

May 22, 1951.

BUREAU OF PUBLIC ROADS
DEPARTMENT OF COMMERCE

THE FUNDAMENTALS OF HIGHWAY PLANNING

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May 1951

What I shall say to you today will be by way of preface. While you are in the United States you will hear a great deal about highway planning. The words are on everybody's tongue, you will find; and what I shall say will be merely introductory to a great deal more you will hear on the subject.

WHAT IS HIGHWAY PLANNING

It is possible that the words do not mean the same thing to everyone who uses them. I am sure they do not have an invariable connotation to all in our own country. Perhaps they may not mean the same to you as to me. So, before we go farther, let's see whether we can come to a common understanding of what we mean when we speak of highway planning.

We may say that we plan a highway when we make a survey and locate the highway, determine its line and grades and its other geometric features, and design its foundation, its pavement and its drainage. That is a part of what we mean when we speak of highway planning. It is a latter phase of what we mean. It is not, by a wide margin, the whole of what we mean.

We may devise a so-called master plan of a highway system - of the street system of a city, or a State's highway system. We will consider the movements to be served within an area - the area of a city, the area of a State; and we will lay out on paper an integrated system of routes well calculated to facilitate the essential movements and well devised to serve existing or intended uses of the lands of the area. That, too, assuredly is a planning operation. It is certainly not the whole of what we shall mean when in this course we speak of highway planning.

There is a sense in which the word "plan" stands for a goal to be reached, generally a quantity of work to be done or production to be achieved in a specified period. The communists, for example, have their 5-year plans which, being set up by their masters, they are lashed to accomplish. In this

Republic, there is no master to set or goad us to our goals; but the State highway needs and financial studies, of which you will hear report, are perhaps a democratic approximation of the communist "plans". They constitute a determination of what needs to be done to fit a highway system to its desired uses, and the devising of taxing and revenue means for meeting the determined needs in particular or alternate periods. These, too, are parts of the highway planning of which you will hear much in the weeks ahead. The highway needs studies and the financial studies, as they are conducted in this country, constitute large segments of the highway planning of which I am speaking. But, they also are not the whole of highway planning.

Nor would we have you believe that we regard as highway planning the country-wide continuing studies which we call the highway planning surveys. These surveys will be described to you at length and in detail. They are in our view very important fact-finding instruments of highway planning. We would not wish you to think that we confuse the planning surveys with highway planning itself.

If, then, these things of which we have spoken are not highway planning, or the whole of highway planning, what can we say is the whole nature of the highway planning, to the fundamentals of which I shall address my remarks today.

I would say it is this:

Highway planning is a rational process aiming to bring about and maintain an optimum, balanced adjustment of the condition of all roads and streets to their necessary uses in the service of safe and efficient transportation by vehicles of appropriate design. It implies a scientific determination of the needs of highway improvement and conservation as they presently exist and as they are likely to accrue in the future. It implies further a continuing process of determination of the order in which existing needs will be met. It involves an original estimate of the cost of accomplishing the determined needs over an appropriate period and the devising of financial measures calculated to produce revenue at a rate commensurate with the accrual of need; and a periodic re-estimate of such costs and revision of means. It includes an equitable apportionment of the burden of cost among all beneficiaries of the improvements in proportion to their respective benefits. The highway conditions envisaged as necessary are those which, in the presence of expected maximum weights and dimensions of vehicles and anticipated volumes and compositions of traffic, will conduce to a minimum cost and maximum convenience, safety and efficiency of highway transportation. In the presence of highway conditions so adjusted, it is the further function of highway planning to regulate

or define the regulation of highway vehicles and traffic in such manner as to maintain the planned adjustment of road and vehicles as fully as may be; and indicate the necessity, and time the alteration of the adjustment in such manner as to conserve the existing investment in roads and vehicles in optimum degree.

It will be evident from this description that highway planning, as we regard it here, is not merely a matter of highway design or of the physical planning of highway systems. It is not a one-time operation productive of a plan to be executed forthwith and outright. It is a process anticipatory of things to be done, of the control and timing of things that are done, and of revision of the earlier anticipation. It is, therefore, a continuing process. It devises the financial means of accomplishing the highway program it defines as necessary to achieve an envisaged state of highway transport efficiency; and it attempts to maintain in operation, by appropriate control and regulation, a relation of the roads and their traffic at all times conducive to a maximum efficiency of highway transportation.

