Price Theory and Tax Equity in Highway Finance

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Highway user taxes act as prices for the use of highways, thus influencing the allocation of traffic (and resources) among the various transportation agencies. Assuming that optimal use of the transportation system is one of the aims of public policy, it is important that highway user tax rates be constructed so as to foster attainment of this goal. Although this calls for a pricing or market approach to highway finance, it is equally important to segregate, identify and allow for those values (indirect benefits) which are not reflected in the market choices of individuals.

It appears that the traditional allocation of highway cost between users and non-users does not in general represent a response to indirect benefits. Rather, it reflects administrative problems and certain notions about equity or justice. The theoretical conditions under which a non-user share is appropriate may be specified, but application of the theory raises difficult practical problems. Notwithstanding these practical difficulties, it seems clear that the allocation of shares between users and non-users should follow, not precede, the determination of prices for highway use. Moreover, the non-user share should be scrutinized carefully, so that user rates are not diminished or distorted by deductions for indirect benefits which accrue in the form of rents, windfalls and surpluses. Such indirect benefits must be considered in the light of general standards of tax equity.

Economically efficient highway user tax rate structures can be constructed by adhering to the economic price criterion: Price should equal marginal cost. For an optimally utilized highway plant, "program cost" is a reasonable approximation of marginal cost. An equally satisfactory approximation for roads which have excess capacity and low marginal costs is not available. However, such roads may be financed economically through use of the "two-part tariff". The two-part tariff combines a low price which varies with use with a lump sum tax which does not vary with use.

To provide practical guideposts for application of the marginal cost standard, highway design, price theory and financial administration may be interrelated and integrated into an operational framework or "model". The crucial element in establishment of the "model" is the separation of special or incremental pavement cost from common or geometric design cost. Speculation concerning the impact of the framework suggests the possibility of establishing the gasoline tax rate so that gasoline tax "earnings" on the primary roads cover primary road common cost. Additional or incremental pavement cost may be recovered through the use of lump sum registration taxes or weight distance taxes. Lightly travelled roads may be financed through the use of gasoline tax "earnings" supplemented by lump sum license taxes on light vehicle classes. The general conclusion is that it is possible to manage the highway financial structure in the interest of economic efficiency without creating serious inequities.

● WITHIN the past few years the notion that highways should be financed "equitably" has been supplemented by the view that the highway user tax structure should also foster the economic utilization and development of the highway plant. This change in emphasis implies a partial shift from the use of ethical standards of tax equity to the use of more or less objective standards of pricing in the development of the highway financial structure. The aim of this paper is to set forth the relationships between price and tax standards as they apply to highway finance and to establish criteria for the combination of prices and taxes into a comprehensive system of charges for the financing of highways.

Abstract economic theory has established the principle that, within the limits of a given distribution of income, maximum economic welfare is approached when production and consumption are adjusted so that marginal cost and price become equal (1). If income redistribution is not an explicit aim of the highway user tax structure, it might be appropriate to eschew benefit and ability-to-pay standards of taxation and to establish highway user taxes in relation to a marginal cost pricing standard. One of the implications of a pricing or "market" approach is the assumption that the benefits or utilities relevant to highway finance accrue, in one form or another, directly to highway users. However, consideration of the indirect or so-called non-user benefits which accrue to various individuals may lead to a system of taxation based on the premise that individuals should pay in proportion to "benefits-received". Simultaneous application of both price and tax standards may introduce conflict into the over-all financial structure—what is paid as a tax by the non-user does not have to be paid as a price by the highway user. The possibility of unwarranted subsidy to one group or another is obvious. In order to anticipate this problem, the discussion begins with a consideration of the traditional allocation of cost between highway users and non-users.

