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USE OF FORECASTS IN HIGHWAY MANAGEMENT

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Speaking to you yesterday I described in general terms how motor vehicle production and the improvement of roads have each passed in almost identical periods through two stages of the normal "growth process", which we called the "formative years" and the "growing years", and are now entering together the third stage of the process, which we called the "years of maturity." The three stages were described as corresponding to the three distinctive sections of a familiar S-shaped curve, which typifies all growth processes; the "formative years" being represented by the lower section of slight upward slope, the "growing years" by the steeply rising middle section, and the "mature years" by the upper section which is again only slightly inclined upward.

I spoke of the stage at which these developments have now arrived as the beginning of a near approach to limits, and therefore a somewhat critical stage, at which it is desirable to proceed with greater care in highway administration than was necessary when the growth was more rapid.

I have previously employed the metaphor of a sculptor carving a statue from a block of granite to illustrate the character of the change in methods of procedure that is desirable. Knowing the

approximate depth within the block at which lie the imagined planes of the statue the sculptor can safely hack away at the granite with stone-mason blows and apparent recklessness as long as there is still a considerable excess of stone to be removed. But as he approaches the planes of the figure, he will cut with increasing care and frequent measurement to be sure that he reaches the exact depth at every point that is necessary to form the surface of the finished figure. To overcut is fatal; to undercut is to leave the figure undeveloped.

In the administration of highways we have reached the point where a similar change of methods is desirable; and it is this fact that explains the undertaking of the highway planning surveys. The surveys constitute an elaborate effort to establish a base of reference to which we can trace past trends by such indications as the history of the development affords and from which we can more carefully follow future trends to gage and be forewarned of the approach to expected limits.

Henceforth it will be highly essential that we keep a current log of these future trends by continuance of the planning survey effort suitably modified. But simply to know each year what further progress has been made will not be sufficient for the purposes of future planning. We shall also need to make the best possible forecasts of the progress that will, or can, or should be made.

Such forecasts will not be the first to be attempted by highway administration. But there is now a probability that they can be more accurate than the forecasts that have been attempted in the past, simply because we have reached a stage of the "growth process" at which the future course is more clearly perceptible.

When the curve of motor vehicle registration for example was in the middle of its steepest climb, the attempt to predict when it would begin to turn toward the lesser inclination of its "mature" section could be little better than a gamble. But, now, when for nearly a decade it has shown unmistakable evidences of having passed into the "mature" section, the very slowness of its probable further climb reduces the chance of error in estimates of the height which it will reach at any relatively near future period.

Since roads are built to facilitate the movement of vehicles, and since motor vehicles are now, and in the future will be the only kinds of road-using vehicles that need be given much consideration, the numbers and movements of motor vehicles in the future are the principal forecasts of interest to the highway administration. Numbers of vehicles per se are of interest because the vehicle unit is one base of the taxation to which we look for revenues essential for the support of future road improvement and management. The extent and places of the movements of the vehicles we need to know; first, because, through the gasoline tax, the extent of the movements must

enter into estimates of other important future revenues; and, second, because both the extent and places of the movements must be foreseen in order to supply road capacity adequate to serve them.

Forecasts of the future registration or numbers of motor vehicles have often been attempted in the past by various persons and agencies with varying success. In nearly every State efforts have been made for one reason or another to predict the future registration of vehicles within the State. In all of the early traffic surveys made by the Bureau of Public Roads in cooperation with several State highway departments, 1/ such forecasts were attempted; and besides these State forecasts a number of estimates have been attempted for the entire United States. The most important of such estimates are those made by Charles F. Kettering of the General Motors Corporation in 1937, by the American Petroleum Institute in 1935, by John A. Scoville

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1/ Surveys were made in the States of Connecticut in 1923 and 1934, Pennsylvania in 1924, Maine in 1924, Ohio in 1925, Vermont in 1926, New Hampshire in 1926 and 1931, Michigan in 1930 and 1931, New Jersey in 1932 and 1933, Rhode Island in 1934, Florida in 1934, Arkansas in 1934 and 1935, and in the eleven western States of Arizona, California, Colorado, Idaho, Nebraska, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming in 1930.

of The Chrysler Corporation in 1935, and by the U. S. Bureau of Public Roads (now Public Roads Administration) in 1938. 2/

In some of the earlier forecasts future registration was estimated by a simple graphical extension of the curve of actual registration, as it had developed to date. As the actual curves were in some instances not yet sufficiently developed to indicate their future course, such estimates were liable to gross error if extended very far into the future.

2/ Kettering, Charles F., Motor Vehicles and Highways of the Future, Address delivered before the American Society of Civil Engineers. Detroit, July 21, 1937.

American Petroleum Institute, American Petroleum Industry - A Survey of the Present Position of the Petroleum Industry and Its Outlook Toward the Future; 1935.

Scoville, John W., Behavior of the Automobile Industry in Depression, Address delivered before the Econometric Society, New York, December 30, 1935.

Bureau of Public Roads, Motor Vehicle Production and Use in the United States, 1895-1960; 1938.

Later estimates employed the relation between population and motor vehicle registration, and arrived at an estimate of future registration by dividing the predicted population of the future period by the estimated number of persons per vehicle picked from a graphical extension of the past trend of the curve of persons per vehicle. Though this procedure was more reliable than the simple extension of the registration curve it also was subject to considerable error when employed before the curve of persons per vehicle had reached a definite inflection.

Shortly before 1930, the curve of persons per vehicle for the entire United States showed a definite tendency to flatten out at between 5 and 4 persons per vehicle, and most of the estimates that have recently been made for the entire country have been based upon an application to predicted future population of a ratio approximating the lower figure.

There is evidence other than the recent graphical form of the persons-per-vehicle curve to support the conclusion that the assumptions of recent forecasts are approximately correct, some of which is presented in graphical form in Figure 1.

One of the curves shown in this figure (Curve C) represents the past trend of persons per motor vehicle operating up to the year 1938. It will be seen that the value of this ratio first passed

below 5 between 1927 and 1928 and reached in 1929 a low point of approximately 4.5 from which it retreated during the depression to a little over 5. In 1933 the downward trend was resumed and by 1937 and 1938 had reached a new low at about 4.25. The form of the curve alone indicates the probability that its future extension will drop little if at all below the value of 4; and in some of the other curves shown there is strong support for such an assumption.

Particularly convincing evidence of this probability is supplied by two pairs of curves, one of which compares the ratios of Persons per Motor Vehicle Consumed and Persons per Motor Vehicle Sold in the Domestic Market, and the other of which compares ratios of Income per Motor Vehicle Consumed and Income per Motor Vehicle Sold in the Domestic Market. A vehicle consumed, as the term is here used, is a vehicle that has reached the end of its life and passes completely out of use, possibly after successive possession by several owners. The income referred to is the total accountable realized income of the United States, as estimated by the National Industrial Conference Board. Other terms used in the description of the curves will be sufficiently clear without definition.