It is of highway planning so conceived, and of a few of the fundamental principles of such highway planning that I wish to speak to you today. The principles of which I will speak are the distilled essence of our own experience, of experience in the United States of America. You come here from many countries. You will doubtless observe here many conditions that differ in some degree at least from those with which you are familiar at home. You will observe differences in social and economic concepts. You know already of certain differences in political and governmental institutions and practices. You will be quick to note that the place and the environment of highway transportation in the United States, and perhaps the extent of its development, differ in this or that respect from its place and environment and extent of development in your own countries. You may find differences, and perhaps much that you will decide to differ with, in our ways of doing things.

The ends of your highway planning may be different from ours; the means you employ may be different. But the fundamental concepts that I shall describe are in some degree universal. I believe you will find a recognition and a conformity with these principles, to be fundamental to the sound planning of highways and highway transportation in your own countries even as we have found it to be necessary to recognize and conform with them.

Now, what are these fundamentals of which I speak? They are 10 in all - a decalogue of highway planning. I shall state them in numbered sequence and in such manner, I hope, as will aid your memory of them. And the first is:

1. Highway traffic, facilitated, tends to increase. Sound highway planning will foster and suitably provide for this increase.

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A country ages old is devoid of good roads. A feeble traffic moves with difficulty over its primitive trails. Build an improved road and at once, as if by magic, a new traffic appears, and grows.

In another country highway transportation exists in an advanced state of development. Its roads are overcrowded with a teeming traffic. Build an expressway for the better accommodation of a previously congested traffic stream, and a traffic which has not moved before, appears and grows.

These examples of the tendency of highway traffic at widely different stages of development to increase when it is afforded a new facility may be observed today in different parts of this Western Hemisphere.

In a lifetime in the United States we have seen a traffic little above the level of the first example grow to the level of the second, and continue to grow.

It is plainly evident that a fundamental purpose of highway planning at the lower stage of traffic development is the fostering of the growth of the traffic. Somewhere in the course of the rise to the higher stage of development the question may be mooted whether the further increase of traffic is to be encouraged. We need not linger here over that question. When it arises the development of traffic has already passed beyond the need of fostering and highway planning must employ its every resource in response to the inevitable further growth.

The devising of conditions favorable to the growth of traffic or, what is the same thing, favorable to the promotion of highway transportation; and the formulation of means to that end are of the substance of highway planning as we here speak of it.

And let me point out that it is not by highway improvement alone that these conditions are created. Adequate highways exist today in parts of the world where the growth principle, that

everywhere inheres in highway traffic, is less than vigorously active. If, in the United States, in 1900, when motor vehicles and roads suitable for their use were similarly few, there had been imposed upon the infant automotive industry and motor vehicle ownership and usage in its beginning a burdensome taxation in the form of heavy excises or duties, or high motor fuel taxes and vehicle license fees, it may be doubted that anything approaching the actually realized development of motor vehicle usage would have occurred here. It may be doubted that any improvement of the highway system approaching that which we have witnessed would have resulted.

The fortunate forbearance exercised in the taxation of motor vehicle usage at its beginning, either for the financing of highway improvement or the general support of government, was, as we now see it, a sound measure of highway planning. Does it occur to some of you that there has been error in that respect in the highway planning of your own countries? Is it not true that there are countries represented here in which a fuller and more rapid development of highway transportation and usage of the motor vehicle has been thwarted - in some instances intentionally - by excessive taxation and other restrictions placed upon the ownership and use of motor vehicles.

It is plainly obvious that the principle of growth inherent in highway traffic must be taken into account in the design of highway improvements. The highway constructed now will continue as it is now designed in the service of a greater traffic some years hence. Its present design should reasonably anticipate the needs of its future traffic. That, I repeat, is plainly obvious.

It is less obvious that an injudicious provision for traffic of the future may, at least in the earlier stages of highway transport evolution, tend to stifle rather than foster the growth of traffic. Highway systems are necessarily improved section by section. If, in an early stage of highway development, slender means are consumed by the too expensive improvement of a few sections, even in degrees the future growth of traffic may justify, the consequent delay of any improvement of the remainder of the system may be the mark of bad, rather than good highway planning.

Notwithstanding the errors in detail which are now recognized, we, in this country, have had no cause to regret the policy of stage construction which was followed generally in our earlier highway planning. The quicker achievement of a practicable system-wide improvement of pioneer level that permitted traffic to move with enhanced, if less than desirable

facility, between its natural origins and destinations, was a result of a highway planning decision of the period that we account a fortunate result. That, within our means, it created highway conditions under which there occurred a first great upsurge of highway traffic, or, if you prefer it, a first great advance in the utility of highway transportation, this was the sufficient test of its soundness.

So, recognizing the tendency of highway traffic, facilitated, to increase, and accepting the principle that it is the objective of sound highway planning to foster and suitably provide for that increase, this also should be borne in mind: That the appropriate planning means to these desirable ends are not of one, but of various forms, among which it is the concern of the planner to choose those which are best fitted to particular times and circumstances.

