DEPARTMENT OF ECONOMICS, FINANCE AND ADMINISTRATION

Transportation Economics of Highway-Development Policies

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THIS paper deals with two related questions of interest to transportation economists: (1) Are policies dealing with the allocation and use of highway funds consistent with the standard of minimizing highway transportation costs? (2) Are highway-development policies designed to minimize highway transportation costs consistent with the broader economic objectives of promoting the development of an adequate and efficient transportation industry?

An ideal use of highway funds from the standpoint of transportation economics is to invest them efficiently, i.e., in such a way as to minimize highway transportation costs. But when traffic flows are a function of road improvement, highway-investment policies designed to minimize transportation costs may produce anomalies which would tend to discredit the minimization of these costs as a basic principle of investment policy. The complications created for effective planning by erratic changes in traffic flows pose fundamental problems for those interested in increasing efficiency in investment. These problems are not likely to be resolved without broadening the scope of planning surveys to embrace traffic flows over other types of transportation systems.

Improvement of highway facilities may tend to increase the average total unit cost of transportation service produced by the transportation industry as a whole. There is nothing necessarily objectionable about this in a society that is able and willing to bear the expense, for there are important differences in the quality of highway-transportation service and other forms. But too much emphasis can be placed upon efficiency considerations in attempts to justify additional investment in highway facilities.

It is important to realize that in a society that is not static the goal of minimizing production costs of transportation service may not be consistent with the goal of providing adequate service. This is true of our modern transportation industry. In the final analysis, the main justification for large-scale improvement does not rest on efficiency considerations but on consumer preference for a superior, if somewhat more-expensive, type of transportation facility.

Large-scale improvements in the highway plant seem to be justified on the grounds of contributing more- adequate facilities to serve the growing demand for highway travel. To what extent this demand should be satisfied is a matter of social choice. If a choice consistent with the long-run interest of society is to be made, the following point deserves careful consideration: Continued improvement of the highway plant may tend to increase the average total unit cost of all transportation service. This will pose a difficult problem of determining an equitable basis for allocating

certain hidden costs. Equitable solutions to this problem will have to be worked out in the framework of an analysis which focuses attention on the impact of highway development policy on the entire transportation industry.

●THE rapid expansion in the twentieth century of highways, pipelines, inland waterways and airlines has resulted in the creation of a highly developed and extremely complicated system of domestic transportation in the United States. Recent estimates indicate that the total public and private investment in transportation is close to $100 billion, almost 20 percent of the nation's capital values and that close to a fifth of the national income is being spent for transportation service.

As the transportation system grows in size and complexity, it becomes a matter of increasing economic importance to determine whether existing policies are well designed from the standpoint of promoting the development of adequate and low-cost transportation service. The purpose of this paper is to examine this question with reference to highway development policies. We shall deal with two basic questions: (1) Are funds provided for road improvement in the United States being used efficiently? (2) Does improvement of the highway system contribute to the development of an adequate and efficient transportation industry?

In dealing with the first question we shall begin by defining what would be an ideal use of highway funds from an economic standpoint. We shall then consider whether this ideal has influenced highway development policies in the United States and what the major obstacles to practical realization of this ideal consist of.

In discussing the second question we shall utilize concepts developed in the first section of the paper to show that efficiency in the use of highway funds is not necessarily consistent with the advancement of an "efficient" transportation industry. This point does not constitute an effective argument against highway improvement, but it deserves careful consideration if we wish to develop more equitable policies for financing needed improvements in the transportation industry.

Is money spent on road improvement used efficiently? Let us reflect on what is meant by an efficient use of highway funds. What in fact is the basic economic justification for roads?

The justification for the construction of roads is to facilitate the production of transportation service. Transportation involves the movement of persons and goods from place to place. If no traffic is carried on between two points or through two points, it makes little sense to construct roads connecting these points. It is true that roads, railroads, or canals may be built in anticipation of future traffic needs, but if no traffic develops, the resources invested in the construction of the way are wasted. Whether built in anticipation of future traffic or to accommodate existing traffic flows, a road or any similar structure, such as a canal or railroad, is justified on economic grounds to the extent that it contributes to the efficient production of transportation service. A clear recognition of this point and its implications facilitates the analysis of some of the most-complex and controversial questions concerning both promotional policy and regulatory policy in the transportation industry.

From an economic standpoint an ideal use of highway funds is to invest them in such a way as to minimize highway-transportation costs. Transportation service can be looked upon as a product produced by two sets of productive factors. The first set of these factors may be referred to as *equipment* and the second set as *plant*. For example, assume that X tons are to be transported between two points, A and B, a distance of Y miles. (For the time being we may conveniently abstract from differences in the quality, safety and speed of transportation service and refer to differences in the amount of service produced in terms of numbers of passengers or tons of freight carried and the number of miles that these are transported.) XY ton-miles of transportation service may be produced in various ways. The freight could be carried by animals or porters traveling over trails or threading their way through trackless country. Or it may be transported by motor vehicles or other types of transportation equipment traveling over more or less adequate roads, railroads, etc. The important point is that in the production of any given amount of transportation service considerable variation may exist (1) in the type of equipment used for transportation and (2) in the type of road over which the equipment travels. Moreover, some of these combinations of equipment and plant will be more efficient in producing the service in question than will others.

The optimum utilization of two factors of production is a classical problem in economics. In the usual analysis the problem is formulated by conceiving of the two factors as cooperating with each other in accordance with a production function which states the maximum quantity of a product which can be obtained by the use of stated quantities of the two factors. One convenient means of representing such a production function is an *isoquant diagram.* Quantities of one factor of production may be plotted along the horizontal axis and quantities of the other factor along the vertical. The isoquants are curved lines convex to the origin. Each isoquant corresponds to a definite quantity of output, an increase in output is indicated by moving to a higher isoquant, i.e., to a curved line farther from the origin. An isoquant diagram may be likened to a contour map with the isoquants representing different levels of physical output.

If the prices per unit of the two factors of production are known the combinations of these factors which can be purchased for a fixed total expenditure can be shown by a sloping straight line, like *RS* in Figure 3. The slope of this line depends only on the relative prices of the factors. Two interpretations follow immediately: First, the minimum cost of producing the output represented by any isoquant can be achieved by using the combination of the two factors which correspond to the point where that isoquant is tangent to a price line. Second, the greatest output attainable with any given expenditure is represented by the isoquant which is tangent to the price line corresponding to that expenditure. The diagram and its analysis rest upon the assumption that the two factors are continuously substitutable for each other in such wise that if the amount of one factor is reduced by a small amount it will be possible to maintain the quantity of output by a small increase in the other factor. In order for the isoquants to be smooth arcs convex to the origin, it is also necessary to assume that each successive unit decrement in the amount of one factor of production will require a slightly larger increment in the amount of the other factor if output is to remain constant.

The use of an isoquant diagram is convenient in an analysis of an ideal use of highway funds. With its use we may clearly define what is meant by an ideal combination of highway plant and equipment in the production of transportation service taking into account (1) the amount of traffic that is to be accommodated, (2) the relative prices of plant and equipment, and (3) the rate of interest. In terms of the diagram it will be possible for us to clearly specify what we mean when we talk of efficient or inefficient use of highway funds, and we may conveniently determine how changes in the rate of interest, in the relative prices of highway plant and highway equipment or changes in traffic volumes, will tend to affect the ideal combination of productive factors.

In Figure 1, let the horizontal axis measure the capital invested in highway plant and the vertical axis measure the capital invested in

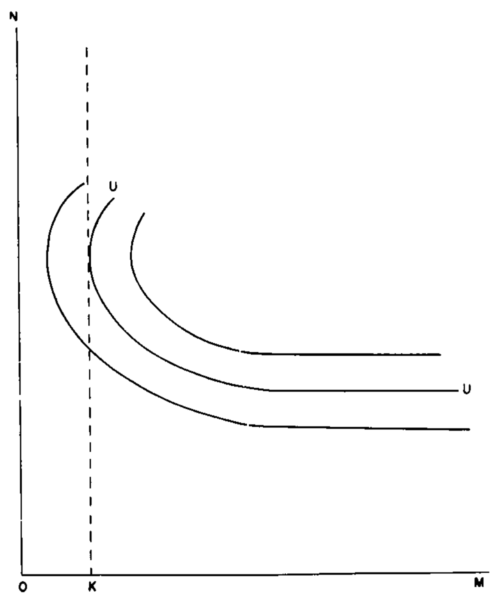


Figure 1.