If we refer first to the pair of curves comparing persons per vehicle consumed and sold, it will be seen that the ratio of vehicles sold, was at all times well below the ratio of vehicles consumed from

the late 90's of the last century until 1930. This means that throughout that entire period of more than 30 years vehicles were being sold at a faster rate than other vehicles were passing out of use, and consequently the number of vehicles in operation, i.e., the registration was steadily increasing, all the while filling the reservoir of demand with an aggregate of new and used vehicles. In 1931, for the first time the curve of vehicles sold passed above the curve of vehicles consumed, and remained above it until 1934, when revival of demand again caused it to recross and remain below the consumption curve until 1938 when it crossed back again. This course of the two curves during the 30's is strong indication of the approach to a condition of the market in which it will be necessary to force an old vehicle out of use before it will be possible to sell a new vehicle, and this is the condition typical of a saturated market. Henceforth it may be expected that the cyclical crossing and recrossing of the two curves will continue and their general trends will be identical; and if this proves to be the case there will be future increase in registration of motor vehicles only as increase of the population provides new potential buyers.

In the relative courses of the pair of curves representing ratios of realized national income to vehicles consumed and sold there are exactly similar indications; and here we perhaps reach the root cause of the apparent approach to an equalization of the

rates of vehicles sold and consumed. As it is money that makes the mare go, so it is also the same necessary purchasing medium that makes the motor vehicle go, and there are definite indications that the expenditure for ownership and operation of motor vehicles is approaching a level, expressed in percentage of the total realized income of the country, above which it is not likely to rise. Indication that this is true will be found in figure 2, but before discussing that figure it is desirable to direct attention briefly to the remaining curves of figure 1, all of which bear out the curves previously discussed in their indications of a present near approach to definite limits upon the future growth of motor vehicle registration and use. Particular reference is made to the curve of motor fuel consumption per vehicle, which in 1938 stood at approximately 650 gallons per vehicle. The American Petroleum Institute, estimating from 1935, forecast an increase to 730 gallons in 1940, partly due to the increase in trucks; after which, because of the trends toward lighter cars and changes in engine design, it expected a continuing reduction to bring the requirement down to 670 gallons in 1960. Whether the expected decline is realized or not it is probable that no important increase will occur after 1940 and no increase at all, except as it may be occasioned by the greater relative operation of motor trucks and busses.

Turning now to figure 2, we can see in the curves there presented the fundamental reason back of the apparent approach to limits of motor vehicle registration and use that is indicated in all the other curves discussed. Ordinates of the two curves in this figure represent the total expense of ownership and operation of motor vehicles and the expense of operation only expressed as percentages of the national income by years from 1896 to 1938. Similarly expressed, the portions of annual ordinates intercepted between the two curves represent the expense of ownership exclusive of operation of the vehicles.

In passing, it is of interest to note, with particular reference to its effect on highway traffic, the fact that the ups and downs of vehicle operating expenditure are by no means as marked as those of the total expenditure, implying that enforced reductions in total expenditure are absorbed in reduction of the expenditure for ownership (i.e., avoidance of the purchase of new vehicles) without greatly affecting the expenditure for operation of vehicles, which is expressive of the amount of travel. This indication, most marked in the early years of the depression, agrees with observations of the remarkable persistence of motor vehicle usage in the face of hard times which was a matter of common notice at the time.

In the general trend of these fluctuating curves there is definite indication that the time is not far distant when the percentage of the national income that will be expended for the

ownership and operation of motor vehicles will have reached a maximum level. In 1937 the total expenditure reached an all-time high of 11 percent of the total national income, dropping in the following year to little more than 8 percent. The several horizontal lines drawn through the curves represent the average percentages for 11-year plateau periods; and it will be noted that the average total expenditure for the 11 years from 1928 to 1938, inclusive was nearly 9 percent of the total national income. Similar horizontal lines shown for the plateau period 1939 to 1949 indicate our belief that in that period total motor vehicle expenditure will reach a maximum averaging 10 percent of the national income for the period, with slight decline in the following period, extending from 1950 to 1960, inclusive. It will be noted that, while we expect a slight decline in total expenditure we anticipate a slight increase in the expense of vehicle operation and consequent road usage.

In the light of all the available evidence we have considered it reasonable to assume that future growth of motor vehicle registration over the 20 years between 1940 and 1960 will approximately parallel the increase of population, with a ratio of approximately 4 persons for each motor vehicle, including all classes of vehicles.

On the basis of this assumption we can estimate the future registration of vehicles if we can decide upon a reasonable prediction of population growth. The rate of future population growth depends

upon a number of factors, none of which can be certainly evaluated, and for this reason estimates of future population vary rather widely. In the excellent work on Population Trends in the United States, by Warren S. Thompson and P. K. Whelpton, published under the direction of the President's Research Committee on Social Trends, in 1933, the authors present a number of estimates varying according to certain assumed trends of net immigration, specific birth rates and expectation of life. These estimates by 5-year periods from 1930 to 1960 are presented in the attached table.

It is practically certain that the population of the future will be smaller than the figures given in Columns I or J of this table, and quite probable that it will be larger than those in Columns A or B. We have accepted the conclusion of Thompson and Whelpton that the course followed may be more like that of Column E, than any other. These are the figures corresponding to the assumptions of "medium" birth rates, expectation of life, and immigration; and they indicate, for 1940, 1950, and 1960, total U. S. populations of 133.1, 142.9, and 149.8 million persons respectively. Applying to these figures the ratio of 4 persons per motor vehicle there result estimates of motor vehicle registration in 1940, 1950, and 1960 of 33.3, 35.7, and 37.4 million vehicles respectively. It is believed that these estimates are as large as may be expected at the several periods and they are employed in projecting the trend

Future Population of the United States According to Certain Assumed Trends of Net Immigration, Specific Birth Rates, and Expectation of Life

Year	A	B	C	D	E	F	G	H	I	J
	"Low" birth rates and expectation of life, no immigration	Same as A except fewer births	Same as A except "medium" expectation of life	Same as C except some immigration	Same as D except more immigration	Same as D except more births	Same as D except "high" expectation of life	"Medium" birth rates, expectation of life, and immigration	Same as J except less immigration	"High" birth rates, expectation of life and immigration
	FUTURE POPULATION (MILLIONS)									
1930.....	122.8	122.8	122.8	122.8	122.8	122.8	122.8	122.8	122.8	122.8
1935.....	127.8	127.3	127.8	127.8	127.8	127.8	127.8	128.0	128.4	128.4
1940.....	131.9	130.9	132.2	132.5	133.0	132.9	132.5	133.1	134.5	135.1
1945.....	135.0	133.7	135.9	136.8	138.0	137.7	137.1	138.3	141.5	142.8
1950.....	137.1	135.6	138.8	140.4	142.3	141.8	141.1	142.9	148.7	150.8
1955.....	138.0	136.4	140.9	143.2	145.8	145.0	144.6	146.8	156.0	159.0
1960.....	137.9	136.0	141.9	145.0	148.4	147.4	147.7	149.8	163.3	167.3

of past motor vehicle registration, as Curve A in figure 3. For purposes of comparison, the trends estimated by Kettering, Scoville, and the American Petroleum Institute are also shown in the same figure. It will be noted that Curve A agrees with the 1950 forecast by Scoville and is slightly higher than the estimates for 1960 by Kettering and the American Petroleum Institute.

From the curves presented in this figure it will be apparent how far the process of motor vehicle growth has proceeded into the state of maturity referred to in yesterday's lecture; and as I then said there is indication that the turn toward this state was already setting in as far back as 1929 or 1930.