So much, then, regarding our first fundamental. Let's turn to the second and state it in this fashion:

2. We should pay less for improved roads than for the absence of them.

We should pay less for improved roads than for the absence of them. This phrasing of our second fundamental principle of highway planning, I hasten to confess, is a paraphrase of an often quoted expression of Commissioner MacDonald's. The Commissioner long ago asserted as a fact that "we pay for good roads whether we have them or not, and we pay less if we have them than if we have not."

If we think of the consequences of road improvement in the large-country-wide, system-wide - and if we think of the probable degree of any such widespread improvement that is likely to eventuate, I believe we may all subscribe to the essential truth of Mr. MacDonald's dictum.

It is, indeed, a fundamental principle of highway planning that it must make certain that we pay less for the good roads that we plan than we would pay for the absence of them, assuming that there is the same traffic to be moved under the two conditions.

Expressed in more technical terms, we may state the same principle in this way: Highway improvements should be so planned as to result in a benefit - cost ratio exceeding one. In this form it may present to you a more familiar aspect. And, if it does, I trust that you will have noticed that in each of my several repetitions of the principle variously stated I have applied it in a plural sense - to roads, plural, not to a road, singular.

So applied, a proper conformity with this principle determines the justifiable downward reach of an improvement program into the segments of lesser utility within a system of highways. Only a patently extravagant planning would result in the improvement of highways of substantial traffic volume that would fail to conform to this principle. The excess of benefit over cost accumulated by the improvement of the more heavily traveled segments of a highway system is available to offset the deficit in the same relation that will mount as the improvement program includes more and more of the non-paying mileage. As long as the algebraic sum of the gains and losses remains positive, the improvement of the system examined will conform to the stated principle. We shall be paying less for the improved roads than for the absence of them.

The same principle in singular application, i.e., in application to a single road section, may expose the error of a proposed gross over-improvement of a road of little importance, if such exposition be necessary. But, similarly applied to a low-traffic section of a major road, it may lead to an erroneous conclusion.

Application of this fundamental principle of highway planning is troubled by a difference in the degree of possible ascertainment of the improvement costs, which are tangible and determinable with almost complete exactness, and the benefits of the improvement, which being intangible are not exactly determinable. Benefits accrue to highway users and to property the highways directly serve, as well as to the general community. The latter benefits, difficult and sometimes impossible of calculation, may far outweigh the benefits to road users, particularly in urban areas.

Dispute over the values assigned to the intangible benefits by various planners we had better adjourn to another session. It is sufficient for this discussion to take comfort in the belief that the actual resultant benefits probably exceed the most liberal estimates of them, and to uphold as a fundamental of sound highway planning the principle involved, that we should pay less for improved roads than for the absence of them.

There is, then, a third fundamental which I think I might state in this way:

3. Traffic is where people are.

Traffic is where people are. In a broad sense this brief statement is a full statement of a fundamental fact. Traffic is greatest where people are most numerous. Cities are places of relatively great population density. Traffic in cities is more dense than in rural sections. In the United States, the heavier concentrations of population are along the Atlantic and Pacific seaboard and in a wide band stretching from New York to Chicago. In those areas also we have our heaviest traffic.

In a more particular sense it may be that the brief statement sacrifices something in exactness to the desired ease of remembrance. Perhaps it would be somewhat more exact to say that traffic is where people are and want to be. Since traffic is movement it has both origins and destinations. Its origins are invariably where people are; its destinations are where people want to be. Thus, in a city the diurnal tide of traffic flows in the morning from the homes where workers are to the business and manufacturing sections where they want (or are required) to be; in the evening it flows from the places of employment where the tired workers are, back to the homes where they want to be.

If we were planning a highway system in a country in which highways exist in only a rudimentary state, in which, therefore, there has been as yet no considerable development of traffic, connection of the places where people are would with little doubt place the principal lines of the system where they ought to be.

That, in fact, was the way in this country we originally chose the roads that were to constitute the primary highway systems over which our States would assume control, the systems that we call our State highway systems.

Fifty years ago in the United States there had been no such designation of a primary highway system. Even that first essential step of the highway planning process had not been taken. There were then almost as many miles of roads in the country as there are today; but they were roads in a rudimentary state. They were uniformly roads of little traffic and that traffic everywhere the traffic of the immediate neighborhood. Intercity traffic was virtually non-existent. Traffic data, the modern highway planners' factual guide, were unheard of, and would have been valueless had they existed.

