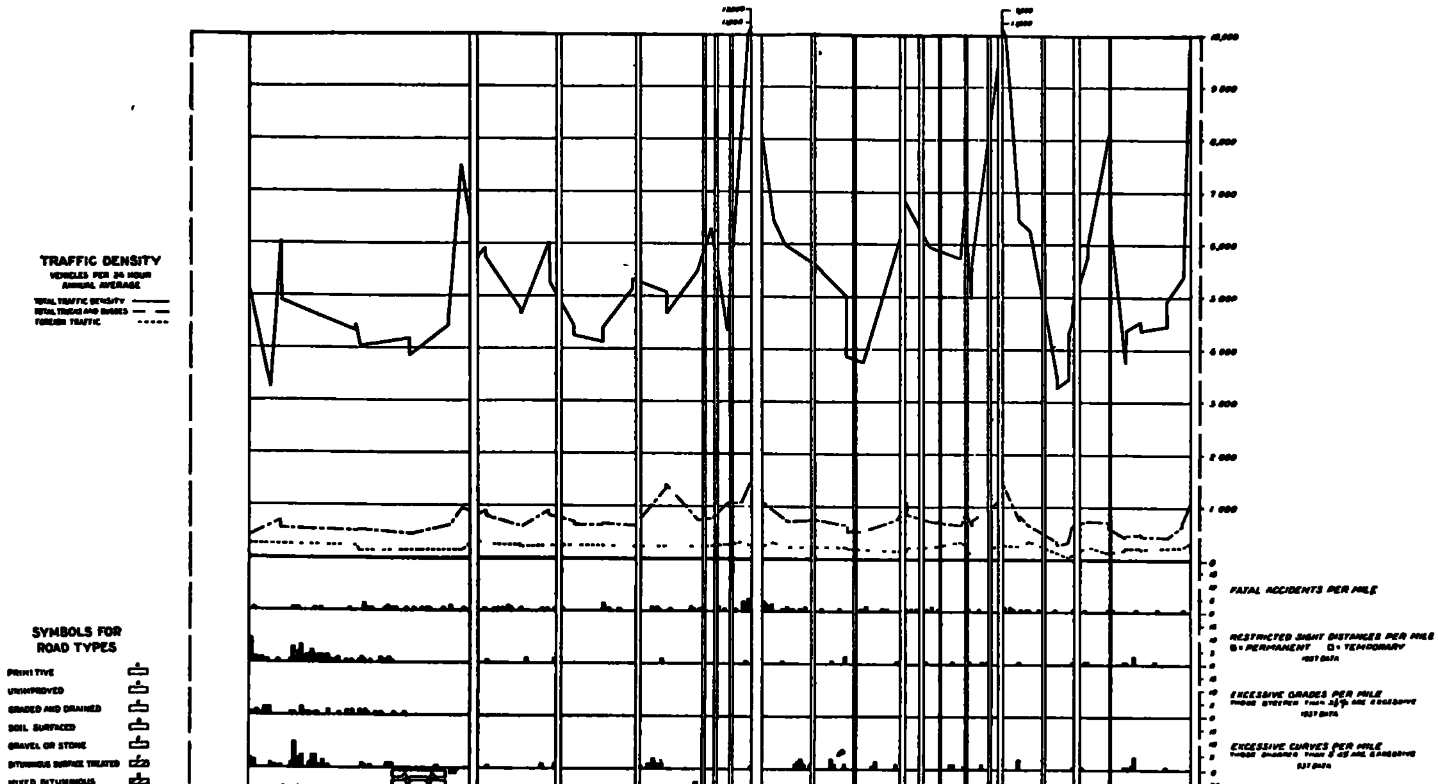
Studies were made on 12 sections of 2-lane road tangents with only minor restrictions in alignment and grade beyond the limits of the sections under study in Massachusetts, New York, and Illinois According to records obtained on the best of these sections, vehicle speeds in the periods of lightest traffic will generally average between 42 and 45 m p h., with 10 percent of the vehicles traveling at 52 to 54 m p.h. or faster With an hourly rate of 750 vehicles, the worst condition that may be expected on 2-lane roads, the average speeds will range from 39 to 42 m p h , with 10 percent of the vehicles moving at 48 to 50 m p h or faster The average difference in speed between successive vehicles (designated herein as the congestion index), which is a measure of the freedom of movement, decreases from around 8 m p.h. in the lightest traffic to 5 or less at a rate of 750 vehicles per hour. As moving traffic shifts from a 2-lane to a 4-lane divided road at this volume of 750 vehicles per hour, corresponding to 3,000 vehicles per day, the average speed increases to 47 m.p.h. or faster, with 10 percent of the vehicles moving at 58 m.p h. or more. The congestion index would show a speed difference between vehicles of about eight miles per hour. Studies made on the best of four sections of road in two States indicate that as the average daily volume increases to 10,000 vehicles per day, the speed on an undivided 4-lane road on which the traffic is not retarded by intersections and roadside establishments, the maximum anticipated hourly volume of 1,200 vehicles in one direction would move at an average speed of 40 m.p.h., with 10 percent exceeding 54 m.p.h. and the congestion index would become about seven miles per hour. On roads of more modern 4-lane divided design on which the sharper peaks will be expected, the maximum hourly rate in one direction may reach 1,750 vehicles per hour, but it is likely that the speed indices will equal or exceed the values listed above for 1,200 vehicles per hour.

Figure 14 shows a portion of the system from near Los Angeles to Sacramento. Distance on the diagram is represented by a very small scale. Beginning at the top, 1937 traffic density for the route is shown in terms of vehicles for 24 hours annual average classified as total traffic, total trucks and busses and that portion of the total that is classified as foreign (carrying out of State registration tags). Below traffic is shown the number of fatal accidents per mile and their location to the nearest mile. Below fatal accidents the number of restricted sight distances are given per individual mile classified as permanent and as temporary. The number of sight distances shown are those in each individual mile that are shorter than desirable limits of 1,000 ft. and 650 ft. in non-mountainous and mountainous areas, respectively; below sight distance data is shown the number of grades, longer than 500 ft in each individual mile exceeding 5 percent in non-mountainous areas and 8 percent in mountainous areas, considered generally as desirable maximum limits

Below grade data is represented to the indicated scale the number of curves in each individual mile of the highway that in 1937 were sharper than certain indicated desirable standards generally 6 deg. in non-mountainous areas and 14 degrees in mountainous areas

Below the curve data are shown pavement and right-of-way widths in feet. The character of the highway surface is represented by the shading or hatching within the broad bands extending across the diagram. The width of the pavement or surface on each mile is represented to the indicated scale by the width of the hatched band. The right-of-way width is shown to the same scale.

Next below pavement and right-of-way width follow data on the number of bridges per mile having rated capacity of less than 30,000 lb , and the rated capacity of the weakest bridge in each mile in pounds; the number of vertical clearances (less than 18 ft.) per mile, and the minimum vertical clearance in the mile; the number of restricted horizontal clearances per mile, and the minimum horizontal clearances per mile expressed as the number of feet less than the specified base width of 30 ft. for 2 lanes, 42 ft. for 3 lanes and 54 ft. for 4 lanes The lowest data on the diagram show the maximum gross loads in pounds for the sections involved, based on the data for the loadometer stations located as shown by the circles on the lowest line. The maximum gross loads are shown for one day frequency by a solid line and for frequency in the


TRAFFIC DENSITY
VEHICLES PER 24 HOUR
ANNUAL AVERAGE
TOTAL TRAFFIC DENSITY
TOTAL TRUCKS AND BUSES
FOREIGN TRAFFIC
SYMBOLS FOR
ROAD TYPES
PRIMITIVE
UNIMPROVED
GRADED AND DRAINED
SOIL SURFACED
GRAVEL OR STONE
BITUMINOUS SURFACE TREATED
MIXED BITUMINOUS
10,000
9 000
8,000
7 000
6,000
5 000
4 000
3 000
2 000
1 000
FATAL ACCIDENTS PER MILE
RESTRICTED SIGHT DISTANCES PER MILE
EXCESSIVE GRADES PER MILE
EXCESSIVE CURVES PER MILE

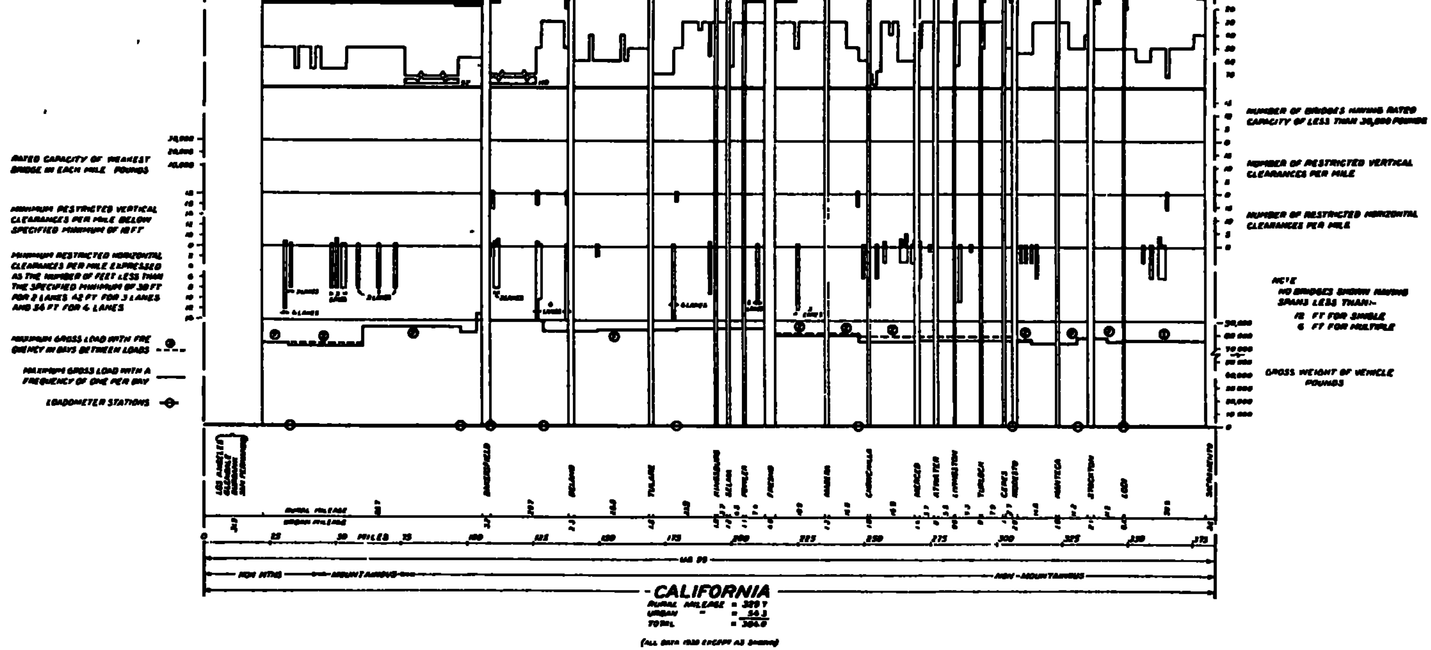


Figure 14. Traffic Profiles, Limiting Physical Components of the Road, and Limiting Features of Bridges for a Section of the Interregional Highway System

number of days as indicated by the number within the circle by a broken line.