The trends indicated in figures 1, 2, and 3, are for the United States as a whole. In the corresponding trends for the several States we may expect a rather wide range of variation; and the information available does not usually permit decisions to be made in the States with as high a probability of accuracy as we may consider to exist in the national trends. Nevertheless, it is desirable in every State to undertake the determination of trends for the State similar to those with respect to motor vehicle registration and gasoline consumption that have been here discussed for the whole United States; and this undertaking is now proceeding with quite satisfactory results in State after State, employing the same methods that were used in determining the national trends and the best information available in

each State. This is an essential and highly important process of the State-wide highway planning surveys, for upon it depends in large measure the application of other observations of the surveys to the development of the future highway program in virtually all its phases. It is particularly important as a basis for decisions in respect to the design and capacity of the highways and their structures for decisions in respect to required and supportable highway costs, and for other decisions in respect to necessary and equitable rates of highway taxation and their yields. For all of these purposes the estimates of future vehicle registration need to be classified to the extent practicable into numbers of passenger cars, busses, and trucks, and the latter, in such detail as possible, into classes of various sizes of single vehicles and trailer and semitrailer combinations. In this connection it must be said that the task of developing useful forecasts in most States is rendered particularly difficult by reason of the classification inadequacy, and lack of rationality and continuity of the registration records of the trucks and busses.

In addition to these reasons, associated with the inadequacy of past records of trucks and busses, the forecasting of future registration of these classes of vehicles is rendered more difficult than the forecasting of passenger car registrations by the

fact that the growth in use of these vehicles has not yet proceeded as far toward its ultimate units as has the growth of passenger car use. This circumstance and the fact that the usage of trucks depends to such large degree upon the future growth and distribution of business and industry, makes the forecasting of truck registrations particularly difficult. About all that we can be sure of is that the rate of growth in both truck and bus registrations is certain to be for some years more rapid than the growth of passenger car registration.

In the curves for the United States, presented in figures 1, 2, and 3, the various trend lines represent changes in the registration and use of all motor vehicles together. While these are adequate as a basis for general discussion, the studies made for the purpose of actual forecasting in the several States are dealing separately with the various classes of vehicles and attempting, by such indications as are available, to forecast separately the future numbers and use of each class of vehicles.

For the estimation of future revenue to be derived from the taxation of motor vehicles and motor fuel the estimates thus made provide the necessary basis. They do not, however, supply a sufficient basis for the estimation of traffic on particular roads, and cannot be directly used to raise the observed present traffic volume on any road to its probable future volume.

It is not even certain that traffic as a sum total will increase in proportion either to the number of vehicles registered or to the gallonage of gasoline consumed. The larger number of vehicles expected in the future may be used more or less than the vehicles in present use. The gasoline consumption of the future may be used more efficiently than the present consumption and so produce more miles per gallon. Also, as has been remarked, the relatively greater increase in trucks and busses, with their larger fuel consumptions per mile, will tend to lower the average ratio. between mileage and gasoline consumption.

As shown in figure 1, the past upward trend of motor fuel consumption per vehicle per year, for the United States as a whole, shows a tendency to flatten out at a consumption somewhat above 700 gallons. The past increase has coincided with a substantial increase in the annual mileage use of vehicles, and a cessation of the increase in consumption might indicate a similar halt in the increase of vehicle-mileage, but this would not necessarily follow. By changes in the design of motor vehicles the further rise of annual fuel consumption per vehicle might be halted or even turned into a decline, as the American Petroleum Institute anticipated in 1935, without corresponding effect upon the annual mileage use of the vehicles.

In the approach to a limit upon the percentage of the national income expended for ownership and operation of motor vehicles, previously discussed, there is a definite incentive

to manufacturers of vehicles, by design changes, to reduce fuel consumption and other operating costs of vehicles as much as possible in order to make available for the purchase of vehicles a larger part of the total expended for ownership and operation. But whether such changes in the efficiency of operation would actually increase the amount of vehicle use would depend upon possible changes in the unit price of fuel and the speed of vehicles. Both of these factors have unquestionably influenced the considerable past increase in the usage of vehicles. It is today possible to travel further at the same cost and also further in the same time than it formerly was, and both of these incentives combine to induce greater travel. A similar combination of incentives, by the further reduction of the cost and time of travel, would doubtless contribute to the still greater use of vehicles in the future, but if either the time or cost advantage were lacking such greater use might be prevented by the inability of owners to spare either the greater cost or the greater time, as the case might be, that would be required for a more extensive operation.

It will be seen that these questions are highly speculative and probably susceptible to no very certain answers. Moreover, even if it were possible to forecast with some certainty the effects of probable design changes in vehicles of all or any classes, the fact that fuel tax records, as they are now kept, do not permit a clear determination of the consumption of fuel by each class of

vehicles, would put serious obstacles in the way of an estimate of the vehicle-mileage equivalents of changed total fuel consumption.

Considerations such as these suggest that, at least in the present state of available information, it is not feasible materially to improve the accuracy of future vehicle-mileage estimates by the fine spinning of theories of the effect of possible vehicle design changes. This being true it follows that a computation of vehicle-mileage from estimated future total fuel consumptions by application of the presently determined average miles per gallon cannot be greatly improved within the limits of practicality. Practically, then, the estimate of future vehicle-mileage would result from multiplication of the forecast future vehicle registration by the estimated annual fuel consumption per vehicle, and the multiplication of this product by an average value of vehicle-miles per gallon, based reasonably upon the determined present value of the latter rate. Finally, comparison of the future total vehicle-mileage per year, thus computed, with the estimated present total based upon current traffic counts, will determine the average rate of traffic growth in the future period.

The rate of growth thus established, however, cannot reasonably be applied to the observed present traffic on any road to form an estimate of the probable future traffic on the same road, because traffic does not increase at a uniform rate on all roads. In general it is apparent that the rate of traffic growth is greater

on primary roads than on secondary roads. Consequently a reasonable estimate of the future growth of traffic on all sections of a composite system of roads must depend upon a determination of growth factors applicable to the various order of roads in various localities within the system, that will be both consistent with observed past trends on roads of the respective orders in the several localities and equal in their weighted average to the determined average rate of traffic growth for the whole system.

Figure 4 shows how traffic is presently distributed over the entire rural road systems of the States of Iowa, Texas, and California as determined by the highway planning surveys of those States. It will be observed that in each State a large part of the total vehicle-mileage is concentrated on a small part of the mileage, and that the concentration is greater in California than in Texas, and greater in Texas than in Iowa. There is reason to believe that in each State the present distribution is a stage in a development marked by an increasing concentration of traffic on the more important primary highways.