But automobiles did exist and their numbers, though still very small, were expected to increase. We were thinking of planning a highway improvement for a traffic, an expected automobile traffic yet to come. Within an existing road network

approaching 3,000,000 miles the country over, we wished to choose a limited mileage of greatest potential usefulness for earliest improvement. For this choice our only guide was the assumption - then still an unproved principle - that traffic would be where people were.

In largest numbers the people were in the cities and there also the automobiles were. In each State we composed our State highway systems, our primary highway networks, of roads extending outward from each larger city and joining to connect the cities.

When, much more recently, with a wealth of traffic data available, we reexamined our highly developed highway system with a view to the selection of a very limited system of inter-regional highways of maximum importance, the facts of traffic use determined a selection of identical character. The Act of our National Congress which later gave legal sanction for the selection of such a system, advised by the previous planning study, defined it as a system "so located as to connect by routes, as direct as practicable, the principal metropolitan areas, cities, and industrial centers . . . "

Since traffic is where people are and want to be, it is not surprising, but rather to be expected, that we find that 50 percent of the traffic on our rural highways is a traffic moving between cities, its origins and its destinations both urban; and that another 36 percent has a city as either its origin or its destination. The cities are the places where people are or want to be in greatest numbers. So it follows that only about 14 percent of the traffic on our country roads is a traffic moving between origins and destinations both rural, that is, between places where there are few people.

We have found an interesting consequence of this principle in our studies of the probable usage of proposed city by-passes. The construction of such by-passes was formerly advocated as a means of reducing the congestion of traffic on routes through cities. Our traffic origin-and-destination surveys have now convinced us that the greater part of highway traffic at the approach to a city cannot be kept out of it by providing a by-pass route, simply because for this greater part the city is its origin or its intended destination. Traffic is where people are or want to be; and we find that on roads approaching our larger cities close to the city boundaries upwards of 90 percent of the traffic is either generated by the city as its place of origin, or is bound to the city as the place where it wants to be.

Even at towns of 2,500 population we still find that 50 percent of the approaching traffic is destined to the town and would not use a by-pass built around it. You will notice that I am here regarding the function of the city by-pass as means for the relief of the city street system of the fraction of rural road traffic that is by-passable. In the larger cities, where this relief is most to be desired, the small fraction of the city-approaching traffic which would prefer the by-pass, if offered, would subtract from the heavy traffic of the city arterials affected a volume so small as to afford them little relief.

I do not mean by this to discount the usefulness of circumferential routes at cities. Their value derives, in our view, primarily from their utility as means for the distribution of city-bound, and the collection of city-originated traffic and as means of connection between peripheral city areas. Provided for these purposes mainly, they are also available as means for the by-passing of the city by the generally small traffic segment that finds them useful for that purpose.

Nor should I fail to concede that under conditions substantially differing from ours in respect to the distances between major cities, the relative percentages of by-passable and city-bound traffic as we find them here, may differ considerably. Where large cities are close together, as in Western Europe, for example, I suppose that a substantial volume of traffic may be facilitated by by-passes provided around cities intermediate between its other-city origins and destinations, which in such case are the populous places where it was and wants to be.

Now, if we have sufficiently tested the principle that traffic is where people are, suppose we examine for a while another and a fourth fundamental of highway planning, which we may simply state like this:

4. Highway traffic is by nature essentially a traffic of relatively short range.

Highway traffic is by its very nature essentially a traffic of relatively short range of movement. This is obviously true in respect to the great accumulations of traffic that we find in the cities. It is likewise true in only slightly different degree in respect to rural highway traffic.

A few years ago we made what we called a road-use survey, by which we discovered that nearly 40 percent of all the traffic using the rural roads of this country was composed of vehicles making trips of less than five miles. More than 25 percent of the trip lengths were found to be between five and ten miles.

Another twenty percent of the traffic was found to be moving on trips between ten and twenty miles in length. In summary, about 85 percent of all rural road traffic was found to be made up of movements less than twenty miles in length; only 15 percent of longer movements. And the traffic at that time using our roads which was bound on trips more than fifty miles in length was less than 5 percent of the total. I do not suggest that the small percentage of long-distance movement is not, transportation-wise, of much consequence. Indeed, I should add at once that the 15 percent of trips that exceed 20 miles in length perhaps generate over 50 percent of the total vehicle-mileage. But, in the planning of the character of highways and even their location, the volume of traffic is more significant than its vehicle-mileage and the predominantly short range of highway traffic from the cities where it principally originates and has its destinations, has much to do with the variation of traffic volume along even the most important of trunk lines.