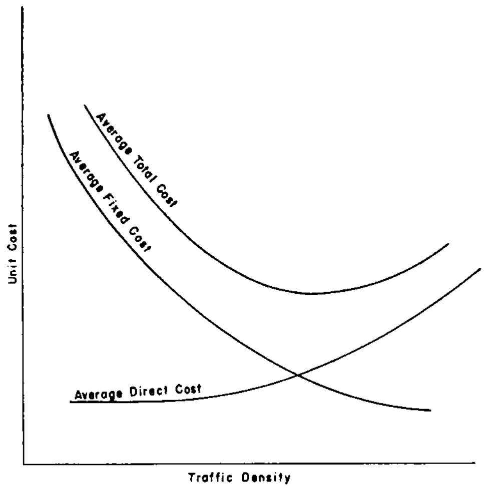


Figure 2.

equipment. The isoquants represent various quantities of transportation service measured in ton-miles.

With a given type of road between *A* and *B*,[1] as *X* (the tonnage to be carried between the two points) increases, increasingly large inputs of equipment would be required to produce the transportation service in a given period of time. If the traffic between *A* and *B* is required to remain on the existing road, a point will eventually be reached where congestion will result. Eventually there would be a reduction in the amount of transportation service that could be produced. Thus the isoquants will curve away from the *ON* axis (Fig. 1).[2]

For a given highway plant, as traffic increases the cost of transporting freight eventually increases. For low volumes of traffic, however, the fixed cost per unit of the road declines rapidly with increases in traffic volume. Thus, for any given highway plant we tend to get a U-shaped curve to express the relationship between traffic density and unit cost. Average total unit costs are likely to decrease at first for low traffic volumes, flatten out, and eventually rise, jumping to infinity as congestion becomes acute (see Fig. 2).

[1] And a given technology in regard to equipment.

[2] Up to a certain point expenditure on road improvement will increase the amount of highway transportation service that can be produced from a given expenditure on equipment. Eventually a point will be reached where such expenditures would have a negligible effect on increasing output. Thus the isoquants tend to become parallel to the horizontal axis.

Roads are subject to considerable variation in design. The width of the road; type of surfacing; design features, such as curvature, grade, separation of lanes, number of grade crossings, etc., are subject to wide variation. For a given volume of traffic between *A* and *B*, additional investment in the roadway could be undertaken to reduce the cost of producing *XY* ton-miles of transportation service. In Figure 3 let isoquant *UU* represent *XY* ton-miles of transportation service. Assuming that the existing highway plant represents *OK* investment in roads, *KL* investment in highway plant should be undertaken if *XY* ton-miles of transportation service are to be produced at minimum cost.

The ideal proportion of input quantities of equipment and plant is represented by *P* in Figure 3. Given the relative prices of the factors of production (represented by *RS*) and given the rate of interest, the ideal proportion of factors is achieved when the ratio of the marginal productivity of equipment to the marginal productivity of plant is equal to the ratio of the price of plant to the price of equipment.

The position of *P* will change as changes occur in the relative prices of the factors. Changes in the relative prices of the factors can be represented by shifts in the slope of *RS*. Generally, it will be economic to substitute the less-expensive factor for that which

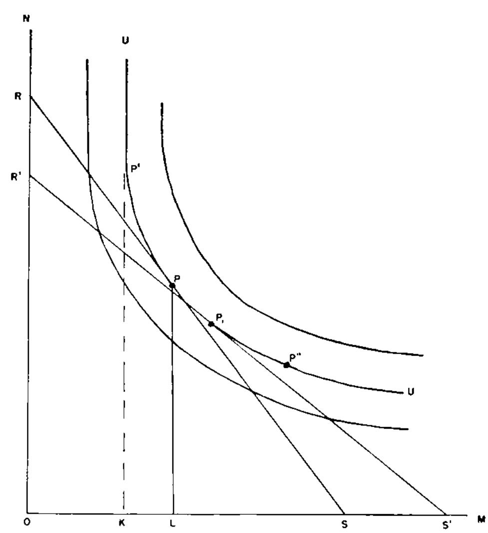


Figure 3.

has become more dear. If, for example, the cost of highway construction should drop while the price of equipment rose, the ideal proportion of factors would be represented by P_1 if the slope of the line $R'S'$ represents the new situation with regard to the relative prices of the factors.

The ideal proportion of the factors of production will also be affected by changes in the rate of interest. The diagrams we have drawn assume a constant interest rate. If the period of turnover of the factors of production differs as between one factor and another, changes in the rate of interest will affect the relative cost. In general, the period of turnover of equipment used in the production of highway transportation is considerably shorter than the turnover of the highway plant. Thus, a decrease in the rate of interest will decrease the relative cost of using highway plant in the production of a given output of highway transportation service.

We define a road or network of roads as *ideal* when a given volume of transportation service in a given time period can be produced at minimum cost. An ideal road is one in which the amount of investment is that represented by point P. An *inadequate* road is defined as one in which the amount of investment is less than that represented by point P. A road which is *more than adequate* is one in which the amount of investment is greater than that represented by P. In all of these cases it is assumed that the amount of transportation service to be produced is XY ton-miles represented by isoquant UU.

We define highway investment as *inefficient* when a given expenditure on road improvement does not tend to minimize the cost of a given output of highway-transportation service. When the problem involved in allocating funds for road improvement consists of choosing between several projects, each one of which would lessen vehicle-operating costs, it is apparent that difficult technical problems are likely to be involved in determining the proper course of action, i.e., the most-efficient use of the funds. A special case of inefficiency in highway investment, but one which is not without practical significance, is that in which roads which are ideal or more than adequate are improved while roads which are inadequate are neglected. Even in this apparently clear-cut case of inefficiency, however, certain tech-

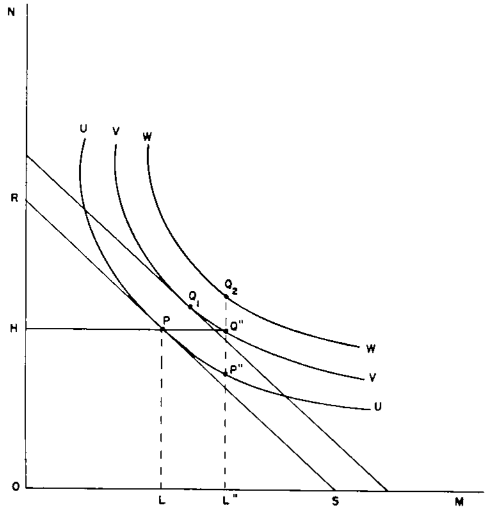


Figure 4.

nical difficulties are created by the problem of indivisibilities.

A second standard might be adopted in defining efficiency in highway investment. It is conceivable that expenditure on road improvement may be undertaken to maximize the amount of transportation service that could be produced with a given outlay on equipment. For example, OH investment in equipment and OL investment in highway plant might be optimum from the standpoint of producing XY ton-miles of transportation service (represented by isoquant UU). Additional investment in the road, LL'', might be undertaken in order to maximize the transportation service that could be obtained from OH investment in equipment (Fig. 4). Note, however, that Q'' represents a combination of productive factors which is not ideal for the production of $X'Y$ ton-miles of transportation service (represented by isoquant VV). Excess highway capacity has been created. Q_1 represents an ideal proportion of factors for the production of $X'Y$ ton-miles and Q_2 represents the ideal proportion of productive factors assuming OL'' investment in highway plant. In this case further outputs of highway-transportation service beyond $X'Y$ are likely to be subject to decreasing cost up to the point where $X''Y$ ton-miles of transportation service (represented by isoquant WW) is produced. Thus, expenditure on road improvement designed to maximize the amount of transportation service that can be produced from a given expenditure on equipment does not result in an ideal highway plant according to our original definition. Application of this second standard is likely to result in the creation of excess highway capacity giving rise to a situation where average total unit cost is a decreasing function of output (as in Fig. 2).