How this process may have proceeded in the past and how it may continue in the future in one of these States is indicated in figure 5. In the beginning the traffic on all roads was probably within narrow limits equal. This was substantially the condition that existed before the introduction of the motor vehicle. All

roads were then, by modern standards, local roads; all served a traffic generated almost exclusively in their immediate localities and varied in the amount of their usage only as the density of settlement along them varied. Under these conditions a curve defining the relation between cumulative mileage within the system and the corresponding cumulative vehicle-mileage would approximate the straight dashed line, marked Initial Uniform Distribution. From this initial state the observed distribution of 1936 must have developed by a process passing through successive states such as are indicated by the curves marked with the dates 1920 and 1925, and if this has been the manner of the past growth, it is probable that the same process will continue in the future and produce in 1960 some such distribution as is indicated by the curve marked with that date. While this is a speculative conclusion that cannot be proved because of the lack of records of traffic distribution over the whole highway system antedating the planning surveys, it is a conclusion that seems consistent with a general historical knowledge of the development of roads and with intimate observation of present traffic trends. If it is sound (and there is little doubt that it is approximately correct) it implies, as a general rule that at any given time after the process of concentration has begun the rate of traffic growth is greatest on the roads of greatest developed traffic and decreases approximately with the volume of developed traffic.

Expressed in graphical form this theory of traffic growth is presented in figure 6. The various curves in this figure have no certain factual basis. They represent the diagramming of an idea and not a plotting of relationships of either particular or general application. They are probably, however, quite similar in form to curves that might be prepared wherever or whenever essential data with regard to past traffic growths are available; and if such data are not now available they should be accumulated by continuing studies of traffic growth of such character as will supply them.

The significance of the theory may be illustrated by comparing the past and future traffic development on roads of two widely different volume classes as represented in the theoretical diagram of figure 6. According to this diagram a road, which in 1920 served an average daily traffic of approximately 100 vehicles had probably developed by 1936 a traffic of 400 vehicles per day, and this volume will probably be increased by little more than 15 percent by 1960, so that its traffic at that time will still be less than 500 vehicles per day. Compared with such a road, one which in 1920 served an average daily traffic volume of 1,200 vehicles had probably developed by 1936 a traffic of 12,000 vehicles daily and by 1960 will be carrying 80 percent more, or around 21,600 vehicles daily.

It is emphasized that the curves of figure 6 and the examples cited are intended for illustrative purposes only and are not based, except by general inference upon any specific data; but there is

every probability that they represent typically the normal laws of traffic growth, and they illustrate the importance of obtaining the data necessary for establishment of such trends in each State. Only when this has been done will it be possible with confidence to project estimates of future traffic growth on the various parts of the highway system; and the necessity of projecting such reliable estimates is becoming steadily more urgent as we approach the limits within which we should eventually establish a consistent state of improvement.

The determination of factors of traffic growth applicable to particular sections of road, in one respect, more important than it formerly was, because the traffic on some roads is now approaching the volume at which it is desirable to increase the number of lanes from two to four. A considerable mileage in most States has already reached this point, and the further growth of traffic will bring additional sections to this critical point of development. It is desirable to anticipate this change as much as possible in order that preparations, such as the acquisition of additional rights of way, may be made on the sections involved well in advance of the need. It is desirable to foresee its coming as far ahead as possible, also, because of the largely increased costs that it involves and the necessity of providing adequately to meet such costs as schedules of tax rates are from time to time revised.

The making of such forecasts implies an ability to do two things: First, to estimate with some accuracy the future volume of traffic on particular road sections, and, second, to decide at what stage of volume increase in the particular sections the widening will be required.

Unfortunately the volume of traffic justifying widening is not a fixed quantity, but rather a variable depending upon the alignment and grades of the road and the speed of traffic. This is clearly indicated by the studies of passing practice and highway capacity made by the Public Roads Administration during the last two or three years. These studies make it quite clear that there is no sudden change in the freedom of traffic flow with increasing density, to indicate a point at which the road must be widened. They show rather that the opportunity for passing and the individual choice of speed is gradually reduced until, in the extreme condition, each driver must govern his speed by the speed of the vehicle ahead. This ultimate condition and the various degrees of restriction leading up to it are reached on 2-lane roads of bad alignment and short sight distance at lower traffic volumes than on roads of good alignment, because the restriction of sight distance adds its effect to the volume of traffic as a preventive of free passing.

Studies made on tangent sections of highway in several parts of the country indicate that when the traffic volume rises to 400 vehicles per hour (200 in each direction) more than 50 percent of

the traffic is affected to some degree in its ability to operate freely at desired speeds. With a traffic of 800 vehicles per hour (400 in each direction) the percentage affected rises to 70; and with a total traffic of 2,000 per hour (1,000 in each direction) more than 90 percent of the traffic is affected and a condition of virtually absolute congestion prevails. Just what percentage of the total traffic may be affected without intolerable congestion has not been determined and is probably only relatively determinable. Thus, a State possessed by liberal revenues might decide that the time for widening had arrived when only half of the drivers on a road over considerable periods of time are made aware of the effects of congestion. Another State, with less adequate funds, might of necessity set the criterion percentage higher.

The studies thus far made indicate that there is possibility of undesirable congestion on some roads at average daily volumes of traffic much lower than the figures that have previously been assumed as criterion for widening. They show that there is possibility of such undesirable congestion at any time after the average volume reaches 2,000 vehicles daily; and except where alignment lies on continuous tangent for long distances, the studies indicate that it would be desirable to investigate the particular conditions on all roads when they reach the traffic level of 2,000 a day in order to determine the degree of congestion existing. For the purpose of such investigations the administration has now developed

what appear to be entirely practicable instruments and a satisfactory technique. If by these means the degree of congestion presently existing is measured, the application of factors representative of probable future increase of volume will permit an estimate to be made of the approximate future date at which the effects of congestion will increase to a point at which widening will become desirable.

Of the various conditions that have contributed to increase the rate of obsolescence of highways previously constructed, none has been more influential than the increase of vehicle speed. Highways on which the curvature and sight distances were adequate for the speeds prevailing in the early twenties are today in many instances inadequate or positively dangerous.

It is a matter of common knowledge that the speed of traffic on the roads has substantially increased in the last decade. Unfortunately, it is not possible to form a very satisfactory idea of the extent of the increase, because of the paucity of dependable observations of road speed in the earlier years. We can form some impression from a review of the trend of legal speed limits, but it will be a very inexact one because, as everyone knows, such speed limits have always been honored more in the breach than in the observance.

An index that may be regarded as a measure of the maximum limits of vehicle design at every period is afforded by the records of the Indianapolis Memorial Day races. These records have been

established each year since 1911, with the exception of the war years 1917 and 1918. As shown in figure 7, they trace a steadily rising curve that shows no indication of flattening even in 1938. These records may be assumed to represent the speed capacity of automobiles especially designed for speed when operated under conditions especially advantageous for speed, although they are of course very much below the mile record speeds established under the ideal conditions available at the Great Salt Lake and similar locations.

However, a better indication of the speed capacity of automobiles such as are operated on the public highways is furnished by the official American stock car records established under the supervision of the American Automobile Association. These records have been established irregularly by stock cars of various makes since the later twenties. They have been established for both open and closed cars, for 4 classes of horsepower as indicated by piston displacement, and for various lengths of run by vehicles of the two body types and several piston displacement classes.

In figure 8 are shown the records as they have been established for the 5-mile distance by closed cars of piston displacement classes B, C, and D. For Class A -- the class of largest piston displacement -- there is only one record at the 5-mile distance, and that a record established by a Marmon 16 in the early thirties, which is not shown on the diagram. Unlike the Indianapolis records, it will be noted that these records form, for each class of cars, a curve that shows a definite tendency to level off in recent years.