These may seem to some of you rather surprising figures. They define the actual composition of traffic in the United States a few years ago, and they describe the probable character of a traffic in like stage of development anywhere. I should point out, perhaps, that the stage of development referred to is one which is attained in the presence of a widespread private ownership of passenger cars and a virtually complete motorization of the local distribution and delivery of goods.

If, in some of the lands from which you come, the distribution of motor vehicle ownership is of a different order, the frequency distribution of motor vehicle trip lengths may likewise differ in degree from that which characterizes our traffic. In respect to the composite of all traffic, however, it may be expected that examination would reveal no departure from the fundamental rule of the relative shortness of traffic range.

For proof of the fundamental verity of this rule and of the principle that traffic is where people are, look at the traffic map of a system of primary rural highways. You will find that the bands which represent by their width the volume of daily traffic are widest at the boundaries of the cities and that they taper to much lesser width at short distances from each of the cities. It is the progressive diminution of the volume of shorter movements in and out of the city that causes this tapering of the traffic bands, and we recognize the distance in which it occurs as definitive of the radius of a zone of the city's traffic influence. We find that the radius varies roughly with the population of the city. At cities of the largest size, those of a million population and upward, we find this radius to

be of the order of 35 to 50 miles; at smaller cities a lesser distance. Towns of 10 to 25 thousand population, we find, extend a marked influence upon the volume of primary highway traffic only to distances of 5 or 10 miles from their boundaries.

These zones of the traffic influence of cities have for us at this time a very particular planning significance. They define the areas in which, with the further increase of our traffic volumes to the point of congestion, we must expect to reach first the necessity to convert our highways from their pioneer two-lane to multiple-lane width, and to provide additional arteries of the greater width to accommodate the increasing local movement.

Our knowledge of the extreme shortness of the larger proportion of highway trips has served at times to prevent the diversion of road-improving effort from the uppermost needs that are found in the vicinities of most of our cities to such fanciful projects as the construction of great transcontinental highways of uniformly elaborate design.

The periodically repeated proposal of such projects stems, of course, from the erroneous belief that there is a substantial highway traffic of transcontinental range. Actually, we found some ten or more years ago, when we looked into the matter, that, by actual count there then were just about 300 cars a day that were making the transcontinental trip on all of our east-west highways together. Doubtless the number has since increased in some measure. That the transcontinental movement remains an insignificant percentage of the mounting total of our traffic is, I am sure, beyond question. The vast preponderance of the traffic total is of extremely short range and it centers in large measure in the cities, where most of our people are. These facts we regard as of fundamental significance, and they continue to control the direction of our highway planning policies. There may seem to be some inconsistency between my disparagement of the more fanciful proposals for the creation of elaborate transcontinental arteries and the fact that a large importance attaches in our thinking to the national system of interstate highways recently designated as the principal routes of our entire highway system. Actually, the inconsistency is apparent only. Although the interstate system appears on the map as a system of continuous routes of great length, and although it is a system on which travel of the greater ranges exists in higher than average percentage, the usage of even this system is still predominantly of relatively short range, and the improvement needs of highest priority still are found adjacent to the cities which the system connects.

Highway traffic, facilitated, tends to increase. We should pay less for improved roads than for the absence of them. Traffic is where people are. And, highway traffic is by nature essentially a traffic of relatively short range. These four fundamental concepts of our highway planning we have discussed. We may now add a fifth, and express it thus:

5. All highway traffic is heterogeneous and a composite of various speeds.

All highway traffic is heterogeneous and a composite of various speeds. Your visit with us is perhaps already long enough for you to form the conclusion that ours is apparently a nearly homogeneous traffic. You may have noticed that animal-drawn traffic has all but vanished from our roads; that pedestrians are few and far between; and that the cyclist, ubiquitous perhaps in your native environment, is here conspicuous only by his absence. When you have traveled our roads a little more extensively, you will have discovered that our herds and flocks are rarely driven to the executioner; they usually ride. So, you will doubtless conclude, and correctly, that ours is a relatively homogeneous traffic, composed almost exclusively of motor vehicles. Yet it remains in a degree heterogeneous as all highway traffic is heterogeneous. Ours is heterogeneous mainly in the variety, dimensions, weights, and capabilities of the motor vehicles that compose it. Yet, that is variety enough to concern the planning of highways. For, whatever may be the variety of traffic, whether it go afoot, ahorseback, or awheel, whether vehicles be large or small, or animal-drawn, or pedal or motor-driven, the principal characteristic of their variety affecting the planning of highways is, I take it, the variety of their speed of motion. I do not discount the necessary consideration of differences of size and weight; indeed I shall refer to these separately later. But it is basic to sound highway planning that the highways as planned shall permit movement of the various forms of their traffic, each at the speed of its choice or capability, with a minimum of mutual friction, interference, or obstruction. Freedom of passage on the open road is as deeply ingrained in the plank of desired human rights as any of the other freedoms recently heralded by proclamation from high places. And in its social sense it possesses a dignity that entitles it to place with the other freedoms in future proclamations.