Certain assumptions which were made in defining efficient highway investment as we have done above must be examined. These involve (1) the assumption that there are no significant indivisibilities in the highway plant and (2) the assumptions that we have made pertaining to the quality and quantity of transportation service produced.

We have observed that roads are subject to considerable variation in design. In many cases, however, indivisibilities can prevent a close approximation to the achievement of an ideal road or system of roads. Where the traffic volume between two points is small, as in the case of feeder roads, any improved road is likely to be more than adequate. Where traffic volumes are heavy, the type of improvement required to accommodate traffic may involve such a basic change in the structure of the road that the benefits will not warrant the expense of the improvement; and roads remain less than adequate for the volume of traffic they are required to carry. Thus, indivisibilities may result in roads being more than adequate or less than adequate for normal traffic volumes depending upon the circumstances of the case.

Up to now we have assumed that the traffic flows over the highway in a steady stream. This is an unrealistic assumption. Normally, there are daily, weekly, and seasonal peaks in highway traffic with sharp fluctuations in traffic volumes between peak and off-peak periods. If traffic were forced to flow over a highway system in an even flow, highway transportation would be deprived of what is perhaps its most-fundamental advantage as a form of transportation: flexibility. We must recognize that the flow of traffic over a road system is uneven and that roads should be provided to accommodate peaks of traffic flow. This requires a redefinition of the ideal combination of factors of production, a definition that recognizes the importance of the unevenness of traffic flows. An ideal highway structure must be capable of providing for peak loads of traffic. This means that excess highway capacity is created in the off-peak periods.

In view of the qualifications that have just been made, we recognize that, at best, a highway system can only roughly approximate the ideal structure from an economic standpoint. This is due primarily to the fact that indivisibilities exist in highway construction resulting in feeder roads that are likely to be more than adequate and heavily traveled routes that are likely to be less than adequate for normal traffic volumes. Furthermore, normal traffic volumes must be defined in terms of peak-load flows unless highway transportation is to be deprived of one of its outstanding advantages as a form of transportation.

An approximation to an ideal highway system can be realized, in spite of the difficulties that we have noted, as long as we can assume that the output of highway transportation is independent of investment in roads. If, however, the flow of traffic over the highway system is a function of highway investment, serious problems are created for highway planning. The nature of the difficulties that are produced may be illustrated by the following examples:

Take the case of traffic between two points. We observe (Fig. 5) that if KL expenditure on

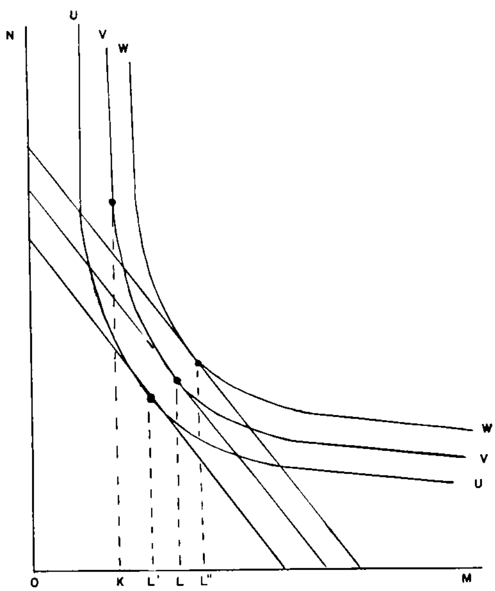


Figure 5.

roads results in a reduction of traffic from isoquant VV to UU (from $X'Y$ ton-miles to XY ton-miles), the ideal investment in highway plant would be OL' rather than OL. On the other hand, if improvement of the highway plant results in an increase in highway travel and output rises to isoquant WW from isoquant VV (output increases from $X'Y$ ton-miles to $X''Y$ ton-miles), ideal investment in highway plant should be OL'' rather than OL. Thus if traffic volume is a function of investment in highway plant, depending on the shape of the isoquants, roads may be overimproved or underimproved according to engineering standards of economic design, and perfect knowledge of the nature of existing traffic flows over an existing system of roads may be inadequate to permit efficient planning of highway investment.

Consider next the problem of road design for traffic flowing over a network of roads between A, B, and C. If the flow of traffic over this network is known, if the relation between vehicle-operating costs and road improvement is known, if the volume and pattern of flows over the system are invariant with respect to improvement of the highway plant, an approximation to an ideal highway plant may be realized by proper planning of highway investment. When dealing with a system of roads, however, we note that not only must the volume of traffic over the system be invariant with respect to highway improvement, but also the pattern of flows over the system must remain the same. If such is not the case, investment that is undertaken to minimize the cost of XY ton-miles of transportation service may not prove to be optimum after the improvement is completed because of the change in the pattern of traffic flows. For example, roads between A and B and A and C may be ideal from the point of view of minimizing transportation costs for highway traffic between those points. At the same time, however, the road between B and C may be inadequate for the volume of traffic it is required to carry. Now if the road between B and C is improved, some of the traffic formerly flowing between A and C may be diverted to routes AB and BC. Total traffic volume may be unchanged, but as a result of the change in the pattern of traffic flow, investment in highway plant may not be optimum.

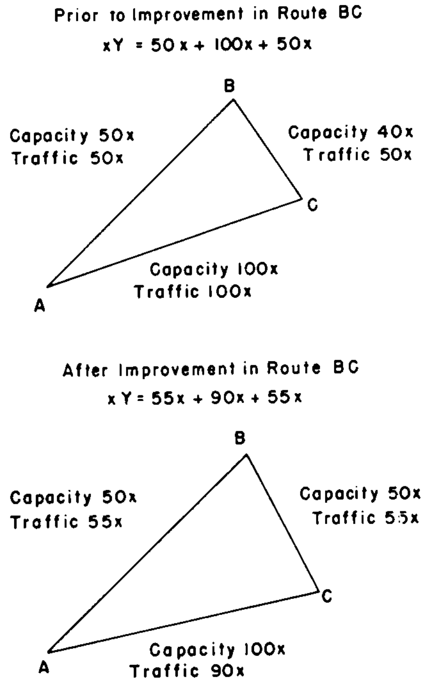


Figure 6.

The following example may clarify the point made above. Traffic flows between A, B, and C (Fig. 6). The amount of transportation service produced is XY ton-miles consisting of $50X$ ton-miles between A and B, plus $100X$ ton-miles between A and C, plus $50X$ ton-miles between B and C. Roads between A and B and A and C are optimum for $50X$ ton-miles and $100X$ ton-miles of traffic respectively. The road between BC is optimum for $40X$ ton-miles of traffic. Since it is called upon to carry $50X$ ton-miles it is less than adequate.

Road BC is improved to carry $50X$ ton-miles of traffic. If after the improvement the pattern of traffic flow changes, the following type of situation may result even though the total volume of traffic over the highway plant is unchanged. XY may now consist of $55X$ ton-miles of traffic between AB, $90X$ ton-miles of traffic between AC and $55X$ ton-miles between BC. With no change in total output none of the roads in the system are ideal. Roads between AB and BC are inadequate, and the road between AC is more than adequate.

As we have just seen, both the volume of

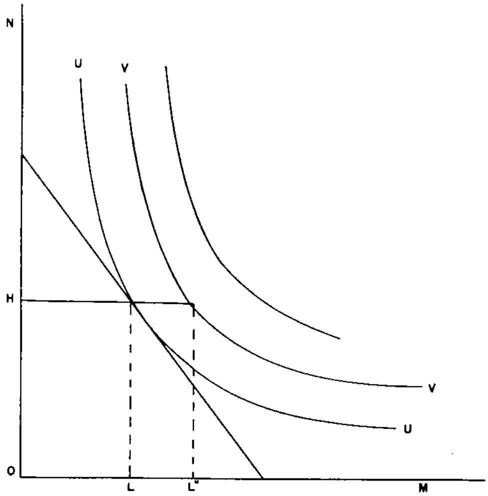


Figure 7.

traffic and the pattern of traffic flows over the highway plant must be invariant with respect to improvements in the highway plant (or the relationship between changes in traffic flows and highway improvement must be known) in order for highway improvement to result in an ideal combination of factors for the production of a given volume of transportation service.