Below the diagram is shown the rural mileage, the urban mileage, a mileage scale, the U. S. route number, and the chart shows that 9.9 percent of all rural sections carry less than 500 vehicles per day, 25.1 percent carry between 500 to 999 vehicles per day, et cetera. The horizontal width of the space for showing

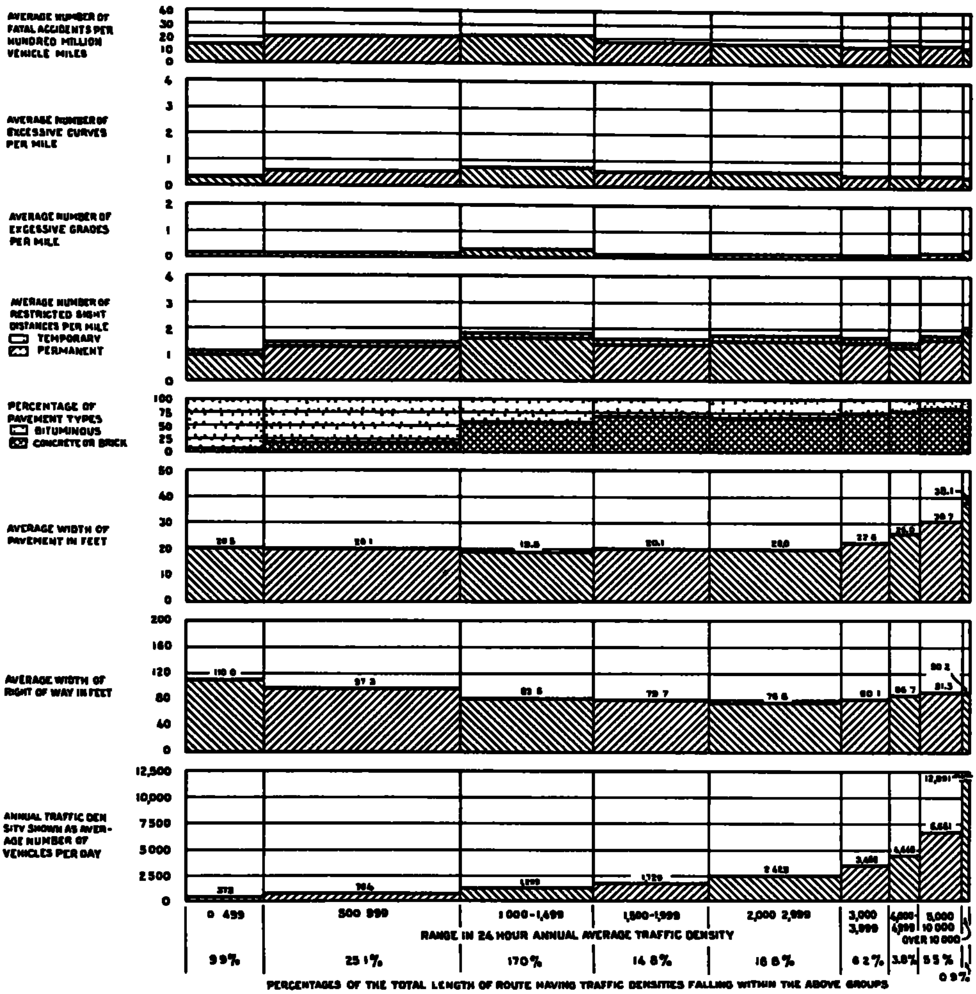


Figure 15. Summary of Physical Conditions on the Tentative Interregional Highway System Arranged in Traffic Volume Groups

classification of the route into mountainous and non-mountainous features within each of the various density groups is proportional to these percentages.

Figure 15 is a summary of all the physical conditions on the existing mileage of the tentative interregional system arranged in traffic volume groups. This

In the lowest space of the chart the average number of vehicles per day for all sections falling within each traffic density group is plotted. Next above this is plotted the average width of right-of-way for all sections falling within each group. Other conditions are shown graphically in the same manner in the other spaces.

On those sections carrying less than 500 vehicles per day are found the widest right-of-way, a relatively wide pavement, the lowest percentage of concrete or brick pavement, the fewest restricted sight distances per mile, relatively few excessive grades per mile, the fewest excessive curves per mile, and a relatively low rate of occurrence of fatal accidents. In sharp contrast are those sections carrying from 1,000 to 1,499 vehicles per day where there is found a relatively narrow right-of-way, the narrowest pavement, slightly more than 50 percent of concrete or brick pavement, a relatively large number of restricted sight distances, the greatest number of excessive grades per mile, the greatest number of excessive curves per mile and the most frequent rate of occurrence of fatal accidents.

Studies may be made of relationships shown in horizontal spaces. The narrowest right-of-way is found to exist for highway sections carrying 2,000 to 2,999 vehicles per day, the narrowest pavement for sections carrying 1,000 to 1,499 vehicles per day, the greatest percentage of concrete or brick pavement for sections carrying 5,000 to 9,999 vehicles per day, the greatest number of restricted sight distances for sections carrying more than 10,000 vehicles per day, the greatest number of excessive grades per mile for sections carrying 1,000 to 1,499 vehicles per day (but only slightly more than the number occurring on sections carrying more than 10,000 vehicles per day), the greatest number of excessive curves per mile for sections carrying 1,000 to 1,499 vehicles per day, and the greatest number of fatal accidents per hundred million vehicle miles for sections carrying 1,000 to 1,499 vehicles per day. The safest sections are those carrying more than 10,000 vehicles per day. They are by far the most congested, carrying 340 vehicles per day per foot of width. The sections which rank second in safety are those carrying less than 500 vehicles per day, or only 18 vehicles per day per foot of width.

Charts of similar form have been prepared for each of the 20 longer routes of the system Their comparison with the summary chart for the entire system indicates, in general, that routes in the southern part of the country are more dangerous than northern routes.

From available data, it is not possible to compare the accident rate on the rural interregional system with that for all rural highways. The accident figures shown have been expressed in terms of the number of fatal accidents per 100 million vehicle miles of travel on the system in 1937. On the rural interregional system there were 16 04 fatal accidents per hundred million vehicle miles. It can be estimated that about 1.2 persons were killed in each fatal rural highway accident in 1937. Assuming that this rate applies to the rural interregional system, it implies a death rate of about 19.2 per hundred million vehicle miles during 1937. The National Safety Council reports that there were 15.8 deaths per hundred million vehicle miles on all rural roads and urban streets in 1937.

Figure 16 is a summary chart showing the accumulative distribution of right-of-way widths by traffic density groups. From it there can be read directly the percentage of the aggregate length of all rural sections which carry less than any chosen number of vehicles per day and have right-of-way widths less than any chosen width For example, if it is assumed that a right-of-way width of 160 ft. is desired for all rural sections of the system carrying less than 3,000 vehicles per-day, the length of the system requiring additional right-of-way is shown to be 79 5 percent of the aggregate length of all rural sections. Similarly, Figure 17 shows the accumulative distribution of pavement widths. If it is assumed that a pavement width of 22 ft. is desired for all rural sections of the system carrying less than, say, 1,000 vehicles per day (this is a liberal assumption for those roads that now carry less than, say, 600 vehicles per day), the length of the system requiring

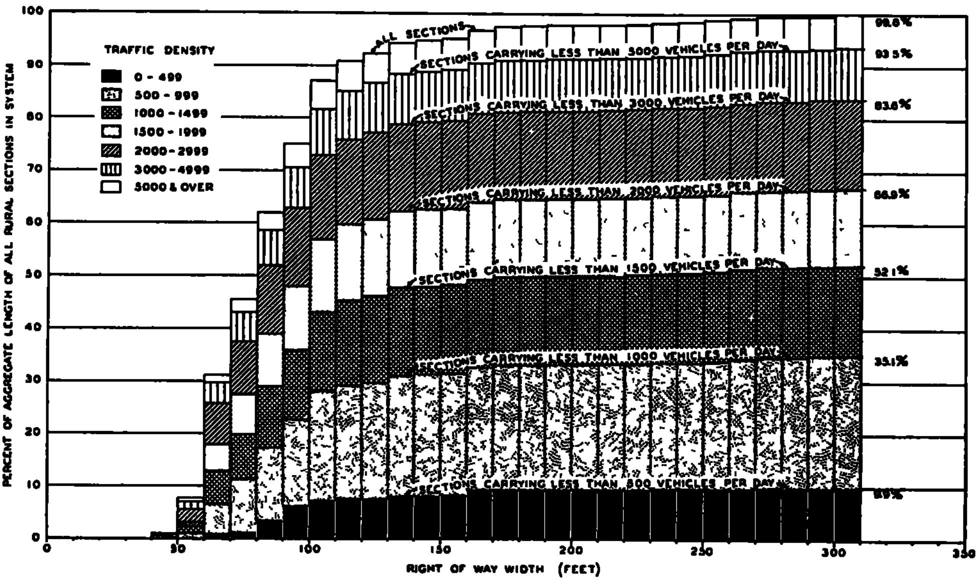


Figure 16. Accumulative Distribution of Lengths of Rural Sections of the Interregional System Having Various Right-of-way Widths and Traffic Densities

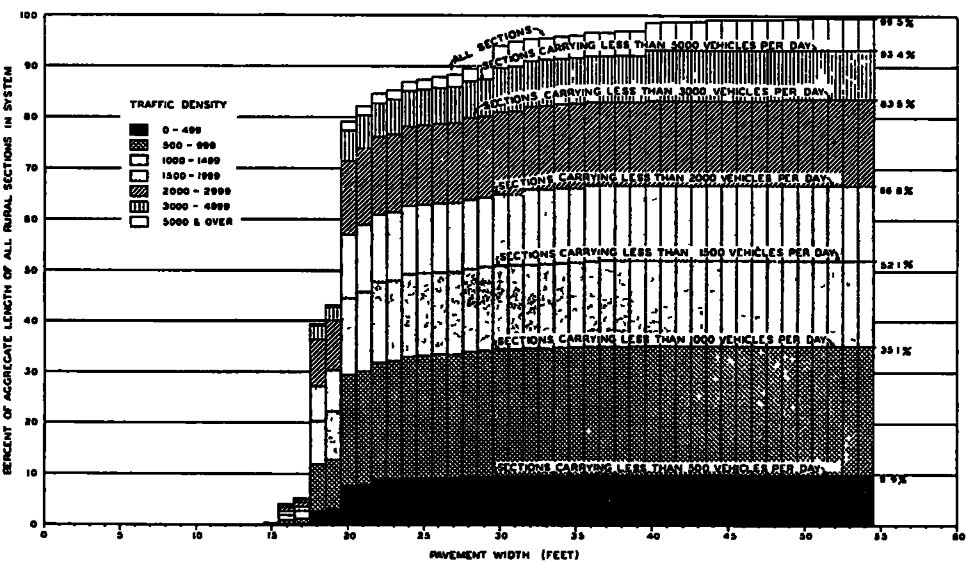


Figure 17. Accumulative Distribution of Lengths of Rural Sections of the Interregional System Having Various Pavement Widths and Traffic Densities

additional pavement width is shown to be 30.1 percent of the aggregate length of all rural sections. If it is assumed that a pavement width of 24 ft. is desired for all rural sections carrying less than 3,000 vehicles per day, but more than 1,000 vehicles per day, the length requiring additional pavement width may be obtained by reading on the vertical line representing 24 ft., the intercept between the 1,000 traffic density line and the 3,000 traffic density line. The length is shown to be 44 8 percent of the aggregate rural length.

A less direct use of these diagrams is the determination of the deficiency in the area of right-of-way or pavement for any desirable width for any traffic volume group. The area between the limits of the traffic volume group and to the left of the desired width is the deficient area which may easily be expressed first in terms of miles–feet and then converted to acres or square yards, if desired.

There is no doubt that, as measured by the diagrams, unsatisfactory conditions with respect to sight distance, curvature and gradient are common. There is no doubt that acquired rights-of-way are largely inadequate. There seems to be generally a reasonable accord between traffic volume and the number of pavement lanes, the amount and character of the traffic, and the kind of pavement or surface in place, but there is inadequate width of pavement lanes on a considerable mileage, usually near cities. These inadequacies are the concomitant of construction operations carried on for more than 20 years, during a period when top vehicle speeds have increased from 30 m.p.h. to well above 60 m.p.h. Then, too, when the oldest of the existing pavements were built there were only two or three million motor vehicles at a time when there was a strong demand for hard surfaced roads to get the traffic through.

These conditions account for the present need for correction of sharp curvature, heavy grades and alignment, that too often followed the narrow winding right-of-way then existing, with its resulting obsolescence and loss of invested capital.

The present need is to bring all of these interregional routes gradually up to a higher degree of usefulness by the reduction of excessive curvature, the easing of heavy grades, the opening up of longer sight distances, the general widening of pavement lanes and the construction of additional lanes, the separation of opposing traffic on heavy traffic sections, arrangements for the accommodation of slow moving traffic on heavy grades, the separation of grades at railroad grade crossings and highway intersections and the installation of protective cross traffic controls at others, the abatement of dangerous roadside conditions of all sorts, studied relocations for directness of travel between important objectives for serving the movements of longer range, and finally the acquisition of new right-of-way of sufficient width to make all of these improvements possible.

DESIGN STANDARDS

During the next 20 years planning technique will be greatly improved. The required number of traffic lanes will probably not be determined on the basis of traffic density, but on the basis of some measures of traffic congestion, which will take into account the magnitude, duration and frequency of occurrence of peak traffic loads, differences in speed of travel, et cetera. Until these measures of traffic congestion are perfected, the best basis for classification applicable to present available information is traffic density.

For immediate planning purposes, all rural sections of the interregional system are classified into six groups as follows:

Group I—Sections carrying less than 1,000 vehicles per day

Group II—Sections carrying 1,000 to 2,000 vehicles per day

- Group III—Sections carrying 2,000 to 3,000 vehicles per day
- Group IV—Sections carrying 3,000 to 5,000 vehicles per day
- Group V—Sections carrying 5,000 to 10,000 vehicles per day
- Group VI—Sections carrying 10,000 or more vehicles per day

Design standards considered in this study of the interregional system are shown in Table 3, and are based on the foregoing classification of rural sections. The "present average daily traffic density" is considered to be the traffic which follows· the existing road immediately before the improvement is undertaken, plus the existing traffic then following other routes which would logically be diverted to the interregional road if the improvement were made. It does not include "generated traffic" which is generally defined as that traffic which results from a new desire for travel on the part of certain people who would not care to perform the same travel in the absence of the improved facility

Groups I and II (traffic density 0-2,000) contain sections which cannot be expected to carry sufficient traffic to warrant construction to more than two lanes during the life of the new surface. The only difference in standards for sections in group I and those in group II is that a wider right-of-way is specified for the latter group. This additional right-of-way is justified by the improved protection to traffic and by the fact that high right-of-way costs can be avoided on those sections which will become inadequate from the standpoint of service in the shortest time, thus placing them in line for widening when the new surface must be replaced.