I do not mean to draw the long bow. We are considering here the fundamentals of highway planning, not the fundamentals of human society. But in the lesser sense we must recognize that there is not freedom of passage, that the road is not truly open, if by reason of deficient provision it does not permit of the movement of any of its traffic at the speed of its capability or reasonable desire.

It should be an objective of highway planning to provide this freedom. Whether it be accomplished by the provision of separate lanes for the more incompatible traffic, such as separate paths for cycles or separate roads or extra hill lanes for heavy goods vehicles, or whether the single highway be so designed as to permit its convenient use by the variety of traffic to be accommodated, the objective is the same: To permit the passage of the various forms of traffic each as nearly as possible at the speed of its capability or reasonable desire.

By intimate study of the behavior of traffic we have learned to rate the traffic capacity of a highway in terms of the number of vehicles, operating at a normal variety of speeds, that can pass over it at a desired average speed in a unit of time. We have learned to associate the possibility of individual vehicle operation at any speed with the condition of liberal capacity. Difference of speed implies the necessity of some vehicles to overtake and pass others. The properly designed road must permit these passings, conveniently and with safety. When passing begins to be impeded, the speed of the faster vehicles begins to be reduced to the speed of the slower, and progressively, as the volume of traffic increases, what has been a possibility of movement at a wide range of speed is reduced to the necessity of movement at a single speed - the speed of the slowest vehicle. We have found that this ultimate condition of absolute congestion is reached on a straight and level two-lane highway at a traffic density of about 2,000 vehicles per hour. But there is relative congestion on even so ideal a highway at considerably lesser density of traffic, and the introduction of curvature and grade differential, intersections and other impediments, and the shortening of sight distance may, and do, greatly reduce the highway's traffic capacity.

Sound highway planning should provide highways of a reasonable and substantial traffic capacity. The conditions of design that affect the provision of capacity have lately been evaluated with remarkable precision and you will discuss these useful findings in later sessions of your course. My purpose is only to direct your attention to fundamental principles and the principle that is here involved is that highway planning must take due account of the fact that all highway traffic is heterogeneous and a composite of various speeds.

In our discussion thus far we have recognized in passing, the variety of size and weight of vehicles among the various manifestations of the heterogeneity of traffic. From this characteristic of traffic we may deduce a sixth fundamental principle of highway planning, and state it in this manner:

6. Highways can be built to accommodate vehicles of any size and weight, but no highway built can accommodate vehicles of unlimited size and weight.

I repeat again. Highways can be built to accommodate vehicles of any size and weight, but no highway built can accommodate vehicles of unlimited size and weight.

Every load bearing structure has a limit of load bearing capacity. That is an axiom which no engineer, at least, would presume to deny. A highway is a load bearing structure; a bridge is a load bearing structure.

Two bodies cannot occupy the same space at the same time. That is an axiom of perhaps somewhat wider acquaintance. A highway built has a definite width. Vehicles must pass each other in that width, and they cannot overlap in passing. Hence there must be a consistency of the width of highway lanes and the width of the widest vehicles. Structures built over the highway must be built at a definite, they cannot be built at an indefinite, height. Vehicles must pass under such structures. Hence, there must be a consistency of the height clearance provided in highway design and the height of the highest vehicles.

These are truths so elementary that I perhaps should apologize for mentioning them, and I would apologize were it not for the fact that they are so often ignored in highway planning. I shall, however, omit explanation of the further truths that there must also be a consistency between the length of vehicles and the degree of road curvature, between the weight and motive power of vehicles and the gradients of highways, and between the braking capacity of vehicles and the length of the road's forward visibility.

If these consistencies must exist then it follows that highway planning must envisage, and highway design must suitably provide for vehicles of particular and definite maximum dimensions and weights and power and braking capacity. It follows, further, that highways so provided may not consistently, efficiently, or safely be used by vehicles of characteristics transcending the maxima foreseen in the highway design. And that highways, when built, must be regulated in their usage to prevent such transcendence.

Here it occurs to me to point out a slight difference between the highway planning significance of the various speeds of vehicles and the various dimensions of vehicles. The variation of speed is a condition that the highway must

have definite qualities to permit. In respect to the size and weight of vehicles, it is with the maxima rather than with the range of magnitudes that planning is principally concerned. A highway or bridge that will accommodate the largest and heaviest vehicles can be depended upon to accommodate the smaller and lighter without difficulty.