Let us now consider the importance of knowledge of traffic flows, especially their volume and pattern, when the criterion for highway investment is the maximization of transportation service that can be obtained from a given expenditure on equipment.

Consider the case of traffic flowing between two points, *A* and *B*. Investment in existing highway plant may be optimum from the point of view of minimizing the cost of *XY* ton-miles of transportation service. However, *LL″* additional investment in roads might be undertaken (Fig. 7) in order to maximize the amount of transportation service that could be obtained from *OH* expenditure on equipment.

In the example given above we have assumed that all the traffic flows between *A* and *B*, that there is no traffic between *AC* or *BC*. Maximizing the output of transportation service to be obtained from *OH* expenditure on equipment implies that all highway improvements would be made on the road between *A* and *B*. Assuming that all traffic flowed between *A* and *B*, nothing should be spent improving roads between *AC* and *BC* if the objective of the expenditure is to maximize transportation service from a given expenditure on equipment. If, however, the pattern of traffic flow is a function of highway improvement, investment in roads between *AC* and *BC* may not be irrational. In any case it would not be an easy matter to maximize the amount of transportation service that could be produced from a given expenditure on equipment by appropriate highway investment if patterns of traffic flow were affected by road improvement.

Our analysis up to this point has shown that special conditions would have to be fulfilled in order for *XY* ton-miles of highway transportation service to be produced at minimum cost. Traffic volume would have to be invariant with respect to highway improvement, and the pattern of traffic flows over the system would have to be invariant with respect to improvements in the highway plant (or else the nature of the relationship between highway improvement and traffic flows would have to be understood). Overinvestment or underinvestment in a particular road or in the highway plant as a whole could easily result unless these conditions were satisfied. Furthermore, unless the relationship between traffic flow patterns and highway improvement could be determined, total output of transportation service from a given expenditure on plant and equipment might be less than optimum in the sense that the proper isoquant in the production function expressing the relationship between inputs of productive factors and outputs of transportation service would not be reached.

To the extent that investment in roads affects the pattern and volume of highway traffic, the results of the best-planned highway improvement may be quite different from that intended. For example, efficient investment may generate new traffic which will make the planned ideal structure inadequate. On the other hand, inefficient investment may result in developments which improve the situation. Thus the construction of a road which is more than adequate may attract traffic to an extent sufficient to warrant the original investment. Or failure to improve an inadequate road may result in a diversion of traffic from the inadequate structure. It is possible that what we have called efficient investment might aggravate the problem of adjusting the highway plant to the volume of traffic it is called upon to carry. On the other hand, inefficient investment may tend to alleviate the problem. Whether or not this is so depends on the degree to which patterns of traffic flow and the volume of highway traffic are invariant with respect to road improvement.

We have been arguing that an ideal use of highway funds is to invest them in such a way as to minimize the cost of producing highway-transportation service. This criterion is a rational one, but our analysis implies that there may be fundamental difficulties connected with its realization as a policy objective. Let us now briefly review highway development policies in the United States in an effort to determine (1) whether they have been designed to achieve the above objective and (2) whether conditions are such that realization of this objective seems feasible.

One of the most-striking facts about American highway development policy in the twentieth century is the extent to which the concept of using funds efficiently has worked its way into highway practice. Substantial progress has been made by highway administrators and engineers in devising techniques for insuring both that roads will be built only in those sections where traffic warrants their construction and that the roads are neither more nor less elaborate than required.

Concern among road builders in the United States over efficiency in the use of highway funds has been a logical development. The early stage of modern road construction was a period when roads were built to get the farmer and the motorist out of the mud; during this period primary interest was directed toward rapid construction of connected systems of roads. Yet, from the beginning the problem of economically providing for the needs of traffic could not be avoided. There simply were not enough funds to improve all roads and streets, and at both state and federal levels the principle of selecting the more-heavily travelled roads for the highest degree of improvement tended to be followed. As traffic increased, interest in developing more-efficient methods of using highway funds grew apace. This trend in thought among practicing highway men in the 1920's is well summarized by the following statement taken from a joint state-federal report on the Pennsylvania highway system published in 1928:[3]

> The extent to which the various highways may be improved and yield an economic return varies greatly, and cannot be left to the hazard of uninformed judgment, but must be determined on the basis of present and future traffic demands. In making this determination, proper consideration should be given to possible savings in vehicle operating costs for present and estimated future traffic as well as location, construction and maintenance costs. So it may be said that the economic highway is one of which every section is improved to the degree required by traffic and to no greater degree.

In view of the unprecedented and unpredictable growth of highway travel in the 1920's and the rapid changes that were taking place in vehicle sizes, weights, and speeds, it is not surprising that some engineers went on record with statements that they regarded calculated economies of the type described in the Pennsylvania report as ridiculous. Despite serious obstacles to its realization, however, the ideal of tailoring roads to traffic needs has not been rejected by American highway builders, and solid progress has been made in applying this concept. Indeed, the major issue for American highway development policy today is not whether to embrace the ideal of building roads which will contribute to the efficient production of highway transportation service but how to overcome obstacles to the realization of this ideal.

A major obstacle to efficient use of highway funds is created by the laws regulating their use. Charles L. Dearing, Wilfred Owen, and other writers have rightly called attention to the fact that the laws and administrative arrangements governing the use of highway funds often prevent them from being employed in the most-efficient way from the standpoint of traffic need. Political and administrative obstacles are serious and difficult to overcome. But there are other important obstacles which should be emphasized.

We noted above that, if traffic flows over the highway system are influenced by road improvement, fundamental problems are created. Indeed, when the volume of traffic flowing between two points is markedly in-

[3] U. S. Bureau of Public Roads and Pennsylvania Department of Highways, Report of a Survey of Transportation on the State Highways of Pennsylvania (n.p., 1928), p. 8.

fluenced by road improvement, investment policies designed to minimize highway transportation costs may backfire in the sense that road improvement may aggravate rather than alleviate traffic congestion. Most highway planners are only too familiar with the fact that in certain areas improvements in the highway plant are accompanied by unexpected increases in the volume and pattern of traffic. Indeed, in some areas it seems almost hopeless to eliminate traffic congestion by improvement of the highway plant. The problems that erratic changes in the volume and pattern of traffic create for effective highway planning are of fundamental importance. The question that must be answered is how these difficulties are to be dealt with.[4]

Despite a number of errors which have been made in predicting traffic needs, there has been evidence of enough stability in overall highway traffic patterns to encourage those actively concerned with road improvement to feel that planned economies in road improvement are feasible. But existing techniques for predicting future needs should be expanded, for often they are too restricted in scope to offer much chance for success in disclosing where road improvement will be successful in relieving the problem of traffic congestion.

The history of highway planning has consisted mainly of an expansion in the scope of highway-traffic surveys. For the most part, studies have been confined to traffic flows over roads. We submit that more-accurate estimates of highway needs could be made if studies were made of *total* traffic flows, i.e., traffic flowing between given points over all types of transportation agencies. Such studies would not only provide useful material for predicting the effect of improvements in highway facilities but also would furnish the data necessary for systematic studies of traffic diversion from other carriers. A major complication in estimating future requirements is created by the possibility of diversion of traffic from other types of transportation agencies.

[4] Changes in vehicle weights, sizes, and speeds have also created major headaches for highway planners. These problems can be and have been dealt with by changes in highway design, changes in vehicles (e.g., the pneumatic tire), and legal limitations. Except for the problem of highway safety, problems arising from changes in vehicle design have proved to be more tractable than the one discussed in the text. The action program outlined by the President's Highway Safety Conference is designed to deal with the problem of highway safety, and we have little to add to the suggestions there made.

Let us assume, for example, that there is a pattern to the flows of people and goods in space which is discoverable. Assume that centers of population are located in space in a pattern that is relatively fixed or that changes in some predictable fashion.[5] Figure 8 represents an idealized conception of the location of population centers in space. Assume that these are connected by various types of transportation facilities. Let *A* and *B* represent large centers of population. *C* represents a smaller town situated between *A* and *B* and connected to them by a railroad, a limited-access highway, and by surfaced roads. *D* is a village connected to *C* by a railroad and a surfaced highway. *D* is also connected to *A* and to the limited access road by surfaced roads. Surfaced roads form direct connections between *A*, *B*, and *C*, and the small villages E_1–E_{10}.