THE NON-USER QUESTION

A recent pricing proposal set forth by Brownlee and Heller demonstrates the validity of a pricing approach insofar as primary or "trunk" road finance is concerned (2). However, there have been objections to this proposal from proponents of a user-non-user allocation of highway cost who maintain that the pricing proposal abstracts the most difficult parts of the problem—the relationship of indirect or social benefits to secondary road finance (3). Some progress in the way of clarifying this issue can be made by recognizing explicitly that the allocation of a share of secondary road cost to non-users is more a response to administrative problems than to indirect benefits. Richard Zettel (4), among others, has noted that property taxes, special assessments and other forms of revenue are simply a crude means of collecting directly from the highway user that portion of his highway bill that cannot be collected through the use of ordinary user charges. The expenditure of "general" or non-user funds for highway purposes does not necessarily imply that highways yield indirect benefits nor does it imply that highways ought to be financed in terms of tax equity. Moreover, the administrative problem of collecting from the user does not call for an allocation of highway cost between users and so-called non-users or indirect beneficiaries. Basically, the cost allocation is among those who use the highway.

Recognition of the administrative basis for non-user revenue sources does not resolve the economic issues raised by valid indirect benefits. In order to examine the economic basis of a non-user share, it is necessary to examine the conditions under which value-of-service or benefits-received allocations of cost are appropriate. There are two such situations: (a) joint cost or supply and (b) joint or collective demand. Joint supply creates a problem of cost assignment because two or more physical products emerge from a single application of resources. Joint or collective demand creates the problem of distributing the cost of a single product (whose cost is determinate) among more than one beneficiary. An examination of these two possibilities may provide the theoretical standards for evaluating allocation of cost between users and non-users.

Joint Cost

Joint cost arises when products cannot be produced separately. The classic example is the case of beef and hides; there are two distinct products whose separate costs are indeterminate. It appears to be settled that the "solution" in such cases requires an allocation of total cost on the basis of the value-of-service or value-in-use of the separate products (5). Highways do create some joint products, and this might justify an allocation of cost to non-users or general taxpayers. Highways create fire stops, openings for light and air and various other physical products which have value. These examples of jointness do not appear to weigh heavily in the usual allocation of cost to non-users. Moreover, the physical by-products of highway development do not appear to play a significant role in decisions concerning expansion and contraction of the plant. On the whole, highways are built for actual or potential highway use and little more. It appears that the physical by-products of highway development do not provide an important basis for a non-user share. On the other hand, these elements should be considered, especially when street programs are affected by plans for municipal redevelopment.

Joint Demand

Joint demand arises when one individual gains or receives benefit from the consumption of another. Economists describe such phenomena as "external economies." A person who provides for the physical protection of his own property also provides indirectly for the protection of his neighbors' property. Similarly, a farm to city highway which is constructed and paid for by farmers indirectly benefits merchants, landowners and others located in the city. Although the farmers will use the road, others stand to benefit from that use. Since only farmers use the road, costs may be allocated directly to farmers. The question that arises relates to the circumstances under which downtown merchants and others would (or should) subsidize the farmers' use. In view of the fact that downtown merchants receive many and varied benefits, it may seem "fair" that they share the road bill. This notion of justice, that is, the benefit theory of taxation, might lead to an initial allocation of cost between users and non-users. In addition to being incorrect technically, such an allocation requires a considerable amount of research time and cost. A far better approach would require attention to these questions: (a) Is it necessary to subsidize the user? (b) Is it "fair" that indirect beneficiaries shoulder a part of the bill? The first question can be evaluated in terms of objective standards; the second requires the adoption of a standard of justice.

SUBSIDY TO THE USER

Figures 1-3 depict the user-non-user relationships relevant to highway finance. In order to simplify the presentation, it is assumed that: (a) highway cost varies directly with some unit, say vehicle-miles, (b) there is only one class of vehicle, (c) highway service is produced under conditions of constant average and marginal cost. Another simplification is made by employing straight lines for the demand curves of individuals. These assumptions and simplifications do not affect the generality of the graphical presentation. Three situations are presented: (a) No indirect benefits of highway use; (b) Indirect benefits which require a non-user share, and (c) Indirect benefits which do not require a non-user share.