This discussion of the principles of highway planning need not enlarge upon the manner in which highways may be designed in consistency with the maximum dimensions and weights of vehicles. The designer now has for his guidance much more useful data for that purpose than only a few years ago were available to him. Road building has risen well above its empirical past and is rapidly approaching a future of complete rationality of design.

We have learned a lot about the normal transverse placement of vehicles in travel on a highway that enables us to decide with good reason what width of lane is required in the presence of any given maximum width of vehicles. We know what grades and what length of grades will permit vehicles of any weight - power ratio to travel at any desired minimum speed. We know what curvature is consistent with given maximum length of vehicles. We have learned much; we will soon know much more of the mechanical properties of subgrade soils and how to better them. We are approaching clarity in our knowledge of the mechanics of the load-pavement-foundation relation. We know that the critical load in respect to the design of pavements and their bases is the wheel load or wheel loads in close juxtaposition and not the gross weight of vehicles. Even to the previously more rational processes of bridge design we are constantly adding a further rationality. We know much about the forces of impact impinged upon the road by moving vehicles. We have some perception of the effects of frequency and intervals of loading upon the road and bridge structure. In short, we have a greater and increasing knowledge of the stresses and strains induced in roads and bridges by vehicular loads that enables us with increasing confidence to design for the withstanding and support of vehicles of any maximum weight and weight distribution.

We can, or almost can, design highways and bridges for any given maximum size and weight of vehicles. We cannot yet be sure what that maximum size and weight should be. That is a matter rooted more deeply in the economics of transportation than we have yet been able to fathom. We must continue our exploration.

But, meanwhile, we must adjust our highway planning to the assumption of some definite maximum size and weight of vehicles; and recognizing that no highway built can accommodate vehicles of unlimited size and weight, we must insist that the limits for which our highways are designed shall not be exceeded when they are built.

Knowing, if not too clearly in what manner, that decrease of the unit costs of vehicular operation accompanies increase of vehicular size and weight, we should recollect also that the same increase of size and weight in some degree spells increase of road cost. Economy of highway transportation is the sum of the economics of vehicular operation and road provision. Assuming, as we must, some limits of vehicular size and weight for purposes of our highway planning, we should endeavor to set these limits as nearly as we know how in consistency with the objective of an optimum relation of road and vehicle costs.

And, the greater road costs of accommodating the larger and heavier vehicles, as nearly as we can estimate the differentials, should be the basis of that equitable taxation of the use of the vehicles, which is also, as I have pointed out, an objective of highway planning as we here conceive of highway planning.

A seventh fundamental of highway planning I think we might state in this way:

7. Highway improvement should invariably be in balance with traffic requirement.

Highway improvement should invariably be in balance with traffic requirement. This principle follows so closely upon the heels of others of which we have spoken that it may need no elaboration in this sequence. Yet, how often, as the consequence of an unthinking acceptance of the demand for uniformity, as the result of a slavish conformity with so-called "standards", or just by the blundering of simple naivete, is it ignored!

We build a high-type road where a low-type road would suffice. We build a low-type road where the traffic requires a high-type road. We repeat the cross-section design essential for the accommodation of heavy traffic where there is only light traffic to be served.

I have spoken of the proposal frequently recurrent in this country that we should have for our prideful possession some grand transcontinental highways. Invariably there is associated with this proposal the suggestion that these great arteries should be built straight as an arrow, from the Atlantic to the Pacific, and throughout of the same design. "Four-lane divided highways, maybe six lanes, crossing the country from the East to the West, that's what we need," we are told. But, of course, we don't. And to follow this suggestion would be to ignore, and most flagrantly ignore, the

principle that highway improvement should be in balance with traffic requirement. For the traffic requirement of roads in the middle areas that these roads would traverse is very different from the requirements of the eastern and western terminal areas.

The same principle applies in another connection as a corollary of others that have been stated. I am referring to a country which is in the early stages of the development of its highways. There will be a recognition, we hope, of the principle that highway traffic, facilitated, tends to increase, and that this tendency should be fostered, not stifled by excessive taxation, or thwarted by other arbitrary restrictions. But there will also be recognition, we pray, of this further principle that the improvements that are made shall be in reasonable balance with the traffic requirement. If so, there will be an appropriate modesty in the design of the fledgling highways consistent with the infant stature of their traffic. The natural desire for the best of highways will be restrained while the better will do, for, indeed, under these conditions the better is the best.