Assume that there is a given and stable volume of traffic flowing between the population centers. The traffic flows are assumed to be stable. They consist of movements of people and goods. Where only one type of transportation facility is available (e.g., between *A* and E_1–E_5, and between *B* and E_6–E_{10}) traffic will flow over the roads in a stable pattern.

Where practical alternative traffic routes exist, however, (as, for example, between *A* and *B*) although the flow of traffic between points does not change, traffic flows over the roads may not conform to any predictable pattern. People and goods moving between *A* and *B* may go by rail, by limited-access road, by surfaced road, or by some combination of the three. Thus where alternative traffic routes exist, flows over the roads may not be stable, even if there is absolutely no change in the total flows of people and goods between the two points.

Let us use Figure 8 to clearly distinguish different types of changes in flows of highway traffic. Assuming absolutely no change in total flows of people and goods between the centers of population the following types of change in highway traffic flows may take place: (1) Traffic may increase over a highway route, which represents traffic diverted from alternate roads. Thus an improvement of the limited access road between *A* and *B* may result in traffic being diverted from surfaced

[5] Instead of talking about centers of population we could talk about points—origin and destination points—for relatively large numbers of people or groups of commodities.

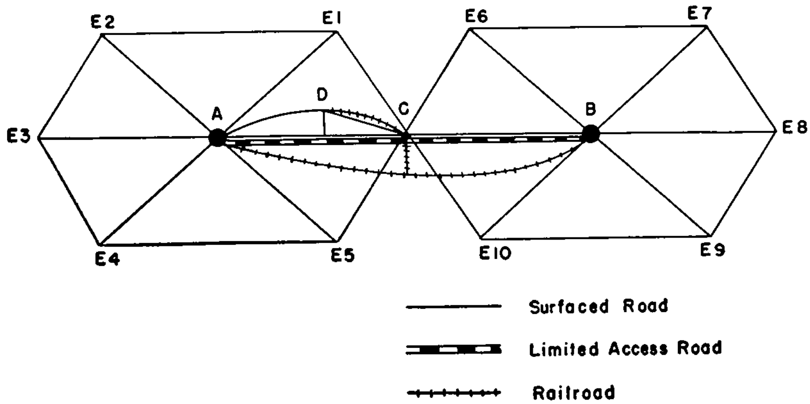


Figure 8.

roads between the two points to the superhighway. Here we assume no diversion of traffic from other types of transport. (2) Assume that the entire network of roads between *A* and *B* is inadequate and that a program of road improvement is planned for roads between *A* and *B*, *A* and *D*, *D* and *C*, and *C* and *B*. Assume that the improvements of this highway network must be carried out in stages. Assume that there is no diversion of traffic from other types of transport. Assume also that the flow of traffic over the road system is unchanged after the entire program is completed. During the period of construction, however, the flows of traffic over the roads will vary depending on the order in which the different routes are improved. If the order of improvement is Road *AD*, then *DC*, then surfaced Road *CB*, then Superhighway *AC*, then Superhighway *CB*, then surfaced Road *AC*, the pattern of traffic over the road system would be different *during the period of construction* than would be the case if the order of improvement was reversed or changed in some other fashion. This would be true even though we have assumed that after the entire system was completed traffic patterns over the roads would be unchanged. (3) Traffic may be diverted from other types of transportation facilities. For example, the improvement of the limited-access road between *A* and *B* may result in a diversion of traffic from the railroad between these points. Here we assume no change in the pattern of traffic flows over the roads, i.e., no increase in flows over the superhighway which represent traffic diverted from other highway routes.

Various combinations of the above types of change in highway traffic patterns could be expected to occur. Thus, without any change in the pattern of overall flows of people and goods between two points, variations in the pattern of highway traffic could be expected to occur as the result of highway improvements.

It is of great importance that all types of traffic diversion which result from improvements in certain parts of the transportation system be distinguished from changes in the overall flows of people and goods between centers of population. A major defect of modern highway-planning techniques is that they make insufficient allowance for traffic diversion.

The study of total traffic flows and the factors which affect them would seem to be essential if we are to obtain a rational solution to some of the basic economic problems confronting the road builder. In order to make rapid progress in determining where highway improvement will relieve traffic congestion and reduce highway transportation costs, it is highly desirable that we expand the scope of traffic surveys. This is a logical extension of existing trends in highway planning. Already, exploratory studies of total traffic flows have been attempted. These deserve greater support. They promise to provide data which may make it possible to make estimates of potential demand for roads. These, in turn, should enable road builders to distinguish between areas where road improvement may help and where it will merely aggravate the problem of traffic congestion.

When appraising American highway development policies from the standpoint of determining whether funds for road improvement are being used efficiently, generalizations can be misleading. Obstacles to efficient use of highway funds are formidable and, in certain fields, particularly that of highway administration, progress in overcoming them is often discouragingly slow. But the success of American highway engineers in devising techniques for using funds efficiently has attracted international attention and, given proper support, is likely to continue.

Let us now turn to a consideration of the second major question raised at the beginning of this paper. For the purpose of discussion, we shall assume that highway funds are used in an efficient manner in the reduction of highway transportation costs. Does this type of improvement of the highway plant contribute to the development of an adequate and low-cost transportation service?

Some of the most-plausible arguments advanced in favor of improving the highway system imply that such improvements are desirable from the standpoint of transportation economics because they lower transportation costs. If we think in terms of the economics of the entire transportation industry, however, the real case for improvement of the highway system today is not that it contributes to lower-cost transportation but rather that it promotes the development of a more-adequate and flexible transportation service. Indeed, there are grounds for believing that continued large-scale improvement of the highway plant which is undertaken to achieve an ideal combination between highway plant and equipment may increase the average total unit costs of transportation service as a whole.

This is a strong statement. Before discussing its implications let us trace the type of reasoning which leads to this conclusion. The argument is based upon a careful analysis of how the unit cost of producing transportation service varies with changes in the volume of traffic carried on between given points by highway, railroad, and (if the argument is extended) by other types of carriers.

Throughout the following analysis of transportation costs, we shall employ the concept of the long-run-cost curve. In other words, we shall assume that the essential factors required for the production of transportation service (plant and equipment) are combined in the most-economic proportions to produce various volumes of output. We deliberately abstract from differences in the quality of the service produced, e.g., its safety, speed, convenience. Our purpose is to compare the relative costs of road and rail carriers incurred in producing different amounts of transportation service between two points in a given time period. We are interested in contrasting the real economic costs of producing different amounts of transportation service.

For any given volume of output, the cost of production can be broken down into two parts: (1) the cost of plant, which we shall call P, (2) the cost of equipment, which we shall call E. Let TC_H represent the total cost of highway transportation and TC_R the total cost of rail transportation. $TC_H = P_H + E_H$ and $TC_R = P_R + E_R$. In other words, the total cost for any given output of transportation service (defined in ton-miles) is equal to the cost of the equipment required to produce the transportation service plus the cost of the roadbed. Total cost for any given output of highway transportation service is equal to the cost of the highway (P_H) plus the cost of equipment (E_H). Total cost for any given output of rail transportation service is equal to the cost of the roadbed (P_R) plus the cost of the equipment (E_R).

If, for any given output of transportation service, $P_H > P_R$ and $E_H > E_R$, we define rail transportation as being more efficient than road transport. Conversely, if $P_H < P_R$ and $E_H < E_R$, road transport is defined as more efficient than rail transport. When $P_H < P_R$ and $E_H > E_R$ or when $P_H > P_R$ and $E_H < E_R$, the actual size of the differences involved must be determined before any conclusion can be reached regarding the relative efficiency of road or rail transportation.

If it can be shown for low traffic densities that TC_H is less than TC_R, and that, as traffic density increases, TC_H becomes greater than TC_R, we will have established a relationship between traffic density and the average total unit cost of transportation service of the following type. For low volumes of traffic between given points, highway transportation provides lower-cost transportation service than does rail, but as traffic densities increase rail transport replaces highway transport as the low-cost carrier.