Practically all of the sections in group III (traffic density 2,000-3,000) will be due for construction as 4-lane divided highways when the life of the new surface has expired. Some of them will be ready for this higher type of construction before that time. The same right-of-way widths are specified for this group of sections as are specified for sections in group II.

All of the sections in group IV (traffic density 3,000-5,000) are assumed to carry sufficient traffic to warrant their construction as 4-lane divided highways.

Four-lane divided highway construction is also specified for sections in group V (traffic density 5,000-10,000), but greater cost allowances are provided for the attainment of the desirable standards, and more rigid limits are specified for the permissible standards Many of these sections may require widening before the new surface needs replacement.

Sections in group VI (traffic density in excess of 10,000) are assumed to require special design, usually requiring more than a 4-lane divided highway

The design standards marked "Desirable" in the table of standards apply wherever the average cost per mile for a section of any considerable length, after deducting the cost of right-of-way, property damage, large river spans, and railroad and highway grade separation structures, does not exceed the amounts shown in column 4 headed "Cost limitation, desirable standards." In order to provide flexibility in these standards, three subclassifications, based on typography of the terrain traversed, are introduced, each carrying a specific cost limitation These are designated relatively level, rolling, and mountainous, respectively

Wherever construction to desirable tandards would exceed these amounts, the standards to be applied are relaxed, but not further than indicated in the columns headed "Maximum" or "Minimum," except in rare instances

RIGHT-OF-WAY WIDTHS

The desirable width of right-of-way for all rural sections is shown to be 300 ft, except where the principles of border control can be employed. Border control consists of State control of development

TABLE 3

Interregional Highway Standards

Classification of section	Present average daily traffic density	Type of topography	Cost limitation desirable standards	Right-of-way width[1] Minimum: Without border control	Right-of-way width[1] Minimum: With border control	Right-of-way width[1] Desirable: Without border control	Right-of-way width[1] Desirable: With border control	Pavement widths[2]	Shoulder widths[3] On embankments[4]: Minimum permissible	Shoulder widths[3] On embankments[4]: Minimum desirable	Shoulder widths[3] In excavation: Inside of curves	Shoulder widths[3] In excavation, Outside of curve or on tangent: Minimum permissible	Shoulder widths[3] In excavation, Outside of curve or on tangent: Minimum desirable	Width of normal median strip[3] Minimum permissible: Rural humid areas	Width of normal median strip[3] Minimum permissible: Rural arid areas	Width of normal median strip[3] Minimum permissible: Suburban areas	Width of normal median strip[3]: Minimum desirable	Curvature: Maximum permissible	Curvature: Maximum desirable	Grades: Maximum permissible	Grades: Maximum desirable	Vertical curves
			dollars	*ft*	*ft*	*ft*	*ft.*	*ft*	*ft*	*ft*		*ft*	*ft*	*ft.*	*ft*	*ft*	*ft.*	*deg*	*deg.*	%	%	
I	0- 1,000	Relatively level	30,000	200	100	300	100	1–22	8	10	Maintain a uniform distance of 24 ft from center line of 2-lane highway to toe of cut slope at ditch bottom, except unwidened curves on grade tangents where 22 ft will be permitted Carry uniform slope from pavement	8	8					3	3	3	3	Vertical curves are to be designed as specified in the appendix
		Rolling	40,000	200	100	300	100	1–22	4	10		4	8					7	3	4 5	3	
		Mountainous	60,000	200	100	300	100	1–22	4	10		4	8					10	3	6	3	
II	1,000- 2,000	Relatively level	40,000	200	160[5]	300	160[5]	1–24	8	10		8	8					3	3	3	3	
		Rolling	60,000	200	160[5]	300	160[5]	1–24	4	10		4	8					7	3	4 5	3	
		Mountainous	80,000	200	160	300	160	1–24	4	10		4	8					10	3	6	3	
III	2,000- 3,000	Relatively level	40,000	200	160[5]	300	160[5]	1–24	8	10		8	10					3	3	3	3	
		Rolling	60,000	200	160[5]	300	160[5]	1–24	4	10		4	8					6	3	4	3	
		Mountainous	80,000	200	160	300	160	1–24	4	10		4	8					8	3	5	3	
IV	3,000- 5,000	Relatively level	100,000	240	240	300	240	2–24	8	10		8	10	32	32	12	43	3	3	3	3	
		Rolling	150,000	240	240	300	240	2–24	4	10		4	8	12	6	12	32	6	3	4	3	
		Mountainous	200,000	240	240	300	240	2–24	4	10		4	8	6	6	6	25	8	3	5	3	

V	5,000–10,000	Relatively level	225,000	240	240	300	240	2–24	8	10	edge to bottom	8	10	32	32	12	43	3	3	3	3
		Rolling	250,000	240	240	300	240	2–24	8	10	of ditch. Pro-	8	10	12	6	12	32	4	3	4	3
		Mountainous	300,000	240	240	300	240	2–24	8	10	vide compara-	8	10	6	6	6	25	5	3	5	3
											ble widths for										
VI	10,000 or more	Relatively level	Special design .						Not specified		4-lane divided	Not specified						3	3	3	3
		Rolling									highways Pro-							4	3	4	3
		Mountainous									vide adequate							5	3	5	3
											foundation and										
											stabilized sur-										
											face for all										
											shoulders										

[1] Additional right-of-way to be provided where required to accommodate grading Border control consists of State control of development of strip of land adjacent to the right-of-way for the purpose of eliminating objectionable features without necessarily preventing cultivation of arable land

[2] Number and width of individual 2-lane pavements All multiple parallel 2-lane pavements shall be separated by a median or dividing strip of land

[3] Design of shoulders and median or dividing strips shall be consistent with recommendations contained in "A Policy on Highway Types", 1940

[4] Exclusive of widening for guard rail

[5] In relatively level and rolling terrain, 100 ft of this width should run continuously on one side of center line

of a strip of land adjacent to the right-of-way for the purpose of eliminating objectionable features without necessarily preventing cultivation of arable land. Agreements for such control may even include an option to buy the adjacent strips at some future time. Where border control can be obtained, the sum of the right-of-way width and the controlled width should be equal to the right-of-way widths shown in the columns headed "without border control." It should be noted that for 2-lane highways, the border control principle will permit reductions in required right-of-way widths to as little as one-third to one-half the width otherwise required, and on such highways, where old alignments are followed, the additional right-of-way width required would often be small, if needed at all.

Where right-of-way costs are abnormally high and border control principles cannot be employed, minimum widths are specified, consisting of 200 ft. for 2-lane highways, and 240 ft. for 4-lane divided highways.

PAVEMENT WIDTHS

Pavement widths are shown to be 22 ft. for traffic densities of less than 1,000 vehicles per day, and 24 ft. for traffic densities of 1,000 to 3,000. Divided highways each 24 ft in width are specified for traffic densities of 3,000 to 10,000 vehicles per day.

SHOULDER AND MEDIAN STRIP WIDTHS

Shoulder widths of 8 ft in cut and 10 ft. in fill are generally specified as desirable. Minimum requirements permit widths of 8 ft in terrain classified as "light," and 4 ft. in terrain classified as "rolling" or "mountainous."

The design of shoulders and median strips is to be consistent with recommendations contained in "A Policy on Highway Types," published by the American Association of State Highway Officials.

CURVATURE AND GRADES

Curves of 3 deg and grades of 3 percent are specified as desirable for all topography and all groups of highway sections and should control the design wherever the estimated cost is less than the limitations appearing in column 4 of the table. In topography classified as "light," no departure from this requirement is permitted, even though the cost should exceed the limitation. For lightly traveled sections carrying less than 1,000 vehicles per day and located in mountainous country, 10-deg. curves and 6-percent grades are specified. The standards become increasingly severe for more heavily traveled routes, reaching limits of 5 deg. and 5 percent for mountainous sections carrying more than 5,000 vehicles per day.

SIGHT DISTANCES

The main controllable features of the highway which restrict sight distances may be classified as cut banks on horizontal curves and the crests in vertical alignment. At night, sight distance is also limited by the rate of change of the profile elevations in sags, which affects the point at which headlamp rays strike the road surface. At the present time, specifications for lengths of vertical curves in sags are incomplete.

The limiting degree of horizontal curvature must usually be selected on the basis of a number of economic considerations, only one of which is the extent to which sight distances are restricted Once the specifications for horizontal alignment and cross sections are settled, the sight distances limited by cut banks on horizontal curves are fixed. Obviously, there is no advantage to the traveling public which can be gained by increasing lengths of vertical curves occurring on horizontal curves beyond those lengths required to provide sight distance equal to that afforded by the horizontal curve There is, therefore, no justification for construction expenditures for this purpose. For sections of the highway located on tangent and short horizontal curves where sight distance is not restricted by cut banks but by crests in vertical alignment, vertical curves should be designed as in Appendix A.

GRADE SEPARATIONS

Highway grade separations are to be designed to conform with the recommendations contained in "A Policy on Highway Types" published by the American Association of State Highway Officials in 1940. For sections of the interregional highway carrying less than 3,000 vehicles per day and designed with two traffic lanes, grade separations are specified for all intersecting highways carrying more than 500 vehicles per day. Grade separations are also to be designed for all railroad crossings. Intersecting roads carrying between 200 and 500 vehicles per day at the time the interregional improvement is to be constructed will cross at grade employing the design principles contained in "A Policy on Highway Types" and "A Policy on Intersections at Grade."

For sections of the interregional system carrying between 3,000 and 10,000 vehicles per day and where 4-lane improvement is specified, grade separations are specified at all railroad intersections and at all intersecting highways carrying more than 200 vehicles per day. Intersecting roads carrying less than 200 vehicles per day will cross the interregional road at grade by means of special design conforming to the recommendations contained in "A Policy on Highway Types" For sections of the interregional system carrying more than 10,000 vehicles per day, grade separations are assumed for all railroad intersections and all intersecting highways left open for public use. Minor intersecting roads are to be closed to public use unless more than 200 vehicle-miles per day of additional travel are required for existing traffic to use an adjacent grade separation structure.

The foregoing discussion relates entirely to design standards for complete modernization of the interregional system. It will be interesting to compare these standards with the standards recently specified for emergency conditioning of principal routes of military importance. In these recent emergency standards provision is made for strengthening of weak bridges having ratings of less than H-15, widening of the narrowest bridges having horizontal clearance of less than 18 feet, increasing the vertical clearances at structures now having less than 12½ feet vertical clearance, widening pavements having surfaces less than 18 feet wide, widening shoulders to 8- or 10-foot widths wherever practical and improving surfaces which are not all-weather, dustless, or designed in accordance with present practice of individual States for repeated application of the 9,000-pound pneumatic wheel load.

The emergency standards provide for the improvement of all weak bridges to withstand H-15 loadings in rural areas and H-20 loadings in metropolitan areas. They provide for the increase of all vertical clearance less than 12½ ft. to a minimum of 14 ft. Where pavement widening is necessary, new pavement widths are specified as 20 ft. for sections carrying less than 600 vehicles per day, 22 ft. for sections carrying 1,600 to 1,800 vehicles per day, and 24 ft. for sections carrying more than 1,800 vehicles per day. Where horizontal clearances on bridges are less than 18 ft., the standards specify their widening to a minimum of 4 ft in excess of the pavement widths specified, and preferably 6 ft. in excess of these widths. Where horizontal clearances on underpasses are less than 18 ft, the standards specify their widening to a minimum of 30 ft., and preferably to a width equal to the new pavement widths specified plus shoulder widths. Except in mountainous terrain where heavy grading is encountered, the standards specify the widening of all shoulders which are now less than 8 ft. to a minimum width of 8 ft, and preferably to a width of 10 ft, wherever widening of shoulders can be undertaken economically. Where such widening is financially impractical or where sufficient right-of-way cannot be obtained without difficulty, the standards specify as a minimum requirement that 8- to 10-ft. shoulders about 2,000 ft long be provided at 4-mile intervals on the same side of the highway. It is recommended in the standards that such intermittent shoulders be staggered on both sides in order to make emergency parking spaces available in one direction or the other at 2-mile intervals.

COST ESTIMATE BASED ON CLASSIFICATION OF SECTIONS IN ACCORDANCE WITH 1937 TRAFFIC DENSITY

For economic development, the improvement of the system must extend over a period of many years. Many existing sections improved to present standards provide reasonably adequate service. The wisest course to follow is to improve each section to the interregional standards at the time when it can no longer continue to provide reasonably adequate service On this basis, the worst sections will be improved first, therefore sections in low traffic density groups as well as those in high traffic density groups will be placed under construction during the same year.