In these latter curves there is some indication that a limit may be placed upon further increase of vehicle speed by voluntary action of the manufacturers. If a limit is not so placed it is probable that it has to be fixed by law, and fixed more positively than it can be by ordinary road speed limits. This, it seems to me, will be necessary for two reasons: First, because the rate of highway obsolescence, unavoidably high in the pioneer period through which we have passed, will have to be reduced by all possible means in the mature period into which we have now advanced; and this will not be possible if speeds are permitted continuously to overleap the limits of safety for roads as they are designed and built. Such a limitation will also be necessary because there is a tendency for the difference between maximum and minimum speeds of vehicles on the road to widen almost to the full extent of the increase in the maximum speed, i.e., minimum speeds do not materially increase. This differential of speeds is one of the most fruitful sources of accident hazard and cannot be permitted greatly to increase without serious consequences.

It certainly would not have been desirable to impose definite restrictions upon the speed capacity of motor vehicles in the early years of their development. I believe, however, that the objection to such restriction no longer exists and that it will be necessary in the near future to impose such definite limits upon the design of vehicles. If this is done the forecasting of speed will no

longer present a problem, and instead of that problem there will be substituted the necessity of deciding, in harmony with a public spirited motor vehicle industry, upon such maximum limits as will be safe in view of the practical limitations of economical highway design.

In respect to the dimensions and weights of vehicles a somewhat similar situation exists. It is possible to design roads consistently with any fixed limits of these vehicle characteristics. It is not possible to design them, with assurance of reasonable economic life, unless such vehicle characteristics are kept within some defined limits.

Already there is substantial agreement upon rather definite limits of vehicle width and height, and upon maximum axle loads, agreement embodied in the laws and rather remarkably honored in operation. The principal remaining uncertainties are those which exist in respect to the lengths and gross loads of vehicles and combinations. In both respects there is still wide variation in the laws of the several States; and in respect to gross weight there is not only the wide legal difference, but also a marked discrepancy between law and operating practice. The latter is particularly noticeable in the case of the trailer and semitrailer combinations, and, in respect to these combinations, the most serious problem is presented by the tendency to overload beyond the power capacity of the towing unit. While this does not often result in the

overloading of road pavements, because of the rather complete conformity to axle load limits, it does impose excessive loads on many existing bridges, and it does often so reduce the speed of such combinations on the steeper grades as to cause an intolerable obstruction of faster traffic.

It will probably be necessary in the immediate future to impose effective limits upon these vehicle characteristics also, limits which will be applied in the manufacture of the vehicles and so certified by the manufacturer; and the recent proposal of the Society of Automotive Engineers favoring a scale of taxation based upon the ratio of gross weight to engine horsepower is significant in this connection.

If the maximum speed, dimensions, and weights of vehicles can be thus definitely fixed by law at least for periods consistent with the necessities of an orderly and economical road program, the necessity of approximating such criteria of road design by forecasting methods, will be avoided, and the problems to which such methods will have to be applied will reduce substantially to those concerned with the numbers of vehicles registered and in operation, the future fuel consumption of vehicles, and the increase of traffic on particular road sections. The ability to deal satisfactorily with these problems will enable us to cope with most of the requirements of a rational determination of financial and administrative policies and a rational design of the road structure. I feel that satisfactory techniques for such forecasting processes will result shortly from the study of the large body of traffic facts now fast becoming available through the highway planning surveys.