Now it is not difficult to show that for large volumes of traffic between two points highway travel is substantially more expensive per unit of service produced than is rail travel and for small volumes of traffic between given points road travel is cheaper than rail. Using this information, it may be shown that when the effect of improved highway transportation on other carriers is taken into account, improvement of the highway plant may result in an increase in the average total unit cost of transportation service.

In developing this point there are two ideas that we wish to stress. The first is that rail costs are substantially below the unit cost of highway transportation when the volume of traffic flowing between two given points is large. The second is that an increase in the number of points between which travel occurs is likely to increase total transportation costs.

In conventional analyses of transportation costs, much is made of the difference that exists between the relative costs of long-haul and short-haul service by rail and road carriers. A more-fundamental relationship, however, is that which exists between the unit cost of transportation service and traffic volume or density. Rail costs are considerably less than road costs per unit of transportation service for large volumes of traffic. This fact is brought out by an analysis of the respective traffic-carrying capacities of roads and railroads. Indeed, from a technical standpoint the railroad may be looked upon as an inexpensive design for a road called upon to carry heavy volumes of traffic.

Some writers have implied that an important reason for the rapid expansion of highway transportation is the fact that roads are cheaper to build than railroads. This is true, however, only in a restricted sense. For low volumes of traffic, roads do not have to be improved to a high degree, and as long as the total volume of traffic that has to be accommodated remains relatively small roads are cheaper to build. But as traffic volumes increase roads become considerably more expensive.

A. P. Usher has estimated that a single-track railroad is capable of carrying more freight than a four-lane highway.[6] Even the most-elaborate highway does not have a capacity comparable to that of the railroad in terms of cost. The cost of constructing a super-highway is of the order of magnitude of $250,000 per mile, exclusive of right-of-way; whereas a four-track railroad costs in the neighborhood of $80,000 per mile.

A detailed analysis would be required to determine at what point and under what conditions the unit cost of roadway for motor-vehicle transport exceeds the unit cost of the roadbed for railroads. It is clear, however, that for large volumes of traffic the cost of the railroad per unit of transportation service is considerably less than the cost of the highway. For low volumes of traffic it is equally clear that the unit cost of the roadbed for highway transport is less than the unit cost of the roadbed for rail traffic, for motor vehicles may be built which can travel over roadless terrain.

Since the traffic-carrying capacity of railroads is appreciably higher than the traffic-carrying capacity of highways and since the cost of constructing multilane-highway facilities is substantially greater than the cost of constructing railroads, it may easily be shown that the cost of plant or roadbed for highway transportation per unit of transportation service (passenger-mile or ton-mile) is related to traffic volume in the following manner. When the volume of traffic between two points is low, the cost of plant per unit of highway transportation service is less than the unit cost of plant for rail transport. As the volume of traffic rises, however, the cost of plant for highway traffic rises relative to that for rail traffic, and for large volumes of traffic the cost of plant for highway transportation greatly exceeds the cost of plant for rail transport.

It can be established that the cost of equipment utilized in transporting goods and people by road and by rail follows the same pattern as does the cost of plant with variations in the volume of traffic. When small loads are to be carried between points there is advantage in using small vehicles in place of large machines. As the loads to be carried increase in size, there is an advantage in using large vehicles instead of a large number of small ones. The relative advantages of using different sizes of equipment according to the needs of traffic can best be summarized in terms of cost per vehicle-mile of operation.

[6] Some unpublished tables based upon reasonable assumptions of the traffic carrying capacities of highways and railroads under varying conditions have been prepared by Usher. These studies were the basis for the statement made in the text, and the author is indebted to Usher for permission to use this information in this paper.

TABLE 1

VEHICLE OPERATING COSTS OF THE U. S. GOVERNMENT

July 1st 1946 to June 30th 1947

U. S. Government Civilian Departments & Agencies

	Automobiles	Special cars	Light duty trucks	1 ton trucks	1½ ton trucks	2 ton trucks	4 ton trucks	5 ton trucks	Over 5 ton trucks	All tractor trucks	Bus
Total vehicle miles (thousands)	25,065	5,089	26,792	6,487	11,805	2,750	315	549	445	735	746
Average miles per vehicle	9,917	6,104	6,645	10,379	3,969	5,479	2,916	2,756	2,830	2,884	5,232
Average miles per gal. fuel	14.535	11.802	12.037	6.715	7.109	5.775	4.403	3.454	3.606	4.528	6.991
Cost Per Mile (Average)											
Operation cost per mile[a]	0.01503	0.02053	0.02114	0.11539	?	0.25243	0.0517	0.09905	0.09351	0.05627	0.02718
Maintenance cost per mile	.01659	.02204	.02157	.03387	.03057	.04101	.04883	.07198	.07909	.07821	.04626
Tire cost per mile	.00212	.00340	.00329	.00423	.00540	.00587	.01158	.01362	.04515	.01630	.00704
Total operation & maintenance cost per mile	.03375	.04597	.04601	.15350	.07854	.29933	.11212	.18466	.21776	.15078	.08048

Source: Commercial Car Journal, LXXV (July, 1948), p. 68.
[a] Less storage and depreciation.

Table 1 conveys an impression of the savings in operating costs that can be achieved in the transportation of large loads by the use of large trucks and busses in place of small trucks and passenger cars. The figures may be somewhat misleading, inasmuch as depreciation costs are not taken into account; but the error introduced on this account is not likely to be large. On the basis of the figures contained in Table 1, the per-mile-operation-and-maintenance cost for transporting five tons of freight in a large truck would be in the neighborhood of 20 cents per mile, whereas the cost of transporting a similar tonnage in one ton trucks would be in the neighborhood of 75 cents per mile, a difference of 375 percent. A comparison of the cost of transporting people in passenger cars and busses, assuming that the passenger car carries 5 and the bus 30 persons, reveals that the per-mile-operating-and-maintenance cost of the automobile transportation would be slightly more than 280 percent greater than the cost of the bus transportation.

The figures given above do not take into account the labor costs of transportation. These are obviously higher for freight carried in a large number of small vehicles. In the example given above, the labor cost of transporting 5 tons in five vehicles could be expected to be roughly five times that of transporting the goods in one large vehicle.

The capacity of the largest truck and bus is small relative to the capacity of the modern freight and passenger car of the railroad.[7] When one takes into consideration the fact that a railroad locomotive is capable of pulling dozens of freight or passenger cars, the inherent advantages of railroad equipment over highway equipment as an inexpensive method of moving large masses of freight or passengers can be readily appreciated. Railroad equipment can, indeed, be looked upon as a specialized type of vehicle designed to reduce the cost of moving large quantities of freight.

A direct comparison of the cost of moving various quantities of freight or people by rail and by road would require a type of data which is not ordinarily obtainable. Evidence of the considerable savings in productive resources that can be achieved in moving large volumes of traffic by rail rather than by road is afforded, however, by the transportation history of the United States during World War II.

During World War II the railroads in the United States handled an unprecedented growth in traffic with a relatively small increase in the use of economic resources.

Rail employment reached an all-time peak in 1920, when Class I railroads alone employed over 2 million persons. Rail passenger traffic reached peak levels in 1919 and 1920, levels which were not surpassed until World War II. Early in the 1920's the private passenger car became the chief competitor of rail passenger service. Bus lines, which had hastened the collapse of the electric railways, came in the 1920's to compete with rail-coach

[7] Railroad passenger cars, for example, are often designed to carry 80 passengers, and freight cars of 50-ton capacity are not uncommon.