From year to year, the sections will progress from one traffic density group to another as the traffic density increases. An estimate of cost, therefore, based on a classification of sections in accordance with present day traffic densities would be low as compared with one which must be developed to represent the actual expenditures required over a period of years. Nevertheless, for planning purposes, an estimate based upon traffic density classifications for a selected year has considerable value in that it can be subdivided by economic regions to show the relative cost, by regions (Fig. 18), of the development proposed. These regional costs can be compared with various economic indices to test the soundness of the proposal, and particularly the distribution of the proposed work among the various regions.

The cost of improving the rural sections of the interregional system to the design standards recommended, based upon a classification of sections in accordance with 1937 traffic densities, is shown in Table 4. Grouped together are all rural sections in each geographic division for which the same number of traffic lanes are recommended The estimated length of 2-lane sections is 21,237.3 miles, and the estimated construction cost is $1,149,404,000, or $54,100 per mile. The estimated length of 4-lane sections is 4,048.3 miles, and the estimated construction cost is $741,447,000, or $183,100 per mile. The estimated length of sections requiring special designs with more than 4 lanes is 268.6 miles, and the estimated construction cost is $117,887,000, or $438,900 per mile. Right-of-way costs for rural sections are estimated to be 7.5 percent of the construction costs, and an allowance for engineering and contingencies equal to 15 percent of the construction cost is made

The estimated cost of improving urban sections is shown in Table 5. There are 3,776 5 miles of urban sections, representing 12.9 percent of the total length of the system The estimated construction cost is $1,902,834,000, or $503,900 per mile. Right-of-way costs are estimated to be 25 percent of this amount, and a further allowance of 15 percent of the construction cost is made for engineering and contingencies.

The estimated costs of urban sections are not sufficient to permit construction to theoretically ideal standards, but they are thought to be reasonable estimates of probable costs which would result from a general program aimed toward providing facilities as nearly approaching the ideal standards as practical, after reasonable compromises had been made. As one test of the consistency of the estimates for individual cities, the costs were reduced to a per capita basis. The estimates showed that per capita costs in large cities were lower than those in small cities. That this should be so is obvious when it is considered that the service rendered to a city by merely projecting the routes of exceeds the rural cost, this urban cost is estimated to be only about one-fifth of the expenditure which must be made to completely modernize all the main connecting thoroughfares in the cities traversed. Unless these additional and greater expenditures are made, the investment in the interregional route is threatened by the rapid obsolescence of urban portions of improved interregional routes which may be anticipated as a result of their attracting a disproportionately large share of traffic. This would probably

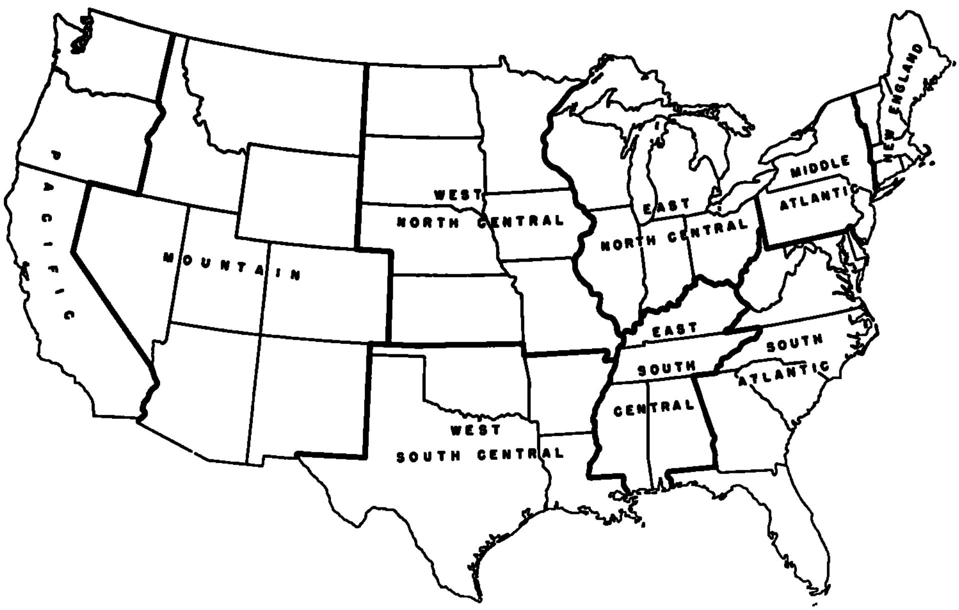


Figure 18. Census Regions of the United States

the interregional system through it varies inversely with the population. This condition implies that attention should be directed to the need for extensive city development, which can be accomplished only in small part by the construction of the trans-city connections of the interregional system. It emphasizes the fact that the larger the area of local congestion, the less is the amount of relief to be obtained merely by development of the system Even though the urban cost, including an allowance for right-of-way, lead to the outward development of the city further than would prove most economical to its interests. Only by construction of comparable facilities in other directions can the economic growth of cities, and the success of the interregional system itself, be assured

In sharp contrast to the cost estimates for the improvement of the interregional system to recommended standards is the cost estimate for its improvement to the standards recently specified for the emer-

TABLE 4

Estimated Cost of Improving the Interregional System, Rural Sections Only

Geographic divisions	Less than 3,000 vehicles per day			3,000 to 10,000 vehicles per day			More than 10,000 vehicles per day			Total length	Total construction cost	15 percent allowance for engineering and contingencies	7 5 percent allowance for right-of-way	Total cost	Total cost per mile
	Length	Cost per mile	Estimated construction cost	Length	Cost per mile	Estimated construction cost	Length	Cost per mile	Estimated construction cost						
	miles	*1,000 dollars*	*1,000 dollars*	*miles*	*1,000 dollars*	*1,000 dollars*	*miles*	*1,000 dollars*	*1,000 dollars*	*miles*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*
United States	21,237 3	54	1,149,404	4,048 3	183	741,447	268 6	439	117,887	25,554 2	2,008,738	301,311	150,656	2,460,705	96
New England	662 2	70	46,354	337 2	192	64,742	70 3	464	32,619	1,069 7	143,715	21,557	10,779	176,051	165
Middle Atlantic	383 0	70	26,810	699 6	270	188,892	102 6	540	55,404	1,185 2	271,106	40,666	20,333	332,105	280
East North Central	2,072 8	60	124,368	720 4	173	124,629	4 1	433	1,775	2,797 3	250,772	37,616	18,808	307,196	110
West North Central	3,516 6	50	175,830	233 4	151	35,243	4 3	250	1,075	3,754 3	212,148	31,822	15,911	259,881	69
South Atlantic	2,442 3	55	134,326	541 7	162	87,755	45 2	350	15,820	3,029 2	237,901	35,685	17,843	291,429	96
East South Central	1,873 1	50	93,655	128 9	161	20,753				2,002 0	114,408	17,161	8,581	140,150	70
West South Central	3,035 6	50	151,780	403 2	130	52,416	6 2	300	1,860	3,445 0	206,056	30,909	15,454	252,419	73
Mountain	5,566 9	50	278,345	143 0	133	19,019				5,709 9	297,364	44,605	22,302	364,271	64
Pacific	1,684 8	70	117,936	840 9	176	147,998	35 9	260	9,334	2,561 6	275,268	41,290	20,645	337,203	132

gency improvement of principal routes of military importance. Table 6 shows that the estimated construction cost of improving rural sections to recommended standards is about six times the cost of improvement to emergency standards.

Although a cost estimate on the latter basis was not prepared for urban sections, it would not seem unreasonable to assume that the same relationship would exist between estimates prepared for the urban sections as is shown for the rural sections.

TABLE 5

ESTIMATED COST OF IMPROVING THE INTERREGIONAL SYSTEM, URBAN SECTIONS ONLY

Geographic divisions	Length	Construction cost per mile	Estimated construction cost	15 percent allowance for engineering and contingencies	25 percent allowance for right-of-way	Total cost	Total cost per mile
	miles	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	
United States	3,776 5	504	1,902,834	285,425	475,708	2,663,967	705
New England	227 0	807	183,189	27,478	45,797	256,464	1,130
Middle Atlantic	407,1	1,052	428,269	64,240	107,067	599,576	1,473
East North Central	628 4	537	337,451	50,618	84,363	472,432	752
West North Central	452 5	385	174,212	26,132	43,553	243,897	539
South Atlantic	549 9	385	211,712	31,757	52,928	296,397	539
East South Central	320 9	365	117,128	17,569	29,282	163,979	511
West South Central	437 6	319	139,594	20,939	34,898	195,431	447
Mountain	371 5	275	102,162	15,324	25,541	143,027	385
Pacific	381 6	548	209,117	31,368	52,279	292,764	767

TABLE 6

A COMPARISON OF THE ESTIMATED COST OF EMERGENCY WORK WITH THE ESTIMATED COST OF IMPROVEMENT TO RECOMMENDED LONG-RANGE STANDARDS FOR RURAL SECTIONS OF THE INTERREGIONAL SYSTEM

Geographic divisions	Length of rural sections	Estimated construction cost of improving interregional system		Ratio of cost of emergency work to the cost based on long-range standards
		Using recommended long-range standards	Using standards recommended for emergency work	
	miles	*1,000 dollars*	*1,000 dollars*	*percent*
United States	25,554 2	2,008,738	365,657	18 2
New England	1,069 7	143,715	21,799	15 2
Middle Atlantic	1,185 2	271,106	18,548	6 8
East North Central	2,797 3	250,772	25,690	10 2
West North Central	3,754 3	212,148	52,206	24 6
South Atlantic	3,029 2	237,901	57,170	24 0
East South Central	2,002 0	114,408	33,220	29 0
West South Central	3,445 0	206,056	54,351	26 4
Mountain	5,709 9	297,364	66,116	22 2
Pacific	2,561 6	275,268	36,557	13 3

INTERREGIONAL DISTRIBUTION OF THE SYSTEM

The report on "Toll Roads and Free Roads" suggests that the routes of the system be selected "without specific limitation in each State." Although the system described in this paper was selected on the basis of present traffic service to population concentrations and with particular reference to interregional coverage, it may be well to present certain economic facts and see how the selected tentative system measures up to these facts.

Table 7 shows the population, area, national wealth, national income, cash farm income, value of manufactures, and value of mineral production, distributed by geographic divisions. Table 8 shows these same values expressed in terms of the percentage which falls in each of the geographic divisions. To the right of the table are included columns showing the portion of the length and the cost of the interregional system which fall within each geographic division. The distribution is made on the basis of the rural sections, the urban sections, and also on the basis of the rural and urban sections combined. For purposes of comparing the cost of the work that would be done in each region following the long-range recommended standards with the cost of the work that would be done following the emergency standards, the column on the extreme right has also been added which shows the distribution of the costs of the emergency work. Figure 19 shows this same comparison graphically. To the left of the group of plotted values

TABLE 7

SELECTED ECONOMIC DATA BY GEOGRAPHIC DIVISIONS

Geographic divisions	Population 1940[1]	Area 1930[2]	National wealth 1936[3]	National income 1937[3]	Cash farm income 1939[4]	Value of manufactures 1937[5]	Value of mineral production 1937[6]
		square miles	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*
United States	131,409,881	2,973,776	294,481,000	69,419,000	7,711,000	60,710,053	4,672,996
New England	8,426,566	61,976	22,615,000	5,459,000	246,500	5,109,927	24,757
Middle Atlantic.	27,419,893	100,000	87,613,000	19,209,000	672,600	16,596,004	708,951
East North Central	26,550,823	245,564	64,841,000	15,978,000	1,540,900	19,971,022	453,745
West North Central	13,490,492	510,804	29,341,000	6,071,000	1,841,000	4,091,727	417,055
South Atlantic	17,771,099	269,073	27,049,000	6,979,000	789,600	5,403,450	406,084
East South Central	10,762,967	179,509	11,479,000	2,858,000	471,800	1,977,318	220,658
West South Central	13,052,218	429,746	17,363,000	4,569,000	847,200	2,693,027	1,388,412
Mountain	4,128,042	859,009	10,663,000	1,974,000	506,300	928,951	543,091
Pacific	9,682,781	318,095	23,517,000	6,322,000	795,100	3,938,627	510,243

[1] Preliminary figures issued by the Bureau of the Census, total includes 125,000 undistributed.
[2] Figures issued by the U S Bureau of the Census.
[3] National Industrial Conference Board Studies in Enterprise and Social Progress, pages 62, 117.
[4] "Crops and Markets"—January 1940.
[5] U. S Department of Commerce, report dated January 31, 1940.
[6] Minerals Yearbook, 1939, page 9

for each geographic division, there are grouped the general economic indices. The value plotted to the extreme left is the percentage of the United States population that falls within the geographic division, next is the percentage of the area, third, the percentage of the national wealth, fourth, the percentage of the national income, fifth, the percentage of the national cash farm income, sixth, the percentage of the national value of manufactures, and finally, the percentage of the national value of mineral production. The next group of plotted values shows the percentage of the length of the interregional system falling within the geographic division In this group, the value to the left represents the percentage of the length of all rural sections, and the one on the right represents the percentage of the total length including both rural and urban

TABLE 8

GEOGRAPHICAL DISTRIBUTION OF THE LENGTH AND ESTIMATED COST OF THE INTERREGIONAL SYSTEM IN RELATION TO VARIOUS ECONOMIC INDICES