TRENDS IN INTERRELATIONSHIPS OF BASIC ANNUAL DATA ON MOTOR VEHICLE MANUFACTURE AND USE

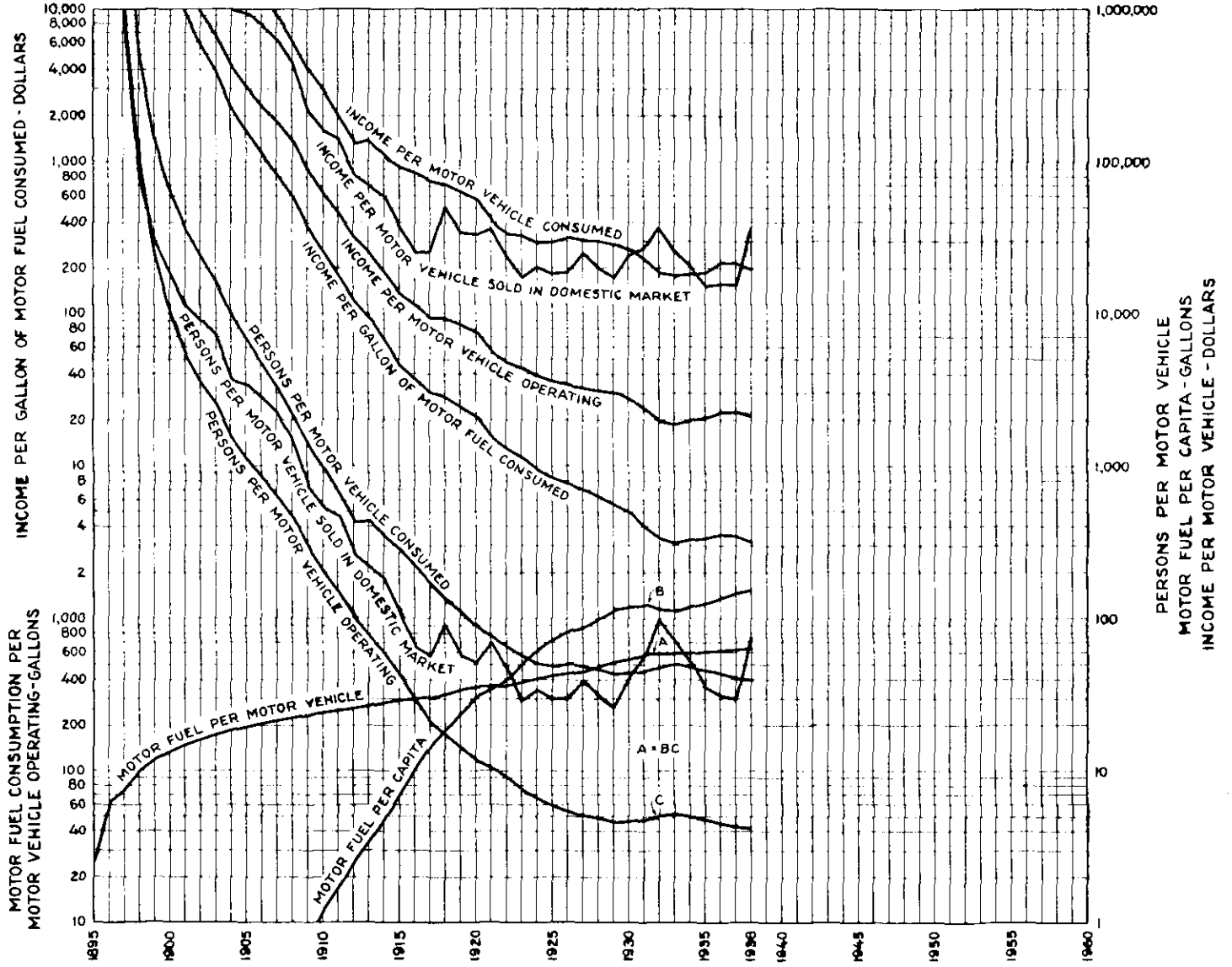

FIGURE 1

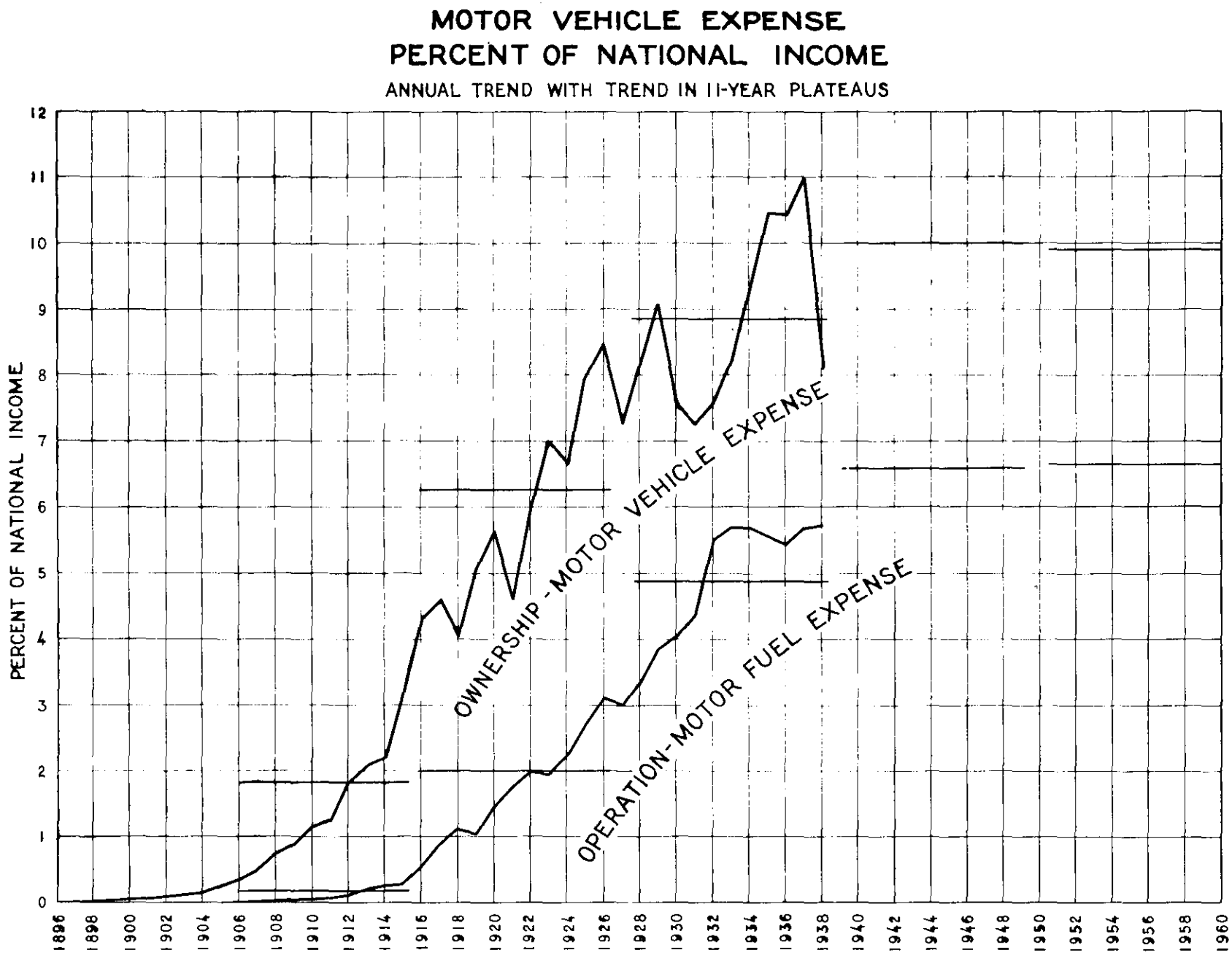
MOTOR VEHICLE EXPENSE
PERCENT OF NATIONAL INCOME
ANNUAL TREND WITH TREND IN 11-YEAR PLATEAUS
PERCENT OF NATIONAL INCOME
0
1
2
3
4
5
6
7
8
9
10
11
12
1896
1898
1900
1902
1904
1906
1908
1910
1912
1914
1916
1918
1920
1922
1924
1926
1928
1930
1932
1934
1936
1938
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
OWNERSHIP - MOTOR VEHICLE EXPENSE