No Indirect Benefits

In Figure 1 the horizontal axis measures vehicle miles, M_c represents the price or marginal cost, D_a represents the demand of individual A for highway use. D_a depicts the quantities of vehicle miles that individual A will purchase at each of a series of prices. If there is no indirect beneficiary, the charge is P, and individual A pays the entire highway bill. The total payment made by A is shown by the area OQRP. The proper procedure, to be described in a subsequent section, requires that user tax rates be established in accordance with market or price standards.

Indirect Benefits Which Require a Non-User Share

Figure 2 represents the situation when individual B is a non-user who receives indirect benefits because of individual A's use of the highway. Individual B may represent a downtown merchant, real estate promotor or some governmental agency which has an interest in encouraging highway use. It is important to note that indirect benefits accrue to B only if the highway is used. The mere existence of a highway does not create indirect benefits, although it does create the joint products previously described. Individual B, the non-user who receives indirect benefits, also has a demand for travel between the same two points as individual A. As a non-user, however, B does not use the road directly. The demand, D_b, of the non-user is for A's direct use of the highway. Both demands may be measured along the same horizontal axis because both demands relate to the same unit of service. Figure 2 might represent the relationship between farmers and downtown businessmen. If the current price is P, and the individuals do not (or cannot) take their interdependence into account, A will purchase Q vehicle miles. Since B is a non-user he can purchase none. In recognition of the interdependence, however, B may offer a subsidy to encourage A's use of the highway. Individual B has already received a windfall in the form of indirect benefits because he would have been willing to pay a price P_o for each vehicle mile that A has traveled. This windfall is depicted by the area $OQSP_o$. Indeed, B stands to gain if he offers to subsidize A's purchase of another vehicle-mile. Individual A is willing

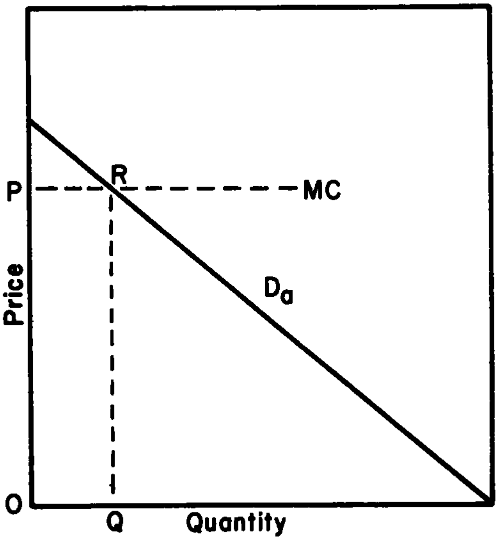

Figure 1. Private demand (The User Share).

to purchase an additional unit at a price slightly below P, while the value of an additional unit to B is a positive quantity slightly below P_o. Assume that B offers an amount U to individual A in order to encourage A's use of the highway. With this offer, the price of an additional unit to A is P-U, and A will increase his purchases to q. Individual B will increase the subsidy offered as long as additional units are forthcoming at a subsidy per unit below his demand price for those quantities. Similarly, A will continue to purchase additional units until quantity Q' is reached such that his (A's) demand price for Q' plus B's subsidy offer (B's demand price for Q') become equal to P, the going price. The equilibrium is depicted by point M where the respective contributions of A and B toward the purchase of Q' are P_a and and P_b ($P_a + P_b = P$). The total amounts paid by A and B are depicted by the areas $OQ'WP_a$ and $OQ'VP_b$, respectively. It should be noted that the user charge is below marginal cost reflecting the general or social desirability of increased highway use.

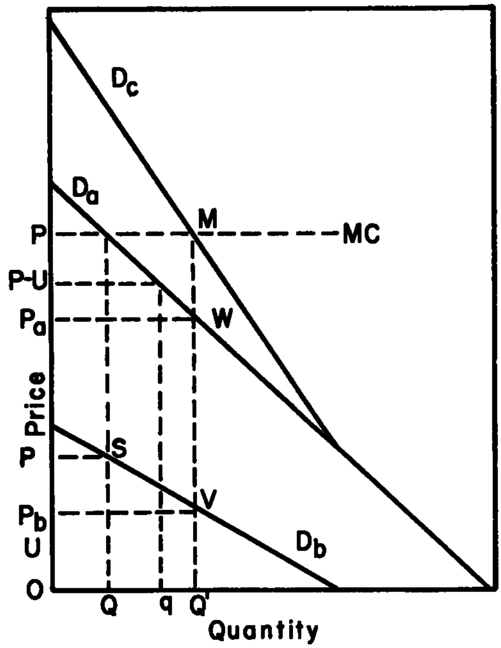

Figure 2. Collective demand (The Non-User Share).