Geographic divisions	Population 1940[1]	Area 1930[2]	National wealth 1936[3]	National income 1937[4]	Cash farm income 1939[4]	Value of manufactures 1937[5]	Value of mineral production 1937[6]	Length of interregional system: Rural sections only	Length: Urban sections only	Length: All sections	Estimated cost of interregional system: Rural sections only	Cost: Urban sections only	Cost: All sections	Estimated cost of improving rural sections of system to "emergency" standards only
	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
United States	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0
New England	6 4	2 1	7 7	7 9	3 2	8 4	0 6	4 2	6 0	4 4	7 1	9 6	8 5	5 9
Middle Atlantic	20 9	3 4	29 7	27 7	8 7	27 3	15 2	4 6	10 8	5 4	13 5	22 5	18 2	5 1
East North Central	20 2	8 2	22 0	23 0	20 0	32 9	9 7	11 0	16 6	11 7	12 5	17 7	15 2	7 0
West North Central	10 3	17 2	10 0	8 7	23 9	6 8	8 9	14 7	12 0	14 4	10 6	9 2	9 8	14 3
South Atlantic	13 5	9 0	9 2	10 1	10 2	8 9	8 7	11 9	14 6	12 2	11 8	11 1	11 5	15 6
East South Central	8 2	6 0	3 9	4 1	6 1	3 3	4 7	7 8	8 5	7 9	5 7	6 2	5 9	9 1
West South Central .	9 9	14 5	5 9	6 6	11 0	4 4	29 7	13 5	11 6	13 2	10 3	7 3	8 7	14 9
Mountain	3 2	28 9	3 6	2 8	6 6	1 5	11 6	22 3	9 8	20 7	14 8	5 4	9 9	18 1
Pacific	7 4	10 7	8 0	9 1	10 3	6 5	10 9	10 0	10 1	10 1	13 7	11 0	12 3	10 0

[1] Preliminary figures issued by the U S Bureau of the Census

[2] Figures issued by the U S Bureau of the Census

[3] National Industrial Conference Board Studies in Enterprise and Social Progress, pages 62, 117.

[4] "Crops and Markets"—January 1940

[5] United States Department of Commerce, report dated January 31, 1940.

[6] Minerals Yearbook, 1939, page 9

sections, and the mid-section represents the percentage of all urban sections. The third group of plottings shows the percentage of the estimated cost of the interregional system falling within the geographic division. The value to the left shows the percentage of the cost of all rural sections, and the one on the right shows the percentage of the total cost including both rural and urban sections. The single value plotted on the extreme right for each geographic division represents the percentage of the estimated cost of improvement of rural sections to emergency standards.

It will be noted that the distribution of mileage does not always compare favorably with the various economic indices. However, the distribution of costs of construction to long-range standards in all such cases tends to correct this condition. The level of the plotted values for rural costs alone is usually nearer the level of the economic indices, and the level of the plotted values for total costs is still nearer. The conclusion may be drawn that the system selected on the basis of present traffic service to population concentrations is well distributed on a general economic basis.

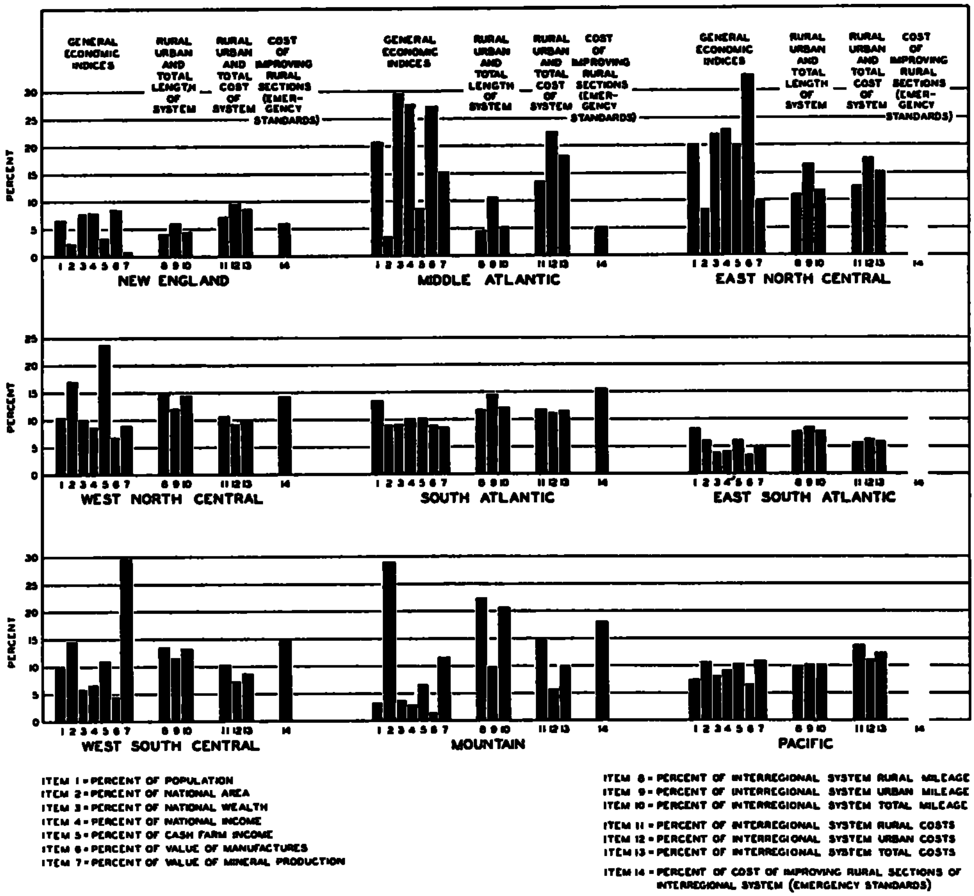


Figure 19. Geographical Distribution of the Length and Estimated Cost of the Interregional System in Relation to Various Economic Indices

The levels of the plotted values representing the percentage distribution of the estimated cost of improvement of rural sections to emergency standards, when compared with the levels of the economic indices is not so favorable. This is percentage which falls in each geographic division, and are compared with the portions of the length and the cost of the interregional system falling within each division. Figure 20 shows these same relationships graphically.

TABLE 9

PERTINENT HIGHWAY FACTS AND FIGURES BY GEOGRAPHIC DIVISIONS

Geographic divisions	Federal-aid allotments 1941	Mileage of rural highways[1]	Mileage of urban streets and alleys[2]	Total mileage of roads, streets and alleys	Motor vehicle registrations 1939[3]	State highway income 1939[4]
	1,000 dollars	*miles*	*miles*	*miles*	*vehicles*	*1,000 dollars*
United States	154,362	2,954,367	303,820	3,258,187	31,007,620	1,144,064
New England	7,134	82,364	14,591	96,955	1,944,510	91,450
Middle Atlantic	17,781	187,494	47,802	235,296	5,813,487	187,911
East North Central..	25,364	438,311	67,033	505,344	7,078,336	195,464
West North Central	25,390	765,604	49,706	815,310	3,862,461	115,000
South Atlantic	19,754	333,472	33,288	366,760	3,274,027	185,365
East South Central.	12,190	238,832	16,758	255,590	1,458,731	94,041
West South Central	18,486	380,273	34,128	414,401	2,800,053	118,104
Mountain	17,253	333,050	14,178	347,228	1,210,838	66,260
Pacific	11,010	194,967	26,336	221,303	3,565,177	90,469

[1] Figures compiled in January 1941 by Public Roads Administration and based on latest inventory data or estimates furnished by the State-wide Highway Planning Surveys

[2] Estimates compiled in January 1941 by Public Roads Administration from fiscal data collected by the State-wide Highway Planning Surveys

[3] Figures include publicly-owned, private and commercial motor vehicles. Figures do not include trailers, semitrailers or motorcycles, nor 2,250 motor vehicles publicly-owned and not registered in any State, compiled from reports of State authorities

[4] Figures include transactions relating to debt service, operations of special bridge and grade separation authorities, expenditures of local authorities on State highways and similar transactions.

caused by the fact that in working to emergency standards, the same degree of improved service cannot be afforded throughout the country. Only the worst conditions can be remedied.

Table 9 shows the distribution to geographic divisions of highway factors. These items include the 1941 Federal-aid allotments, the total rural highway mileage, the mileage of urban streets and alleys, the total mileage of roads, streets and alleys, the 1939 motor vehicle registrations, and the State highway departments' income in 1939. In Table 10 these items are expressed in terms of the

USE OF THE TENTATIVE RURAL INTERREGIONAL SYSTEM BY MOTOR VEHICLES

Freight vehicles

Close estimates of the use of the rural interregional highways by commercial freight vehicles may be obtained for each State from the average daily commercial traffic per mile, the mileage of the system, the average load carried by commercial vehicles and the percent of loaded to total commercial vehicles. All of these data are produced by the highway planning surveys.

Table 11 shows the mileage of rural interregional highways and the average daily ton-mileage of goods carried by commercial vehicles for each region. The commercial vehicle-mileage of loaded miles per mile for the country as a whole. Vehicle loadings in the Mountain States are not below average, but the number of commercial vehicles per mile is lower than in any other region.

TABLE 10

GEOGRAPHICAL DISTRIBUTION OF THE LENGTH AND ESTIMATED COST OF THE INTERREGIONAL SYSTEM IN RELATION TO VARIOUS HIGHWAY FACTORS

Geographic divisions	Federal aid allotments 1941	Mileage of rural highways[1]	Mileage of urban streets and alleys[2]	Total mileage of roads, streets and alleys	Motor vehicle registrations 1939[3]	State highway income 1939[4]	Length of interregional system			Estimated cost of interregional system			Estimated cost of improving rural sections of system to "emergency" standards only
							Rural sections only	Urban sections only	All sections	Rural sections only	Urban sections only	All sections	
	per-cent	*per-cent*	*per-cent*	*per-cent*	*per-cent*	*per-cent*	*per-cent*	*per-cent*	*per-cent*	*per-cent*	*per-cent*	*per-cent*	*per-cent*
United States	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0
New England	4 6	2 8	4 8	3 0	6 3	8 0	4 2	6 0	4 4	7 1	9 6	8 5	5 9
Middle Atlantic	11 5	6 3	15 7	7 2	18 7	16 4	4 6	10 8	5 4	13 5	22 5	18 2	5 1
East North Central	16 4	14 8	22 0	15 5	22 8	17 1	11 0	16 6	11 7	12 5	17 7	15 2	7 0
West North Central	16 5	25 9	16 4	25 0	12 5	10 1	14 7	12 0	14 4	10 6	9 2	9 8	14 3
South Atlantic	12 8	11 3	11 0	11 3	10 6	16 2	11 9	14 6	12 2	11 8	11 1	11 5	15 6
East South Central	7 9	8 1	5 5	7 8	4 7	8 2	7 8	8 5	7 9	5 7	6 2	5 9	9 1
West South Central	12 0	12 9	11 2	12 7	9 0	10 3	13 5	11 6	13 2	10 3	7 3	8 7	14 9
Mountain	11 2	11 3	4 7	10 7	3 9	5 8	22 3	9 8	20 7	14 8	5 4	9 9	18 1
Pacific	7 1	6 6	8 7	6 8	11 5	7 9	10 0	10 1	10 1	13 7	11 0	12 3	10 0

[1] Figures compiled in January 1941 by Public Roads Administration and based on latest inventory data or estimates furnished by the State-wide Highway Planning Surveys

[2] Estimates compiled in January 1941 by Public Roads Administration from fiscal data collected by the State-wide Highway Planning Surveys

[3] Figures include publicly-owned, private and commercial motor vehicles Figures do not include trailers, semitrailers or motorcycles, nor 2,250 motor vehicles publicly-owned and not registered in any State, compiled from reports of State authorities

[4] Figures include transactions relating to debt service, operations of special bridge and grade separation authorities, expenditures of local authorities on State highways and similar transactions.

vehicles by States multiplied by average carried load is the basis of these estimates.