OPERATION - MOTOR FUEL EXPENSE

FIGURE 2

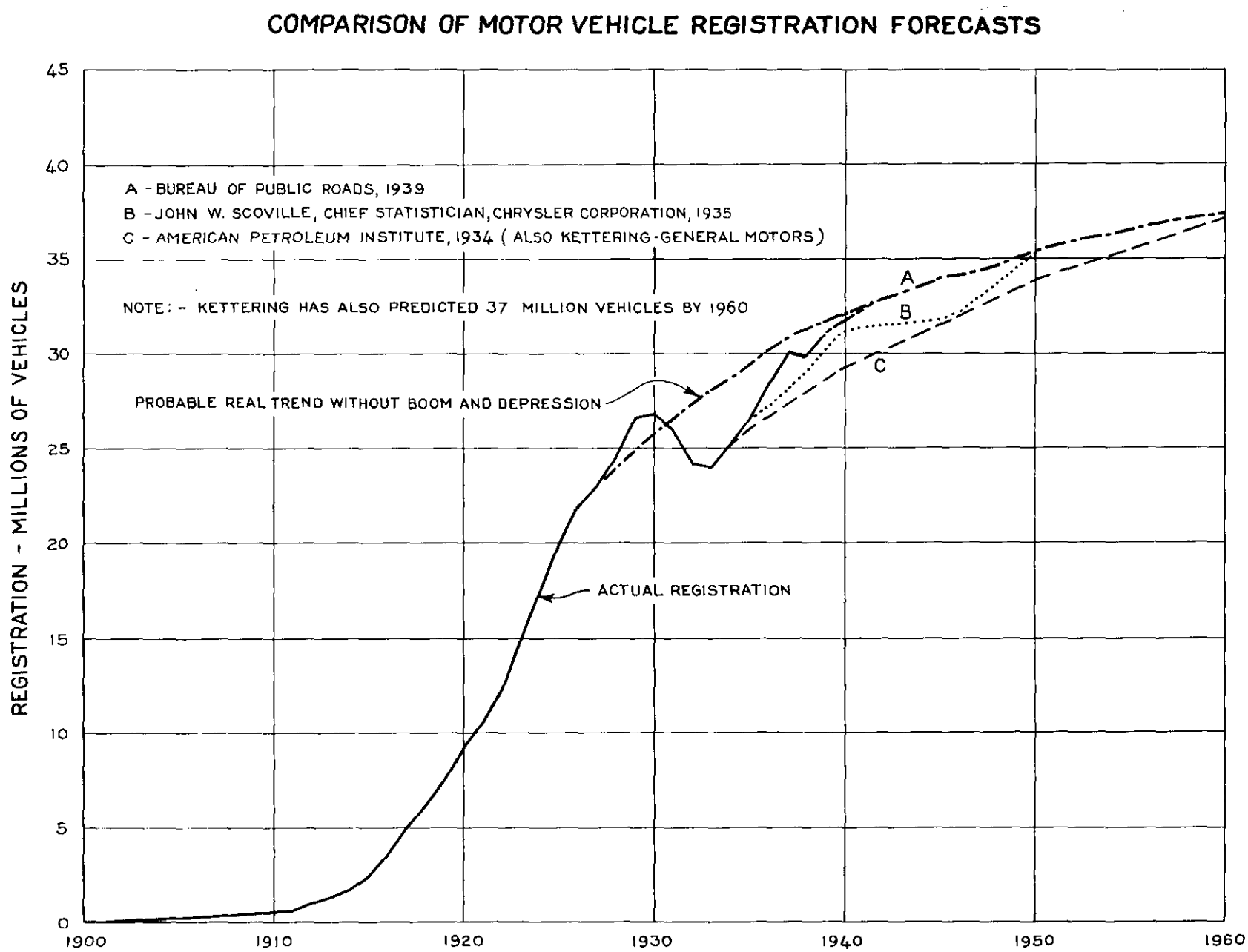
COMPARISON OF MOTOR VEHICLE REGISTRATION FORECASTS
REGISTRATION - MILLIONS OF VEHICLES
45
40
35
30
25
20
15
10
5
0
1900
1910
1920
1930
1940
1950
1960
A - BUREAU OF PUBLIC ROADS, 1939
B - JOHN W. SCOVILLE, CHIEF STATISTICIAN, CHRYSLER CORPORATION, 1935
C - AMERICAN PETROLEUM INSTITUTE, 1934 (ALSO KETTERING-GENERAL MOTORS)
NOTE: - KETTERING HAS ALSO PREDICTED 37 MILLION VEHICLES BY 1960
PROBABLE REAL TREND WITHOUT BOOM AND DEPRESSION
ACTUAL REGISTRATION
A
B
C