As an eighth fundamental let us say that:

8. Roads built must stay built.

Quickly said, but it means so much. Roads built must stay built. The highway planning that conforms with this principle is a far-seeing planning; it is an all-around planning. Obviously, when I so describe the wide connotations of this principle, I am not attributing to it only the meaning that roads built should be maintained, though that is, of course, a part, and a not-to-be-forgotten part of its meaning. (A part, incidentally, that has been forgotten in instances of my acquaintance.)

No, I am thinking of it in this larger sense: That when we plan a highway and build it, or when we plan a highway system and build it, we do not finish; we only begin. We grab a bear by his tail and we can never let go. We ought to think what we are doing before we start.

There is one thing certain about a road. It will wear out. It will wear out in spite of your very best maintenance. It will be outgrown by the creature that wears it. Like a boy's pants.

So if we really intend to plan a highway system, or a highway policy, it behooves us indeed to remember before we start to build that what is built must stay built. Before we start to build we should envisage the necessity of building not once, but of building again, and again. The knowledge of that necessity is basic to the

shaping of a highway financing plan and program; and it may sober the financial judgment to realize that we not only must pay to have a highway system but also to hold it.

If we realize that a highway system now built piece by piece, will wear out piece by piece in the same or a similar order at some time not so very far distant we will want to determine presumably not only if we have the means to build it now but also how we are going to acquire the means to rebuild it in that not distant future.

Every one having the opportunity and the power to shape or alter the planning and conduct of highway programs should understand clearly that a highway system is a living organism something like the human skin; that parts of it are constantly dying and being sloughed off and replaced with new tissue; that the dying will go on willy-nilly; and that if the replacement does not follow as surely serious ill will spread to the entire tissue. If this were really understood widely, we should have less occasion to deplore the tendency in highway financing to go forward (or backward, as the case may be) by fits and starts.

If we, as highway planners, really have an understanding and a respect for this fundamental planning principle that roads built must stay built, we shall realize that we must learn somewhat more than most of us know about the life periods and life expectancy of the roads that we build. We shall realize that we need to know better how not only to budget wisely our means and shape consistently our measures of present building, but how, foreseeing the recurrence of building need and the time and the probable amount of the recurrent need, we may anticipate the essential measures, and plan the accrual of the essential means of the future.

As a penultimate fundamental I would draw to your attention the fact that:

9. Durability of place and sufficiency of space are the good highway's best heritage.

Durability of place and sufficiency of space are the good highway's best heritage. No more prizeworthy gifts can highway planning of the present transmit to highway planning of the future than highways laid on lines and in places on and in which they can rightly persist, and highways given the space that will permit their eventual enlargement of capacity and protection from border encroachment.

Accepting the principle that roads built must stay built, we confidently expect the periodic necessity to rebuild at least the surface structure of our roads. Our planning should justify the equal confidence that it will be reasonable and possible for the roads we now build to remain permanently where we now build them. Permanence of location is the only highway permanence we can hope for; but that permanence we can not only desire but, subject only to the fallibility of human judgment, assure if we will.

The space to which we refer in the statement of our principle is, of course, the more familiar width of right-of-way. There are few other characteristics of highway adequacy more imperative than a sufficiency of needed right-of-way width, and few that in their provision encounter greater difficulty and expense. Highway space is never cheaper than when it is least needed. A long look ahead to the probable future need, and timely acquisition of right-of-way space in advance of its urgent necessity is a hallmark of the best of highway planning.

We have come to the last of our decalogue. The tenth of our fundamentals, which really is but a synthesis of the preceding nine, is this:

10. The totality of highway planning is a trinity of essentially coordinate efforts.

Yes, the totality of highway planning is a trinity of essentially coordinate efforts. Highway planning is not solely, as some may lightly imagine, an engineering effort in the composition of materials to make a road. It is a composite of three essential efforts. They are (1) the effort to plan roads economically to meet the needs of their traffic, (2) the effort equitably to exact from all beneficiaries, but from the traffic largely, the financial means wherewith to build the roads planned, and (3) the effort conservatively to regulate the traffic use of the roads built. The three efforts close a triangle of planning purpose which begins at the point of a determination of the kinds of vehicles and the volumes of traffic to be served; seeks on one side to plan the character of highways and the highway system in efficient relation with the anticipated vehicles and their composition in volume; on the second side estimates the finances required for execution of the planned highway improvements and apportions the incidence of the cost fairly among the beneficiaries; and, finally, on the third side measures and regulates the use of the roads built to assure that the vehicles and the traffic that materialize as the actual usage conform in substantial approximation to the initial determination with which the planning began. When the triangle fails to close, when the actual usage departs, as through error it may and by the changes of time it will - then the circuit must be begun and traversed again. The ceaseless repetition of this circuit - that is highway planning.