The relative use of rural interregional highways varies widely between regions of the country. In the Mountain States average daily ton-miles per mile of highway are 314, as compared with 840 ton-

In the West South Central Region, comprised of Arkansas, Louisiana, Oklahoma, and Texas, the average vehicle load is less than in the Mountain Region, but because the average number of commercial vehicles using the highways in the West South Central Region is higher, the average daily ton-miles per mile is larger than in the Mountain Region

Ton-miles per mile are greatest in the East North Central Region, comprising the States of Ohio, Indiana, Illinois, Michigan, and Wisconsin In this region the average number of commercial vehicles is high, and the average carried load per vehicle exceeds that in any other region

The average daily ton-miles for the country carried by motor vehicles on the tentative rural interregional system totals 21,456,000, on an annual basis the system is estimated to carry 7,831,000,000 ton-miles Total truck ton-miles of carried load for all highways, exclusive of purely local haulage, are estimated at approximately 57 billion in 1939[1] Thus the rural interregional highway system, comprising 25,554 miles or less than one percent of the rural highway mileage of the United States, carries approximately 14 percent of the total truck ton-miles of carried load generated upon all rural highways

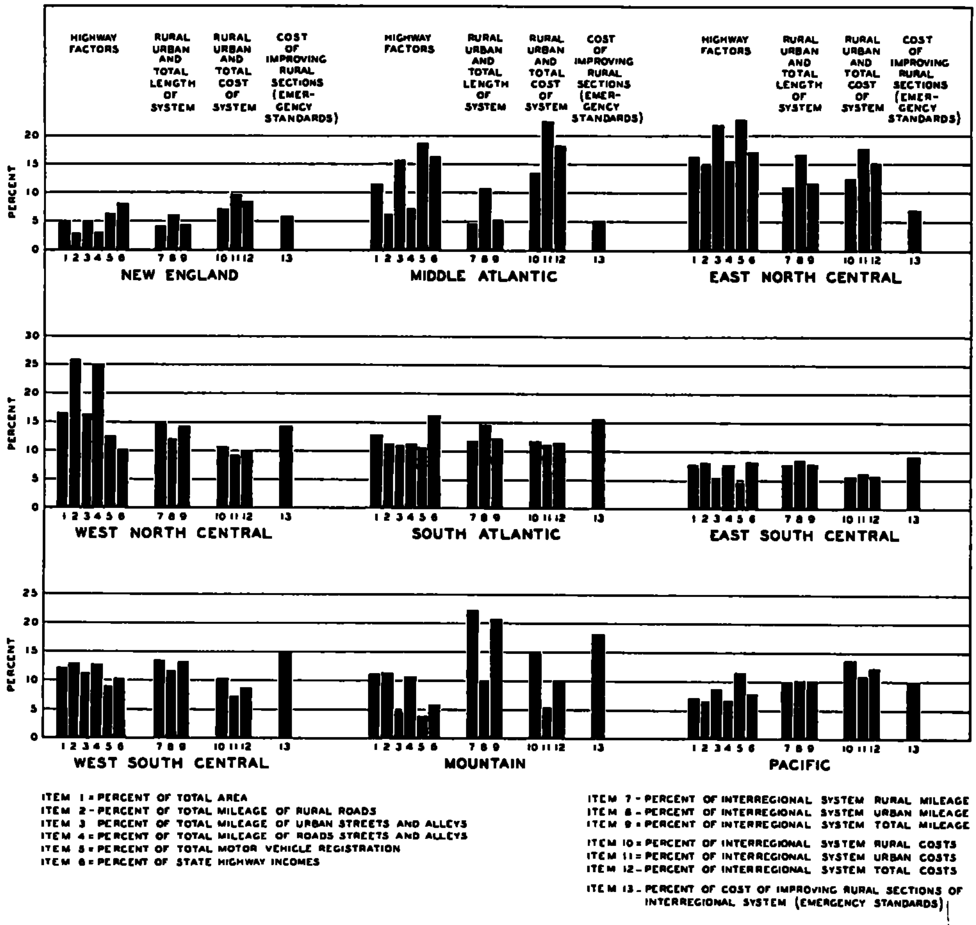


Figure 20. Geographical Distribution of the Length and Estimated Cost of the Interregional System in Relation to the Geographical Distribution of Various Highway Factors

[1] Estimated from data furnished by the highway planning surveys

Passenger cars

Estimates of the use of the rural interregional highways by passenger cars are obtained from the highway planning surveys These data are presented in Table 12, together with compilation of the passenger-car miles per mile

As in the case of freight vehicles, the use of the tentative rural interregional system by passenger cars varies widely by regions; in fact, the variation between regions is much wider than in the case of

TABLE 11

ESTIMATED AVERAGE DAILY TON-MILES AND TON-MILES PER MILE ON THE TENTATIVE RURAL INTERREGIONAL SYSTEM IN 1938

Geographic divisions	Miles	Average daily ton-mile	Daily ton-miles per mile
United States	25,554	21,456,142	840
New England	1,070	1,300,595	1,215
Middle Atlantic	1,185	1,502,850	1,268
East North Central	2,797	4,232,944	1,513
West North Central	3,754	2,534,761	675
South Atlantic	3,029	3,696,614	1,220
East South Central	2,002	1,459,229	728
West South Central	3,445	2,004,491	581
Mountain	5,710	1,794,613	314
Pacific	2,562	2,930,045	1,144

freight vehicles. In the South Atlantic Region, for example, freight vehicle use per mile of the interregional system is 45 percent more than the average for the United States, while passenger-car use per mile in the South Atlantic Region is but 13 percent more than the average for the United States.

Again, in the Middle Atlantic Region the passenger-car use per mile exceeds the average for the nation by 154 percent, while freight vehicle use per mile exceeds the average for the nation by but 51 percent

Thus the road use by freight vehicles, although the range is considerable, tends to be much more uniformly distributed by regions than is the case in passenger-car use.

Total passenger-car miles in 1938 for all rural roads in the United States, derived from the road use surveys, are estimated at 146 billion. Passenger-car use of the interregional system, from

TABLE 12

ESTIMATED AVERAGE DAILY PASSENGER-CAR MILES AND PASSENGER-CAR MILES PER MILE ON THE TENTATIVE RURAL INTERREGIONAL HIGHWAY SYSTEM IN 1938

Geographic divisions	Miles	Average daily passenger-car miles	Passenger-car[1] miles per mile
United States	25,554	40,953,228	1,603
New England	1,070	3,024,787	2,827
Middle Atlantic	1,185	4,833,445	4,079
East North Central	2,797	5,655,758	2,022
West North Central	3,754	4,594,484	1,224
South Atlantic	3,029	5,485,726	1,811
East South Central	2,002	2,461,876	1,230
West South Central	3,445	4,844,882	1,406
Mountain	5,710	4,073,109	713
Pacific	2,562	5,979,161	2,334

[1] Does not include busses Variation in bus loading and the fact that busses are less than one percent of all vehicles make estimates of bus-miles impractical.

Table 12, is 14,948 million passenger-car miles, or approximately 10 percent of passenger-car use of all rural roads of the country.

EARNING CAPACITY

A highway like an automobile earns nothing except when used for transportation service. The more the road is used, the greater are its earnings. These earnings come from various highway user charges, the more important of which are the motor-fuel taxes, registration fees, and Federal excise taxes Motor-carrier taxes and tolls comprise a smaller portion of the cost of operating motor vehicles over the highways Tables 13 and 14 show these data for the years 1934 to 1939, inclusive

The Public Roads Administration has estimated that in 1939 there was a total of 287,747 5 million vehicle-miles of travel by all kinds of motor vehicles, and that the gasoline consumed amounted to 22,685,056,000 gallons, of which motor vehicles utilized 91 40 percent, or 20,735-120,000 gallons On this basis a motor

TABLE 13

MOTOR-VEHICLE TAXES AND OTHER HIGHWAY USER COSTS, 1934-1939[1]

Year	Net total motor-fuel tax receipts[2]	Motor-vehicle registration receipts[3]	Motor carrier tax receipts[4]	Federal excise taxes paid by highway users[5]	Bridge and tunnel tolls[6]	Ferry tolls[6]	Total[7]
	1,000 dollars	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*
1934	566 642	307.260	9,402	235,743	46,693	15,151	1,180,891
1935	619.677	322,974	12,421	256,671	49,375	16 021	1,277,139
1936	691 420	359,783	15,137	297,142	53.600	17,392	1,434,474
1937	761 998	399,613	16,216	326,515	57,082	18,522	1,579,946
1938	771 764	388,825	16,421	267,959	57,424	18,633	1,521,026
1939	821 656	412,494	18,055	320,373	60,621	19,670	1,652,869

[1] Compiled by Public Roads Administration

[2] Figures include distributors' and dealers' licenses, inspection fees, fines and penalties and other similar miscellaneous receipts

[3] Figures include motor vehicle registration fees, dealers' license plates, operators' and chauffeurs' permits, certificates of title, special titling taxes, fines and penalties, transfers or registration fees and other similar miscellaneous receipts

[4] Figures include receipts from gross receipt taxes, mileage, ton-mile and passenger-mile taxes, weight, capacity or flat rate taxes, certificate or permit fees, caravan taxes and other similar miscellaneous receipts

[5] Figures include the estimated portion of taxes on gasoline paid by highway users (90 5 percent), the estimated portion of taxes on lubricating oil paid by highway users (58 0 percent) and the taxes collected on tires, tubes, automobiles, motorcycles, trucks, parts and accessories

[6] Figures compiled for year of 1937 and estimates for previous and later years made on the basis of the relative values of gasoline consumption and motor-vehicle registration for these years

[7] Totals do not include road tolls, municipal or county fees or licenses applicable to motor vehicles or personal property taxes on motor vehicles Reliable estimates of these figures were not available

While the data contained in these two tables are useful for the country as a whole, there is no published information showing the earning power of individual roads Such information must be calculated from various sources such as the vehicle-miles of travel on the road, gallons of gasoline consumed, the rate of gasoline taxes, and the relation between gasoline taxes and other motor-vehicle taxes

vehicle traveled on the average 13 88 miles, while utilizing one gallon of gasoline This mileage figure represents a weighted average of gasoline consumption by all kinds of motor vehicles used on city streets and on highways

From Table 14 it is shown that the average of the gasoline tax during the six years, 1934–1939, constituted 49 0 percent of all motor-vehicle taxes for those years The Public Roads Administration has also calculated that the weighted average State gasoline tax for the country in 1939 was 3 96 cents per gallon. On this basis the total motor-vehicle taxes collected on a motor vehicle while consuming one gallon of gasoline amount to 8.08 cents. By dividing the total taxes collected on a motor vehicle while consuming one gallon of gasoline by the total distance traveled, we obtain the total tax burden on a motor vehicle per mile. This amounts to 0.582 cents

Table 15 shows the annual earnings of rural sections of the tentative inter-regional system grouped in accordance with geographic divisions and 1937 traffic densities, based upon this rate of 0.582 cents per vehicle-mile. A more detailed study of tax rates by regions would make possible some refinement of the regional earnings.

The earnings have been reduced to a per mile basis in order to compare later the annual cost of all sections with their earning capacity.

The annual earnings during the lifetime of an improvement greatly exceed the present earnings of an existing highway because of diverted traffic, generated traffic and the normal rate of increase in traffic. The extent of the influence of each of these three factors will vary considerably with the region, the proximity to urban areas, and the type of service rendered, et cetera. Such variations

TABLE 14

PERCENTAGE OF MOTOR-VEHICLE TAXES AND OTHER HIGHWAY USER COSTS FOR 1934 TO 1939 FROM EACH SOURCE[1]

Year	Net total motor-fuel tax receipts[2]	Motor-vehicle registration receipts[3]	Motor carrier tax receipts[4]	Federal excise taxes paid by highway users[5]	Bridge and tunnel tolls[6]	Ferry tolls[6]	Total[7]
1934	48 0	26 0	0 8	20 0	4 0	1 2	100 0
1935	48 5	25 3	1 0	20 0	3 9	1 3	100 0
1936	48 2	25 1	1 1	20 7	3 7	1 2	100 0
1937	48 2	25 3	1 0	20 7	3 6	1 2	100 0
1938	50 7	25 6	1 1	17 6	3 8	1 2	100 0
1939	49 7	24 9	1 1	19 4	3 7	1 2	100 0
Average	49 0	25 3	1 0	19 7	3 8	1 2	100 0

[1] Compiled by Public Roads Administration

[2] Figures include distributors' and dealers' licenses, inspection fees, fines and penalties and other similar miscellaneous receipts.

[3] Figures include motor vehicle registration fees, dealers' license plates, operators' and chauffeurs' permits, certificates of title, special titling taxes, fines and penalties, transfers or registration fees and other similar miscellaneous receipts.

[4] Figures include receipts from gross receipt taxes, mileage, ton-mile and passenger-mile taxes, weight, capacity or flat rate taxes, certificate or permit fees, caravan taxes and other similar miscellaneous receipts.