FIGURE 3

TRAFFIC DISTRIBUTION IN THREE TYPICAL STATES AT THREE STAGES OF DEVELOPMENT

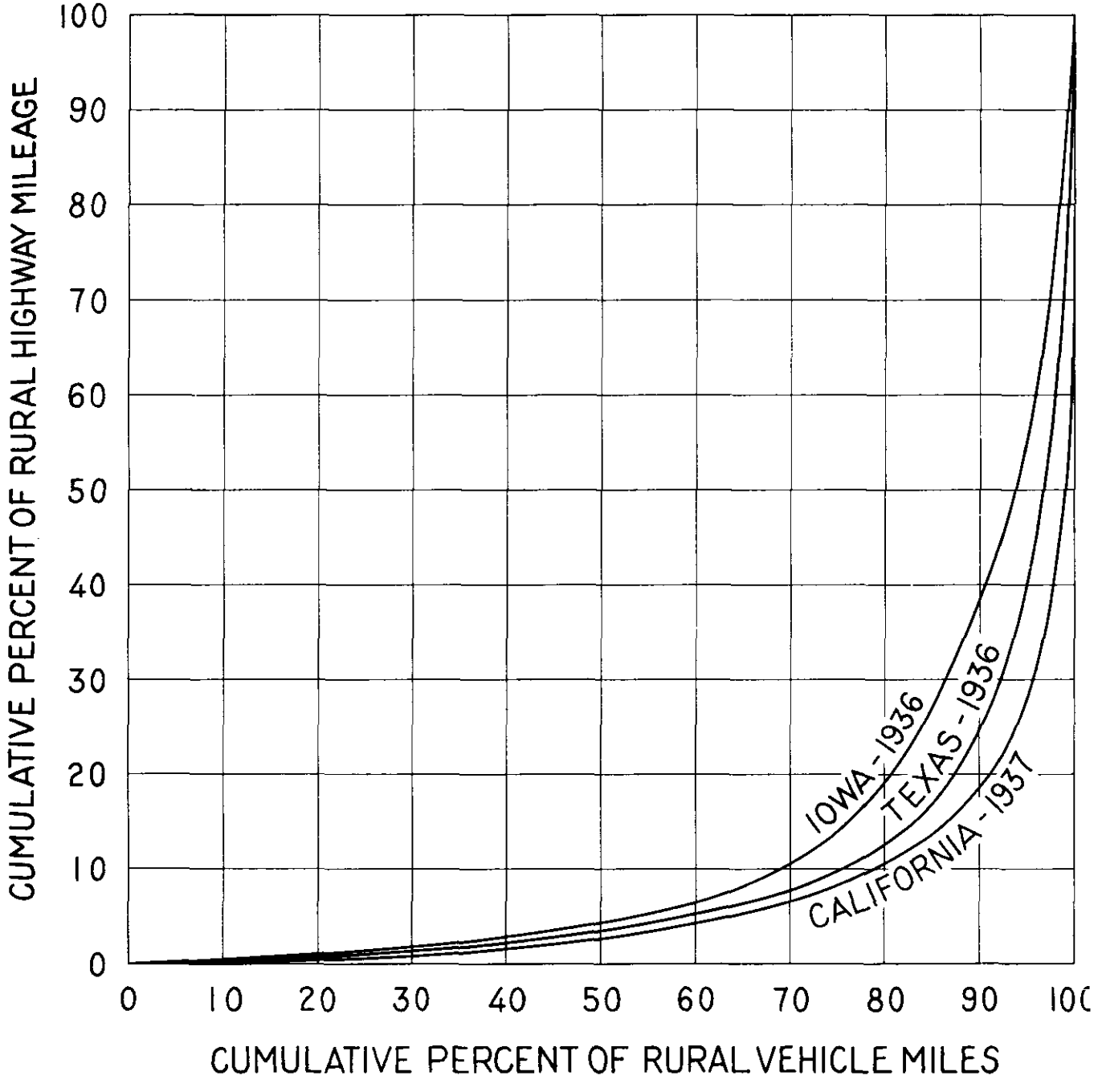

FIGURE 4

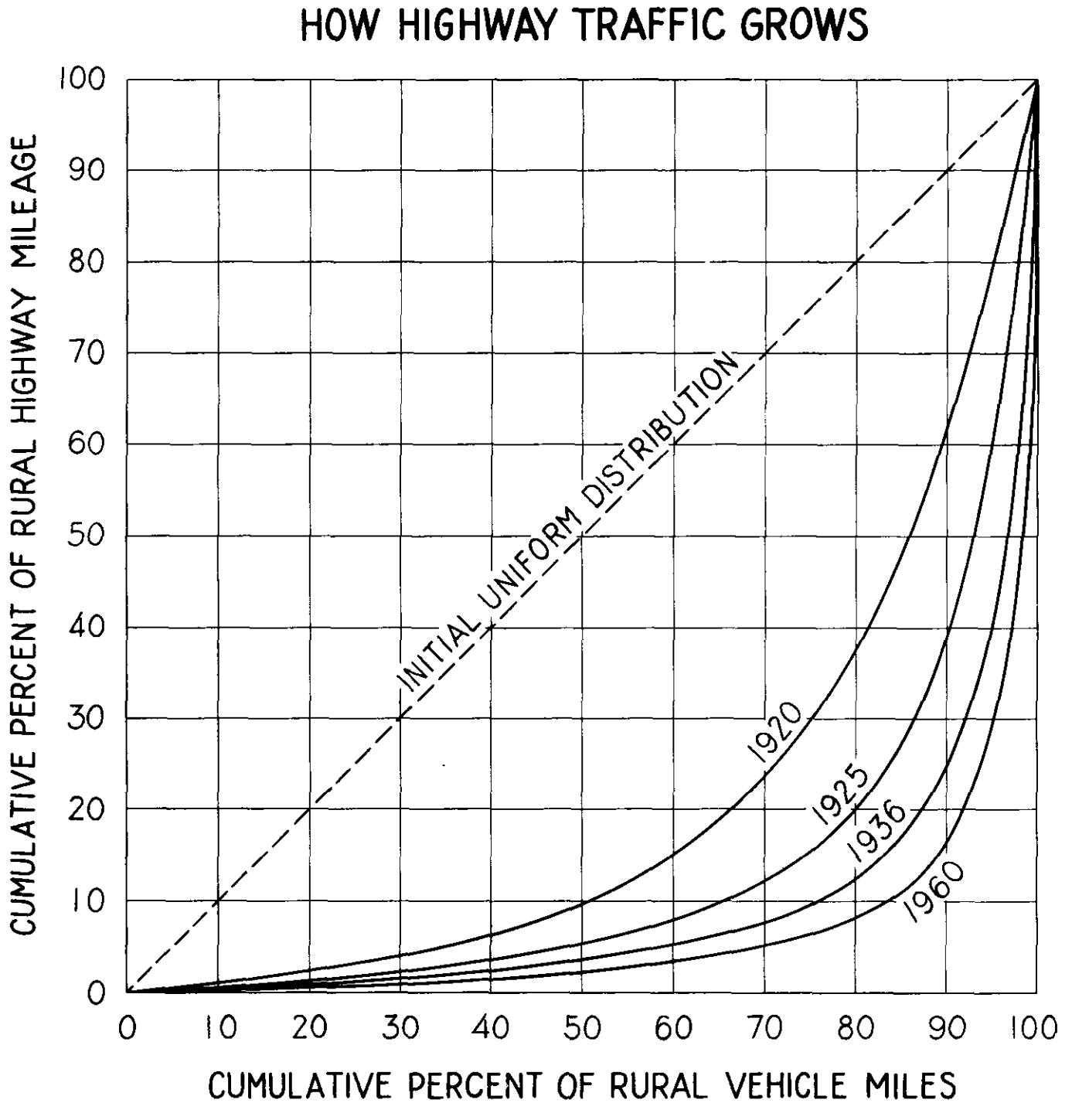
HOW HIGHWAY TRAFFIC GROWS
CUMULATIVE PERCENT OF RURAL HIGHWAY MILEAGE
CUMULATIVE PERCENT OF RURAL VEHICLE MILES
INITIAL UNIFORM DISTRIBUTION
1920
1925
1936
1960
0
10
20
30
40
50
60
70
80
90
100

FIGURE 5

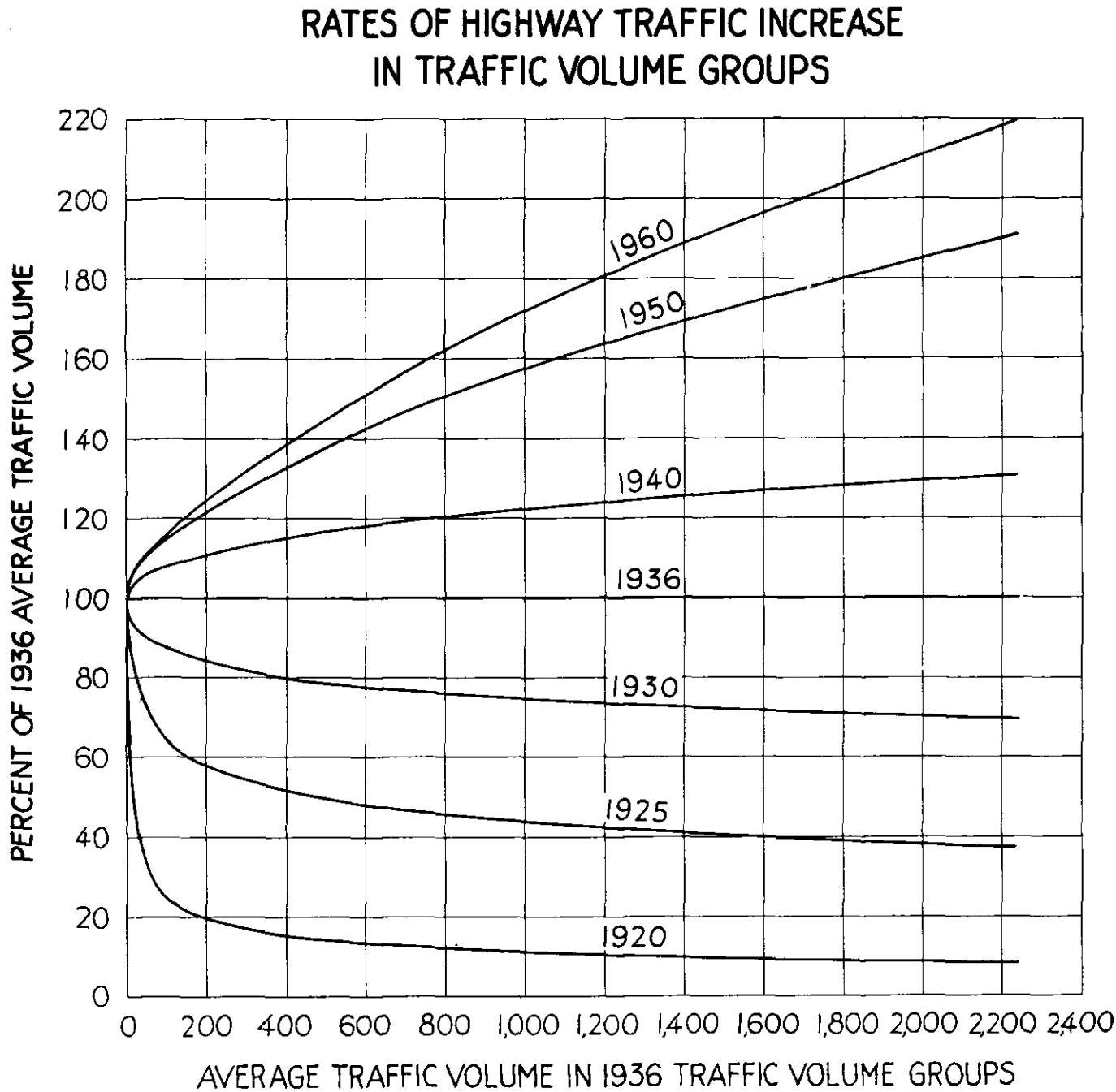
RATES OF HIGHWAY TRAFFIC INCREASE
IN TRAFFIC VOLUME GROUPS
PERCENT OF 1936 AVERAGE TRAFFIC VOLUME
220
200
180
160
140
120
100
80
60
40
20
0
1960
1950
1940
1936
1930
1925
1920
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
AVERAGE TRAFFIC VOLUME IN 1936 TRAFFIC VOLUME GROUPS

FIGURE 6