Other points like M could be determined by assuming a different market price. This series of points determines the joint or collective demand (D_c) for highway use. D_c

can be constructed directly by a vertical summation of D_a and D_b. When the economics of the market place is considered, the demands of individuals are summed horizontally (6). However, when a service yields indirect benefits it takes on a "public" or "collective" character because all individuals demand the same physical product. Police protection, national defense and many other programs instituted in the public interest may be conceptualized through a vertical summation of individual demands. The procedures employed in Figure 2 were set forth originally in Sweden by Wicksell and Lindahl and have been developed recently in the United States by Howard Bowen (7) and Paul A. Samuelson (8). Implicit in the solution is a "neutral" theory of taxation reflecting the voluntary choices of individuals in a collective context.

The allocation of shares depicted in Figure 2, is akin, but not identical, to the traditional allocation of cost between users and non-users. Actual determination of the non-user share poses significant problems of measurement. The subsidy will not be offered by the non-user unless it brings about increases in A's use of the highway. That is, if a subsidy offer in the form of a non-user share would result in no or in negligible change, the subsidy is superfluous and charges for the road are assessed against the users of the road. Although the downtown merchant may benefit from the use of the road, it does not (on economic grounds) follow that he should defray part of the cost of the farm to city system. It is almost certain that rents and windfalls of various sorts will accrue to many individuals. The inclusion of these elements in the highway financial structure may lead only to a redistribution of income from those receiving windfalls to highway users. However, if alms are to be given, there may be others who occupy a higher place on our scales of preference.

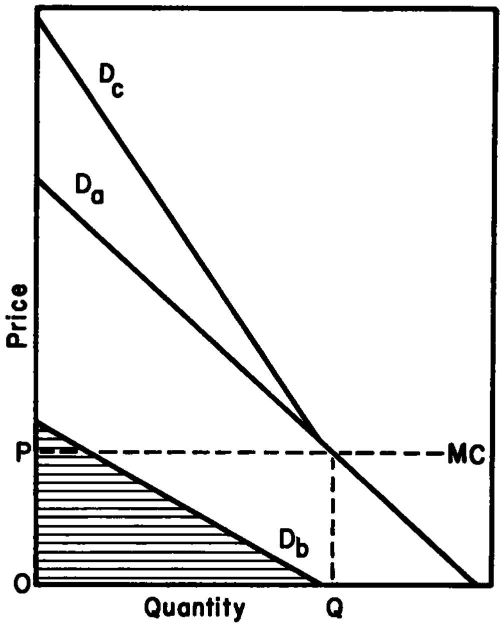

Figure 3. Windfall (Equity).

Silence on the part of indirect beneficiaries is evidence that the indirect benefit is of a surplus character and does not have to be considered in a framework of economic efficiency. If the subsidy is required, businessmen and others will exert pressure on the legislature or the highway authority to provide expanded facilities. As a general rule, collective or political action of some sort will be required. The task of the highway analyst is to reconstruct the pressures and the collective action. The highway financial analyst receives an expenditure program along with the record of legislative and executive hearings and other evidences of collective action. The program is a result of traffic studies initiated by the highway authority and the views of various non-user groups which are affected. A scrutiny of the program and the hearings may indicate the indirect benefits which ought to play a role in highway finance. By inference, the highway analyst can attempt to reconstruct relationships involved in the collective action and within wide limits may be able to determine appropriate payments. Before him are always the following questions: (a) Does this group or individual receive an indirect benefit? (b) If so, is a payment by the indirect beneficiary a necessary condition for receipt of this indirect benefit? (c) What is the minimal amount that he would have to pay to bring about a situation that yields this amount of benefit? The problems are difficult, but not insurmountable. Although perfection may be impossible, it is felt that the approach suggested is superior to the broad and often illusory conception of indirect or "social" benefits so frequently brought into highway financial analysis. Moreover, the opposite extreme of overlooking indirect benefits entirely is avoided. At least a few limits have been set and some criteria have been established.