[5] Figures include the estimated portion of taxes on gasoline paid by highway users (90 5 percent), the estimated portion of taxes on lubricating oil paid by highway users (58 0 percent) and the taxes collected on tires, tubes, automobiles, motorcycles, trucks, parts and accessories

[6] Figures compiled for year of 1937 and estimates for previous and later years made on the basis of the relative values of gasoline consumption and motor-vehicle registration for these years

[7] Totals do not include road tolls, municipal or county fees or licenses applicable to motor vehicles or personal property taxes on motor vehicles Reliable estimates of these figures were not available

TABLE 15

APPROXIMATE EARNINGS[1] OF RURAL SECTIONS OF THE INTERREGIONAL HIGHWAY SYSTEM FOR THE YEAR 1937

Geographic divisions	Sections carrying less than 3,000 vehicles per day				Sections carrying more than 3,000 vehicles but less than 10,000 vehicles per day				Sections carrying 10,000 or more vehicles per day				All sections			
	Rural roads	Daily traffic	Annual earnings		Rural roads	Daily traffic	Annual earnings		Rural roads	Daily traffic	Annual earnings		Rural roads	Daily traffic	Annual earnings	
			Total	Per mile			Total	Per mile			Total	Per mile			Total	Per mile
	miles	*1,000 vehicle miles*	*1,000 dollars*	*dollars*	*miles*	*1,000 vehicle miles*	*1,000 dollars*	*dollars*	*miles*	*1,000 vehicle miles*	*1,000 dollars*	*dollars*	*miles*	*1,000 vehicle miles*	*1,000 dollars*	*dollars*
United States	21,237.3	28,068	59,625	2,810	4,048.3	19,691	41,830	10,330	268.6	3,498	7,431	27,670	25,554.2	51,257	108,886	4,260
New England	662.2	690	1,466	2,210	337.2	2,038	4,329	12,840	70.3	1,103	2,343	33,330	1,069.7	3,831	8,138	7,610
Middle Atlantic	383.0	808	1,716	4,480	699.6	3,682	7,822	11,180	102.6	1,205	2,560	24,950	1,185.2	5,695	12,098	10,210
East North Central	2,072.8	3,915	8,317	4,010	720.4	3,193	6,783	9,420	4.1	45	96	23,410	2,797.3	7,153	15,196	5,430
West North Central	3,516.6	4,761	10,114	2,880	233.4	1,047	2,224	9,530	4.3	53	113	26,280	3,754.3	5,861	12,451	3,320
South Atlantic	2,442.3	3,848	8,174	3,350	541.7	2,579	5,479	10,110	45.2	630	1,338	29,600	3,029.2	7,057	14,991	4,950
East South Central	1,873.1	2,729	5,797	3,090	128.9	541	1,149	8,910					2,002.0	3,270	6,946	3,470
West South Central	3,035.6	4,489	9,536	3,140	403.2	1,667	3,541	8,780	6.2	66	140	22,580	3,445.0	6,222	13,217	3,840
Mountain	5,566.9	4,494	9,547	1,710	143.0	600	1,275	8,920					5,709.9	5,094	10,822	1,900
Pacific	1,684.8	2,334	4,958	2,940	840.9	4,344	9,228	10,970	35.9	396	841	23,430	2,561.6	7,074	15,027	5,870

[1] The earnings are based on a rate of 0.582 cent per vehicle-mile, which is the estimated rate for the period 1934–1939

must be ignored in this paper, and general assumptions must be made for the country as a whole. It seems conservative to estimate that at the time an average rural section is improved to rural standards, the increase in traffic resulting from diversion would be approximately 10 percent and generated traffic would be approximately 5 percent. During the lifetime of the improvement, assuming an average life of 30 years, the normal rate of increase in traffic should be such that the average traffic during the entire period should be at least 50 percent greater than the traffic using it in the first year the improved facility is opened. The average traffic during the lifetime of the improvement would, on the basis of these assumptions, be equal to 150 percent times 110 percent times 105 percent of the traffic using the existing highway, or approximately 173 percent.

The design standards to be applied are controlled by the traffic density of the particular section, adjusted to include traffic which will be diverted to the improvement. The improvements on the system are to extend over a period of years, and the distribution of the rural sections to the various traffic density groups will shift materially by the time reconstruction of all sections has taken place. Some of the sections constructed in later years would still have earnings to compare with improvement costs after the life of some of the first sections had expired. For these reasons, the total earning capacity of the system would have to be estimated on a very complicated basis, requiring many assumptions. However, the total earning capacity of the system is unnecessary in comparing the costs with the earnings. If it can be shown that there is a favorable ratio of earnings to costs for any section regardless of which traffic density group it may happen to fall in at the time of its improvement, the ratio of earnings to costs for the system would also have to be favorable.

TABLE 16

AVERAGE EARNINGS OF RURAL SECTIONS OF THE TENTATIVE INTERREGIONAL HIGHWAY SYSTEM

Initial traffic density adjusted to include traffic which would be attracted by the improvement	Annual earnings for adjusted initial traffic density		Average annual earnings for 30-year period after improvement		Total earnings for 30-year period after improvement	
	Per mile	Per 1,000 vehicle-miles	Per mile	Per 1,000 vehicle-miles	Per mile	Per 1,000 vehicle-miles
	dollars	*dollars*	*dollars*	*dollars*	*dollars*	*dollars*
0–2,999	2,810	5.82	4,410	5 82	132,300	5.82
3,000–9,999	10,330	5.82	16,220	5 82	486,600	5 82
10,000 and over	27,670	5 82	43,440	5 82	1,303,200	5 82

Note: It is assumed that the average traffic density for the 30-year period will be 157 percent of the initial traffic density adjusted to include traffic which would be attracted by the improvement.

For a section falling within any one of three major traffic density groups, when classified on the basis of its traffic density, adjusted to include diverted traffic, the average annual earnings per mile and per vehicle-mile during the lifetime of the improvement are shown in Table 16, it being assumed that the influence of generated traffic and the normal rate of increase combined would be equal to 105 percent times 150 percent or 157 percent. In this same table there is also shown the amount to which these earnings would accumulate during a period of 30 years which is assumed to be the average life of the improvements. These earnings per mile would, of course, shift to higher or lower levels, if the improvement program were carried on in such a manner that the average adjusted initial traffic density of all sections selected for improvement within any density group were allowed to depart from the 1937 determined average traffic density of that group. An increase can hardly be avoided for the lower traffic density group, but, theoretically, the levels for the intermediate and high traffic density groups could be maintained. Difficulties arising from shifts in levels can be avoided by confining appraisals of earnings to a

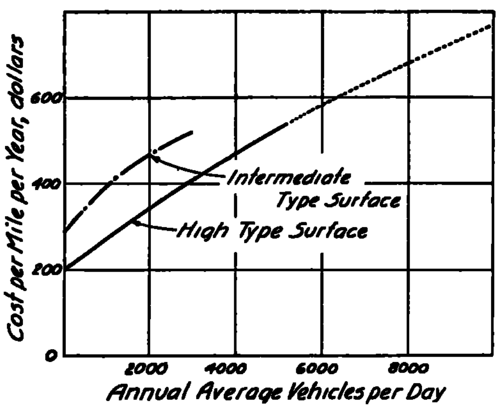


Figure 21. Average Maintenance Costs Per Mile for Various Traffic Densities

vehicle-mile basis. The vehicle-mile basis also applies just as well to one geographic division as to another, whereas the earnings per mile within any density group for a geographic division and for the 30-year period following improvement are impossible to estimate reliably without exhaustive study.

INTERREGIONAL COSTS OF IMPROVEMENT AND OPERATION

The estimated cost of improving and operating the system must include suitable allowances for administration, maintenance, operation and policing, in addition to the cost of the improvements. The cost of improvements actually include the initial cost, the cost of emergency reconstruction caused by floods, slides, et cetera, the cost of widening some of the sections where the rate of traffic increase is abnormally high, et cetera. Allowances for these various classes of construction may be made either in a direct manner or they may be made by considering the average life of the improvements to be a little shorter than the anticipated life of those sections not requiring any reconstruction. The latter basis is preferred, and it is assumed that an average life of 30 years for sec-

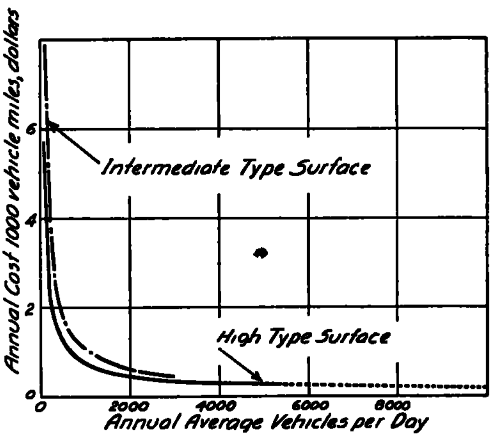


Figure 22. Average Maintenance Costs Per Vehicle-mile for Various Traffic Densities

tions built to the recommended standards is reasonable for the shortened life.

Estimated maintenance costs are based on the unit costs shown in Figures 21 and 22. These curves were drawn through the field of points obtained by plotting the maintenance cost data reported in "Public Aids to Transportation," Vol. IV.[2] The curves for the intermediate type roads were carried no further than the 3,000 average traffic density ordinate, because it is assumed that any intermediate type surfaces would not be placed on sections carrying more than this number of vehicles. The

[2] Published by Section of Research, Federal Coordinator of Transportation, 1940.

portions of the curves for the high-type surfaces shown by means of dashed lines were projected for high traffic densities beyond the range of the plotted points. The curves should not be considered applicable to 4-lane highways but merely as indicative of the extent to which maintenance costs on 2-lane highways vary with traffic densities up to 5,500 vehicles per day. Beyond this traffic density the dashed curves should be regarded as theoretical projections of the trend in the maintenance costs which might logically be used as a measure of the rate of change in maintenance costs on 4-lane divided highways. The 4-lane highway maintenance costs would obviously be at some higher level. Considering the fact that most of the heavier traveled sections requiring 4-lane treatment will be located where more than usual attention must be paid to landscaping, it has been assumed that the amounts indicated by the curves based on 2-lane maintenance costs should be doubled. For highway sections carrying more than 10,000 vehicles per day where special design is recommended, amounts equal to two and one-half times those indicated by curves based on 2-lane maintenance costs have been assumed.

In selecting a value from the curves which is applicable for the life of an improvement, it is, of course, necessary to select the value corresponding with the average traffic density during the period of service and not the value for the traffic density at the time of the improvement In accordance with assumptions made in the calculation of the earning power of the system, the traffic density controlling the selection of the maintenance cost should be 157 percent of the initial traffic density adjusted to include divertable traffic. For values selected for traffic densities of less than 3,000 a point lying somewhere between the two curves should be selected

TABLE 17

AVERAGE COSTS OF IMPROVING AND OPERATING RURAL SECTIONS OF THE TENTATIVE INTERREGIONAL SYSTEM

Initial traffic density adjusted to include traffic which would be attracted by the improvement	Initial cost[1] of the improvement per 1,000 vehicle-miles of travel during the 30-year period	Maintenance and operation costs, including policing, per 1,000 vehicle-miles of travel during the 30-year period	Administration costs per 1,000 vehicle-miles of travel during the 30-year period	Average annual cost of improvement and operation during the 30-year period		Total cost of improvement and operation during the 30-year period	
				Per mile	Per 1,000 vehicle-miles	Per mile	Per 1,000 vehicle-miles
	dollars	*dollars*	*dollars*	*dollars*	*dollars*	*dollars*	*dollars*
Less than 3,000	2 92	0 55	0 17	2,760	3 64	82,800	3.64
3,000-9,999	2 68	0 55	0 16	9,460	3 39	283,800	3 39
10,000 and over	2 40	0 39	0 14	21,900	2 93	657,000	2 93

[1] Includes allowances for right-of-way, engineering and contingencies

Table 17 shows the estimated maintenance and operation cost during the life of the improvement based upon values obtained from the curves shown in Figures 21 and 22. An allowance for policing equal to 15 percent of the maintenance and operation cost is made and an allowance of 5 percent of the total construction and maintenance expenditures is made for administration and overhead.

For a section falling within any one of three major traffic density groups, when classified on the basis of its traffic density, adjusted to include diverted traffic, the cost per 1,000 vehicle-miles and the average annual and total costs per mile during the lifetime of the improvement are shown in Table 18. As in the case of the earnings similarly shown in a previous table, the costs per vehicle-mile would shift to higher or lower levels if the improvement program were carried on in such a manner that the average initial traffic density of all sections selected for improvement within any density group were to depart from the 1937 determined average traffic density of that group. However, in contrast to the tendency for the earnings per mile to increase, a decrease can hardly be avoided in the costs per vehicle-mile for the lower traffic density groups, but you go" basis, from current revenues, and are undertaken after the present improvement has paid for itself and is due for reconstruction. Obviously, other relationships would exist if new improvements were to be financed by other methods or if new improvements were to be undertaken before the present improvements had served their economic life. If the whole program were to be undertaken at once, financing charges would have to be included in the costs, and earnings required to liquidate the unretired balance of the investments in existing improvements would have to be

TABLE 18

ESTIMATED MAINTENANCE AND OPERATION COSTS FOR RURAL SECTIONS OF THE TENTATIVE INTERREGIONAL SYSTEM

Initial traffic density adjusted to include traffic which would be attracted by the improvement	Annual costs for adjusted initial traffic density		Average annual costs during 30-year period after improvement		Total costs during 30-year period after improvement	
	Per mile	Per 1,000 vehicle-miles	Per mile	Per 1,000 vehicle-miles	Per mile	Per 1,000 vehicle-miles
	dollars	*cents*	*dollars*	*cents*	*dollars*	*cents*
Less than 3,000	320	66.336	362	47.798	10,860	47 798
3,000–9,999	1,040	58 580	1,330	47 716	39,900	47 716
10,000 and over	2,150	45 227	2,550	34 167	76,500	34 167

Note: It is assumed that the average traffic density for the 30-year period will be 157 percent of the initial traffic density adjusted to include traffic which would be attracted by the improvement.

it would be possible to maintain the levels in the other groups. The effect of any probable change of levels will always be to improve the relationship between earnings and costs which can be shown by comparison of the estimated earnings and the estimated costs shown in this paper.