TABLE 2

DISTRIBUTION OF COMMERCIAL FREIGHT AND PASSENGER TRAFFIC IN THE UNITED STATES 1926, 1939–1945

Agency	1926	1939	1940	1941	1942	1943	1944	1945[e]
Ton Miles[a] (Millions)								
Steam RR inc. mail & exp.	450,644	338,275	378,343	480,783	644,096	733,420	745,843	689,691
Great Lakes[b]	83,000	69,060	87,593	104,100	112,393	104,006	105,620	102,091
Rivers & canals	9,542	19,937	22,412	26,815	26,398	26,306	31,385	29,709
Motor trucks	23,530	43,000	51,003	57,123	50,207	48,199	49,308	55,619
Oil pipe lines	21,700	63,107	67,270	77,818	74,730	96,257	132,336	123,293
Electric R. R.	1,313	725	818	965	1,166	1,295	1,325	1,300
Air carriers		11	14	16	33	52	71	91
Total	589,729	534,115	607,453	747,620	909,023	1,009,535	1,065,888	1,001,794
Passenger Miles[c] (Millions)								
Steam R. R.	35,673	22,713	23,816	29,406	53,747	87,925	95,663	91,826
Electric interurban	5,537	956	950	1,177	1,326	1,940	2,041	1,991
Inland waterways[d]	1,848	1,486	1,317	1,821	1,860	1,927	2,187	2,056
Buses	4,375	11,198	11,613	13,646	21,515	27,416	26,548	26,813
Air carriers		678	1,041	1,370	1,418	1,632	2,264	3,507
Total	47,433	37,031	38,737	47,420	79,866	120,840	128,703	126,193

Source: American Railroads *Transportation in America* (Washington, 1947), p. 95.
[a] Includes intercity freight traffic by private as well as contract and common carriers, except coastwise and intercoastal traffic.
[b] U. S. domestic traffic only.
[c] Passenger miles in private automobiles not included. Rail passenger miles include commutation passengers.
[d] Great Lakes, rivers and canals.
[e] Preliminary subject to revision.

travel as their range of operations widened. In the 1930's commercial airlines emerged as competitors of parlor-car and sleeping-car traffic.[8]

Against this background the vast expansion of passenger traffic during World War II may be viewed as a partial and temporary return to an earlier output trend, the trend which had prevailed prior to World War I. During 1942 to 1946, private-automobile travel was severely restricted by shortages, and the expansion of intercity busses and commercial airlines was checked. As a result, the smaller railroad mileage of 1944 carried far-more traffic than moved in 1920.

Freight traffic, like passenger traffic on the railroads, was subject to marked retardation of growth over the period 1889 to 1937. Yet during World War II the railroads carried more freight traffic than ever. As in the case of passenger traffic, though in lesser degree, the wartime peak in freight traffic may be regarded as a partial and temporary return to a previous trend.

Table 2 shows the distribution of commercial freight and passenger traffic in the United States in 1926 and 1939–45. Demands of only modest proportions were made by the railroads on the nation's labor supply during World War II to handle an increase in freight traffic of more than 100 percent and an increase in passenger traffic of more than 300 percent. In 1939 the railroad industry employed about 1 million persons. Peak employment during World War II, about 1.4 million, represented an increase in the labor force of only 40 percent. Although traffic loads carried by the railroads in World War II were larger than those carried by rail in 1920, employment was still well below the level of 1920.

During the war years capital expenditures by the railroads for additions and betterments for both plant and equipment were moderate. These averaged $531 million annually from 1941 to 1945, considerably less than the $734 million spent by the railroads annually from 1921 to 1925 and the $812 million annual expenditures between 1926 and 1931.[9]

Against the modest drain that was made on the productive resources of the country by the railroads during World War II to handle a very sharp rise in the volume of traffic, one can compare the demands that would have had to be made on manpower and other re-

[8] Harold Barger, The Transportation Industries 1889–1946; *A Study of Output, Employment, and Productivity* (New York, 1951), p. 69.

[9] Association of American Railroads, *Transportation in America*, A report prepared by the Railroad Committee for the Study of Transportation (Washington, 1947), p. 98.

sources if a similar expansion of traffic were to be handled by highway transport. In 1940 it has been estimated that there were some 59 billion ton-miles of intercity truck traffic which required the full-time efforts of 1.0 to 1.5 million persons. During the same period some 375 billion ton-miles of freight were handled by steam railroads with slightly over 1 million workers.[10] In the absence of reliable statistics one can only guess at the drain which would have been made on the manpower and capital resources of the country if the total volume of highway transportation had doubled during the war. In the interest of conserving strategic raw materials the volume of intercity traffic carried by truck during the war years actually declined.

An increase in the output of highway transportation service during the war years comparable to that of the railroads would unquestionably have required the services of many more workers, the expenditure of much-larger sums for additions to highway equipment and plant, and the consumption of much-greater quantities of fuel and other resources than were used by the railroads.[11] The record of the transportation industry during World War II indicates that the real cost of transportation by rail is substantially less than the real cost of transportation by road when the volume of traffic is large.

Both an analysis of the relative costs of moving various volumes of traffic between given points and available historical evidence supports the hypothesis that the unit cost of transportation service is a decreasing function of traffic volume and that railroads are much-more-efficient carriers of large volumes of traffic than are highway carriers in terms of the real resources required to produce the service.

Our analysis up to this point has, of course, abstracted from differences in the quality of the service provided, and it may also be objected that it is not legitimate to abstract from storage and handling costs when examining the relationship that exists between the unit costs of road and rail transportation and the volume of traffic. Deferring for a moment the consideration of qualitative differences, let us say a few words about terminal charges and the costs of transshipment of freight.

Terminal charges and the cost of handling freight can be considerable. The transport of many types of goods by rail requires the following sequence: (1) loading into road vehicles, (2) road transport to the railroad station, (3) off-loading from road vehicles and possibly storage, (4) loading into railway vehicles, (5) railway transport proper, (6) off-loading from rail vehicles and possibly storage, (7) loading into road vehicles, (8) road transport to the consignee, (9) off-loading from road vehicles. Where road transport direct from consignor to consignee is possible as an alternative, no operations except 1 and 9 are added to actual haulage charges.[12]

For freight traveling short distances, the relative importance of handling and storage charges is greater than it is for long-distance freight. Reductions that can be achieved in ton-mile costs by rail tend to be nullified for short-haul traffic by storage and handling charges. To the extent that it does tend to eliminate these charges, highway transportation possesses a basic cost advantage over rail transport. As traffic increases in volume, however, and as the distance that the freight travels increases, this advantage is nullified by the savings in ton-mile costs of rail traffic and, also, by the reductions in storage and handling charges that may result with increases in the volume of traffic.

Handling and storage costs modify the relationship that exists between unit costs of road and rail transportation and the volume of traffic. They do not, however, invalidate the generalization that railroads provide a more-efficient and more-economical method for transporting large volumes of traffic between given points than do highways.

Throughout the present analysis, when speaking of transportation, we have referred to the flow of people and goods between points. The question should be raised as to what happens to total transportation costs if the number and spacing of the points between which transportation occurs does not remain constant. This is a matter of great practical im-

[10] Barger, *op. cit.*, pp. 93, 246.

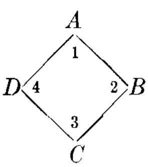
[11] It seems unnecessary to labor this point. The existence of excess traffic-carrying capacity in the railroad industry was a factor which accounts for the increase in output during World War II with such a modest drain on productive resources. It is unlikely, however, that an adjustment of the statistical data to take this into account would seriously affect our conclusions.

[12] This subject is discussed in detail by J. Edwin Holmstrom in *Railway and Roads in Pioneer Development Overseas* (London, 1934).

portance, and one which should be carefully treated in an analysis of overall transportation costs.

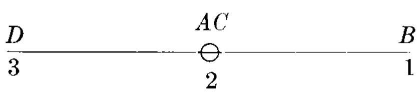
Consider a society with a given population and resources. Assume that people and goods move between Y points. For small values of Y the flow of traffic between points would be likely to be larger and the cost of a given volume of trade and social intercourse smaller than it would be for large values of Y.

The idea that we wish to convey may be illustrated by the following example. Consider a community consisting of four producers located at *1*, *2*, *3*, and *4*. Producer *A* visits his business acquaintances, *D* and *B*, once a week to trade with them. Producer *B* visits *A* and *C* once a week, *C* visits *D* and *B* once a week, and *D* visits *A* and *C* once a week.



In the example given above eight trips are made weekly. Assuming that the distance between adjacent pairs of points is 10 miles, a total distance of 80 miles will be covered by the traders.

Consider a second case, a society with the same four producers *A*, *B*, *C*, and *D*, with similar trading habits. We now assume, however, that *A* and *C* are located at the same location and that there are only three points between which travel occurs.[13] Let *B* be located at *1* and *D* be located at *3* with *A* and *C* located at *2*. With a reduction in the number of points the transportation costs of trading between *A*, *B*, *C*, and *D* are substantially reduced.