CONCLUSION

Table 19 shows a comparison of the estimated earnings during a 30-year period with the total estimated costs during a 30-year period which is assumed to be the average life of a section improved to the recommended standards This is the picture that is obtained when improvements are financed on a "pay as

subtracted from the earnings. These two operations would narrow or possibly wipe out the excess earnings of the system.

Before these excess earnings, shown in Table 19, excite too much enthusiasm for the interregional highway system proposal, and before they invite false conclusions as to the advisability of proceeding immediately with a great portion of the work financed by borrowed money, careful consideration must be given to their true meaning.

Existing practice does not consist of financing highways of a single class with funds earned by that class of highways. If costs and earnings were balanced for each class of highways, lightly traveled routes could seldom be improved with available funds to the minimum standard satisfactory to the highway users The construction of lightly-traveled secondary and local roads must be subsidized from excess earnings of heavily-traveled routes Unless this practice were followed, lightly-traveled routes could not be developed unless additional funds from a new source were made available. Unless lightly-traveled or "feeder" routes, which provide access to widely scattered points were developed, the main highways would be less heavily traveled, and the earning capacity of the main traveled routes would be reduced.

would exceed the total costs during the 30-year period by greater amounts for the more heavily traveled sections than for the more lightly traveled sections. The percentage of the earnings required for expenditures over a 30-year period on sections having adjusted initial traffic densities of less than 3,000 vehicles is shown to be 63 percent For sections falling within the intermediate traffic density group where 4-lane highway design is recommended, this percentage of the required earnings drops to 58 and for sections falling within the highest traffic density group, the percent of the required earnings drops to 50.

TABLE 19

COMPARISON OF COSTS AND EARNINGS OF RURAL SECTIONS OF THE TENTATIVE INTERREGIONAL SYSTEM

Initial traffic density adjusted to include traffic which would be attracted by the improvement	Total cost of improvement and operation during the 30-year period		Total earnings during the 30-year period		Excess of earnings over costs during the 30-year period		Ratio of costs to earnings during the 30-year period
	Per mile	Per 1,000 vehicle-miles	Per mile	Per 1,000 vehicle-miles	Per mile	Per 1,000 vehicle-miles	
	dollars	*dollars*	*dollars*	*dollars*	*dollars*	*dollars*	*percent*
Less than 3,000	82,800	3 64	132,300	5 89	49,500	2 25	63
3,000-9,999	283,800	3 39	486,600	5 89	202,800	2 50	58
10,000 and over	657,000	2 93	1,303,200	5 89	646,200	2 96	50

The interregional highway system tentatively selected is the most heavily traveled integrated national system that it has been possible to select The routes in each State are invariably the most, or at least among the most heavy revenue-producing routes. It would seem that even a lower percentage of their total earnings should be applied to the development and operation of the system than is applied to the remaining heavily traveled routes of the State highway systems, if equilibrium is to be maintained amongst the various systems.

It is interesting to note that even within the interregional system, Table 19 shows that the total earnings during the 30-year period following improvement

These relationships are only preliminary indications. The main problem still lies ahead in refining the analysis by substituting facts and field determinations for present assumptions and estimates The present analysis must be extended to include various methods of financing and complete studies must be made by regions and by States. Coincident with these studies, studies must be made of the amount which local roads must be subsidized from excess earnings of the more heavily traveled systems. In fact, analyses similar to this interregional system analysis must be applied to all systems Standards for all systems must be adjusted to levels which can be afforded. These refinements and extensions of the analysis of the rural sections will require a great deal of work, but the larger and more significant job which lies ahead is planning the improvement of urban sections.

The best preliminary estimates of the cost of the urban sections of the tentative interregional system is only about one-fifth of the expenditures which must be made to modernize highway and street facilities in the cities traversed. The modernization of only the interregional system in the vicinity of cities would be but a palliative because the system would soon be overloaded by traffic attracted to its superior facilities. Only by construction of comparable facilities in other directions on the cities' street network can the economic growth of cities and the success of the interregional system itself be assured.

APPENDIX A

In the discussion of design standards it was stated that

> The limiting degree of horizontal curvature must usually be selected on the basis of a number of economic considerations, only one of which is the extent to which sight distances are restricted Once the specifications for horizontal alignment and cross sections are settled, the sight distances limited by cut banks on horizontal curves are fixed Obviously, there is no advantage to the traveling public which can be gained by increasing lengths of vertical curves occurring on horizontal curves beyond those lengths required to provide sight distance equal to that afforded by the horizontal curve. There is, therefore, no justification for construction expenditures for this purpose.

On horizontal curves having sufficient length for the view between vehicles on the curve to be restricted by the cut bank, there is a constant, for any distance between the centerline of the highway and the cut bank, which, when divided by the degree of curvature, may be multiplied by the algebraic difference in grades to give the length of vertical curve whose crest will limit sight distance to the same extent as the cut bank will limit it Such a constant is specified for the interregional system and its value for the interregional highway cross section is 700

For sections of the highway located on tangent and short horizontal curves where sight distance is not restricted by cut banks, but by crests in vertical alignment, constants, as shown in Table 20 are specified These constants, when multiplied by the algebraic difference in grades, give lengths of vertical curves which will provide sight distances as great as can be afforded and yet maintain equilibrium between this feature of design and the other features It will be noted that shorter vertical curves, and correspondingly shorter sight distances are specified for 4-lane divided highways than are specified for 2-lane highways This is done because the chief advantage in increasing the sight distance on 4-lane divided highways is that safe stopping distances for higher speeds of travel are provided, but on 2-lane highways, the further advantage is gained that vehicles traveling in the same direction may pass one another at higher speeds without increasing the hazard of meeting an oncoming car before completing the passing maneuver This hazard obviously does not exist on 4-lane divided highways

For the various classifications of 4-lane highway sections, the speeds for which adequate sight distances on vertical curves are provided, are related to the speeds at which horizontal curves of the maximum degree may be negotiated safely, because the economic limits of both the degrees of horizontal curvature and the lengths of vertical curves for various classification of highways are determined by the type of topography and the traffic service. Also, in terrain where drivers are required to reduce their speeds most in order to negotiate the horizontal curves, relatively short vertical curves should not be found to be objectionable as in smoother terrain Careful consideration of the rate that excavation quantities increase with lengths of vertical curves has led to the conclusion that the greatest speed for which sight distances on crests in vertical alignment can be made equal to safe stopping distances, without excessive expenditures, is the maximum speed which can be traveled around horizontal curves of one-half the maximum degree specified for the particular classification of the highway section This criterion has been selected because: (1) most of the curves occurring on any section have shorter radii than the radius of a curve of half the maximum specified degree, which means that drivers of vehicles will generally be accustomed to reducing speeds below this critical speed on most of the horizontal curves, and (2) an examination of resulting speeds indicates that they are reasonable in relation to other factors

Values of the constants for computing lengths of vertical curves occurring at crests on 2-lane highways are based on providing sight distances permitting passing maneuvers: (1) in "relatively level" topography when the passing and oncoming vehicles travel 60 m p.h. and the passed vehicle travels 50 m.p h , (2) in "rolling" topography when the passing and oncoming vehicles travel 50 m p.h and the passed vehicle travels 40 miles per hour, and (3), in "mountainous" topography when the passing and oncoming vehicles travel 40 m p h

TABLE 20

VALUES OF K[a] FOR COMPUTING LENGTHS OF VERTICAL CURVES ON HORIZONTAL TANGENTS AND SHORT HORIZONTAL CURVES[b]

Classification of section	Present average daily traffic density	Type of topography	Values of K	
			Minimum permissible	Maximum desirable
I	0– 1,000	Relatively level	1,070	1,070
		Rolling	550	550
		Mountainous	260	260
II	1,000– 2,000	Relatively level	1,070	1,070
		Rolling	550	550
		Mountainous	260	260
III	2,000– 3,000	Relatively level	1,070	1,070
		Rolling	550	550
		Mountainous	260	260
IV	3,000– 5,000	Relatively level	465	465
		Rolling	233	465
		Mountainous	175	465
V	5,000–10,000	Relatively level	465	465
		Rolling	350	465
		Mountainous	280	465
VI	10,000 or more	Relatively level	465	465
		Rolling	350	465
		Mountainous	280	465

[a] Length of vertical curve = algebraic difference of grades x K For use only where sight distance is restricted by vertical curve

[b] For computing lengths of vertical curves occurring on long horizontal curves where sight distance is restricted by cut bank, use formula $K = \frac{700}{D}$ in all traffic classifications and on all horizontal curves whose lengths are in excess of the following values:

1° curve—1,060 ft	6° curve—440 ft
2° curve— 750 ft	7° curve—410 ft
3° curve— 620 ft.	8° curve—380 ft.
4° curve— 530 ft	9° curve—360 ft
5° curve— 480 ft.	10° curve—350 ft.

Maximum lengths of vertical curves in relatively level topography shall be 4,000 ft., in rolling topography 3,000 ft , and in mountainous topography 2,000 ft

TABLE 21

MAXIMUM SAFE SPEEDS PERMITTED BY LIMITING VERTICAL CURVES SUGGESTED FOR INTERREGIONAL HIGHWAYS

Classification of section	Present average daily traffic density	Type of topography	Speeds permitted on vertical curves occurring on long horizontal curves when sight distance is restricted by cut bank: Minimum permissible length of vertical curve: Lowest maximum safe speed[1]	Minimum permissible length of vertical curve: Lowest maximum passing speed[2]	Minimum desirable length of vertical curve: Lowest maximum safe speed[1]	Minimum desirable length of vertical curve: Lowest maximum passing speed[2]	Speeds permitted on vertical curves occurring on horizontal tangents or short horizontal curves: Minimum permissible length of vertical curve: Lowest maximum safe speed[1]	Minimum permissible length of vertical curve: Lowest maximum passing speed[2]	Minimum desirable length of vertical curve: Lowest maximum safe speed[1]	Minimum desirable length of vertical curve: Lowest maximum passing speed[2]
			m p h	*m p h*	*m p.h*	*m p h*	*m p h*	*m p h*	*m p h.*	*m.p h.*
I	0– 1,000	Relatively level	68	28	68	28	80+	53-60[3]	80+	53-60[3]
		Rolling	53	20	68	28	76–80+[3]	44–50[3]	80+	50
		Mountainous	47	17	68	28	61–70[3]	35–40[3]	80+	40
II	1,000– 2,000	Relatively level	68	28	68	28	80+	53-60[3]	80+	53-60[3]
		Rolling	53	20	68	28	76–80+[3]	44–50[3]	80+	50
		Mountainous	47	17	68	28	61–70[3]	35–40[3]	80+	40
III	2,000– 3,000	Relatively level	68	28	68	28	80+	53-60[3]	80+	53-60[3]
		Rolling	56	20	68	28	79–80+	44–50[3]	80+	50
		Mountainous	52	18	68	28	64–70[3]	35–40[3]	80+	40
IV	3,000– 5,000	Relatively level	68	68	68	68	80+	80+	80+	80+
		Rolling	56	56	68	68	70	70	80+	80+
		Mountainous	52	52	68	68	64	64	80+	80+
V	5,000–10,000	Relatively level	68	68	68	68	80+	80+	80+	80+
		Rolling	63	63	68	68	78	78	80+	80+
		Mountainous	59	59	68	68	73	73	80+	80+
VI	10,000 or more	Relatively level	68	68	68	68	80+	80+	80+	80+
		Rolling	63	63	68	68	78	78	80+	80+
		Mountainous	59	59	68	68	73	73	80+	80+

General note When sight distance is restricted by cut banks on horizontal curves, vertical curves have been selected which provide the same sight distances as do the horizontal curves Therefore, lengthening of vertical curves would not make higher safe speeds possible

[1] Lowest maximum safe speed is the maximum speed which vehicles can travel and yet stop safely within the sight distance provided on the shortest vertical curve permitted for the indicated classification of highway

[2] Lowest maximum passing speed is the maximum speed which passing and oncoming vehicles may travel and yet complete a passing maneuver when the passed vehicle is traveling 10 miles per hour slower on the shortest vertical curve permitted for the indicated classification of highway

[3] The lower speed applies when the algebraic difference in grades is the maximum permitted, the higher speed applies when the algebraic difference in grades is less than two-thirds of the maximum allowable.

and the passed vehicle travels 30 m p h. Actually, passings can probably take place safely at higher speeds than these because the calculations are based on existing passing maneuver theory which appears to be on the conservative side In cases where maximum algebraic differences in grades are approached, the standards specify reduced lengths of vertical curves below the values obtained by the use of the constants These reduced lengths are necessary because of topographical difficulties and should be accepted even though the speeds at which passing maneuvers may take place are lowered by about 10 percent.

The maximum safe speeds which can be traveled at any point where the sight distance is limited by any feature of the design are shown in Table 21.