This is true not only because the distance of the trips required to carry on trade is reduced, but also because the volume of traffic between points is increased. It is this latter aspect in particular that needs to be emphasized.

The clustering of people into groups constitutes a method whereby society may reduce the real cost of transportation. Not only does this reduce the distance which has to be covered for a given number of exchanges to take place, but also it makes possible the utilization of the more efficient types of transportation than can be used when the volume of traffic between given points is large.[14]

As highway traffic has increased in relative importance in the transportation system, not only has traffic been diverted from rail carriers, but also there has been a tendency for changes to occur in the distribution of population.[15]

> When travel between home and work was by foot or on trolley cars or suburban railroads, factories and other establishments had to be located in the immediate vicinity of a labor supply or in a district easily accessible by public transit. Long tentacles of built-up territory extended out from the centers of large cities along lines of public transit that furnished the only practicable means of journeying any great distance. The economic structure of cities was highly concentrated at the central nucleus where the various transit routes came together and the chief shopping and office buildings were located. The compact means of transportation developed a highly intensified usage of lines and building space within the heart of the city, and the advantage of transacting various businesses in close proximity furthered the trend of concentration.
>
> Today our cities still follow the main lines of this pattern, but also show quite a different pattern that is gradually replacing it owing to the widespread use of passenger automobiles. For with the automobile came a vast increase in the mobility of labor, particularly in daily commutation. It became possible to locate a plant not merely with respect to the immediately surrounding labor supply or to that available by way of public carrier communication, but actually to tap the labor supply of a radius of 20 to 30 miles around the plant.
>
> The motor truck . . . by increasing the number of locations to which satisfactory transportation service can be rendered and by reducing the differential advantages of large plants and of locations at major terminals,

[13] Other combinations of the producers located at the same point will lead to similar results. Complications may be introduced for the type of analysis attempted here when variations in the spacings of the points are taken into account. The main point that we wish to bring out in the present discussion is the increase that tends to result in the volume of traffic flowing between given points in a society of given trading habits as population concentrates in a smaller number of centers.

[14] Mass transportation techniques substantially reduce the ton mile or passenger mile cost of transportation for large volumes of traffic flowing between given points. In the absence of the existence of such flows, the use of such facilities is inexpedient.

[15] Edgar M. Hoover, "The Location of Economic Activity," *The Growth of the American Economy*, edited by Harold F. Williamson (New York, 1944), p. 599.

permits a much looser scattering of plants. The location of industrial establishments in and around cities is an indication of the working out of this effect at its height. Locations away from congested railyard districts have become feasible. . . .

The dispersion of homes and business establishments alluded to in the above quotations represents a scattering and an increase in the number of points between which travel occurs in our modern economy. In the sense indicated in the above example, this tendency for the number of points between which travel occurs to increase has tended to increase the overall costs of transportation throughout the economic system.

To the extent that improvement of the highway plant leads to diversion of traffic from rail carriers to the highways, and there is evidence that it has, to the extent that improvements in highway transportation service contribute to a decentralization of population, and there is evidence that they have, total transportation costs are likely to rise rather than decline. Thus, the argument that improvement of the highway plant is socially desirable because it reduces transportation costs must be restricted to the proposition that it will reduce highway-transportation costs. The evidence is strong that improvements in the quality or reductions in the cost of highway travel may increase rather than reduce both the total amount spent by society on moving people and goods and the average total unit cost of the transportation service provided.

The main conclusion to which our cost analysis leads is that a reduction in highway transportation costs does not necessarily imply a reduction in total transportation costs. It may be objected, however, that this conclusion is practically worthless, since we have made absolutely no allowance for differences in the quality of service. It may be argued, for example, that the American public has expressed its preference for highway travel over other forms of transportation and that additional road improvement is warranted, regardless of its effect on competing types of service; since the public prefers the added convenience and is willing and able to pay for it.

This line of argument is relevant to a consideration of the economic justification for road improvement, but as we have already observed, in the final analysis the basic justification for modern road improvement from the standpoint of transportation economics is not that it contributes to lower cost transportation but rather that it promotes the development of a more-flexible and more-adequate transportation service.

The implications of this conclusion for transportation policy are important. The fact that large-scale improvement of the highway plant may tend to increase average total unit transportation costs does not imply that continued improvements are economically undesirable. It does imply, however, that if we are interested in developing policies whereby the cost of providing transportation facilities is to be borne by users, it will be necessary to think in broader terms than we are often accustomed. We must be willing to recognize that improvements undertaken to bring greater efficiency in one branch of the transportation industry may increase rather than reduce the average costs of transportation as a whole. Extra costs incurred in improving one branch of the transportation system should not be overlooked in devising equitable ways for allocating the cost of providing adequate transportation facilities among all transportation users. To put the matter in a slightly different way, development of adequate transportation facilities may not be consistent with low-cost transportation service. We must often choose between adequacy and efficiency in building and maintaining the total transportation plant. To the extent that we wish to have convenience, flexibility, and speed—as well as dependability and large-scale capacity—built into the transportation plant, we must recognize that extra costs may be incurred.

Today there is a great deal of interest in where we should build and how we should pay for roads. There is little disagreement about the fact that we need more and better roads, but if we wish to successfully promote adequate and efficient transportation service, we should be careful where we spend money on road improvement, and it may be necessary to look beyond the traffic that flows over the roads to find out where highway improvement is justified. One method of approaching this problem that should prove helpful is to collect and analyze data on traffic flowing between given points over all types of transportation agencies. In this way we may begin to perceive order in total traffic flows of a type not yet suspected. In this way we may be in a position to better understand the factors which influence the movement of traffic over the different routes which are available. In this way we may be able to determine more successfully than we have in the past where highway improvement will, in fact, relieve rather than aggravate traffic congestion. As we begin to think in terms of total traffic flows, we may be able to perceive how changes in one part of the transportation system affect other parts and how changes in rates affect traffic flows over the different branches of the transportation plant. With knowledge of this type we would be in a better position than we are today to devise effective and equitable policies both for building and paying for the transportation facilities that the country needs.

Highway Research in Iowa

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●IN 1949 research attained official and legal status in Iowa as an essential function of highway administration. As a consequence, a new approach to highway research has been developed and employed there during the past 4 years. The purpose of this paper is to describe the procedure now in effect in Iowa for the discharge of the highway research function and to explain the various operations of that procedure.

The current situation with respect to highway research in Iowa is the direct result of an emphatic conclusion of the Highway Investigation Committee of 1947 with respect to highway research in a report to the governor in 1948. This committee was created in 1947 by a joint resolution of the 52nd General Assembly, to investigate the primary and secondary problems of Iowa, to recommend a program of improvement, and maintenance of both primary and secondary roads and means of financing such program, to prepare drafts of bills for legislation where required to inaugurate and implement the proposed program of improvements and to report through the governor to the 53rd General Assembly. This committee was occupied intensely over a period of about 18 months in the task assigned to it. During that period, the committee examined carefully and thoroughly every feature of the highway problems of Iowa in evidence at the time of the study and for some years prior to the study.

The work of the Highway Investigation Committee was completed late in 1948 with the preparation of a report bearing that date. This report was handed to the governor on November 15, 1948, and transmitted to the elected members of the 53rd General Assembly on December 15, 1948, about a month prior to the opening of the session in 1949. One of the 11 principal conclusions of the committee dealt emphatically with the need for research in highway administration. In the reference to research, the committee stated that if sound progress is to be made by the public in providing modern highway facilities for the use of modern motor vehicles, such progress must be preceded by a sound and comprehensive research program covering all of the phases of the highway transportation business for which the public has accepted responsibility. The committee further stated that, among other things, information on traffic volumes and traffic needs must be kept current if costly errors are to be avoided, that the possibilities of using new materials and new processes in construction and maintenance of highways must be explored, that better ways of utilizing and conserving known materials must be sought, and that these must be done by the technical forces in Iowa charged with the responsibility of engineering for the Iowa highway program.

In further emphasis of highway research and to eliminate possible handicap to research through narrow construction of certain existing laws, the highway investigation committee devoted one of the 16 bills drafted for legislative consideration that were included in the