Indirect Benefits Without a Non-User Share

Figure 3 represents the situation when there are indirect benefits which have no significance unless a standard of tax equity is adopted. The horizontal summation of D_a and D_b yields the collective demand, D_c. At price P, both D_c and D_a yield a quantity Q. At output Q the demand of B, the non-user, for additional increments of traffic is zero. An increase in traffic beyond Q does not yield any additional advantages to the indirect beneficiary. No subsidy is offered and A pays for the highway. The shaded area in Figure 3 represents a windfall or rent which may or may not be extracted from the indirect beneficiary depending on equity. These rents and windfalls, of course, would provide an excellent source of revenue for redistributive purposes. However, the notion that "like things should be treated alike" along with principles of tax equity such as "neutrality" or "reasonable classification", imply that rents and windfalls associated with the highway function should be treated in the same manner as any other rents or windfalls. On administrative and opportunistic grounds, the case for the extraction of such rents is much stronger. For example, the uncapitalized rents associated with a new highway program are easy to measure and in this writer's opinion represent an excellent source of general tax revenue. This opinion is based on opportunistic and administrative grounds coupled with a notion about justice. However, such opportunistic taxation should not be related to the highway tax structure without first assessing the implications of reducing the share assigned to users.

Perhaps the most significant practical conclusion is that the traditional allocation of cost between users and non-users is primarily a response to an administrative problem. However, the proper place to consider administration is after costs have been allocated, not before. The first step in highway financial analysis should establish the cost of highway use. If the "socially" desirable amount of highway service (depicted by D_c) "clears the market" at a cost-determined price, a non-user share is not required. If the "socially" desirable amount does not "clear the market", highway use must be encouraged through subsidy in the form of a non-user share. Equity may also call for a non-user share; this requires evaluations concerning the distribution of income. Although the attainment of equity is desirable, it does not provide a principle for the determination and allocation of highway cost. The practice of incorporating either a "benefit" or "ability to pay" theory of taxation within the analytical framework of cost allocation may serve only to reduce the amounts assessed against users, and could lead to an unwarranted subsidy disguised in the form of a "scientific" allocation of cost. The result might well be a misallocation of resources and traffic in the domestic transportation system.

HIGHWAY PRICING

It has been suggested that the determination of prices for the use of highways ought to be the first, not the second, step in highway financial analysis. In the abstract, the appropriate price is found at the point on the theorist's marginal cost curve which corresponds to the quantity of service taken. Theoretical marginal cost curves are interesting analytical tools, useful in demonstrating the principle, but of little help in applications. The ensuing discussion deliberately eschews the traditional theoretical machinery in favor of an applied interpretation of the marginal cost standard.

Marginal cost has been defined as the difference in total cost at two consecutive levels of output (9). Alternatively, it is the cost which could be avoided if an additional unit, block of units, or class of units were not produced. According to James E. Buchanan (10), there are two components of marginal cost relevant to highway finance: (a) The direct marginal money cost imposed by a user and (b) the indirect additional burdens imposed on other users, that is, delays and inconveniences associated with congestion. Direct marginal money cost is "that portion of total maintenance costs which vary directly with road usage." Indirect or "real" marginal cost cannot be translated easily into a money equivalent. Employing this two-pronged conception of marginal cost, Buchanan concludes that:

1. Secondary road users who cause little congestion should be required to pay less per ton or vehicle mile than primary road users.

2. Heavier and larger vehicles should be charged higher rates than lighter and smaller ones because both the direct and indirect components of marginal social cost are greater.

3. Slower vehicles which add more to congestion should pay higher rates than faster vehicles.

4. Vehicles known to travel more during congested time periods should be charged higher rates. Higher rates should be charged on week-ends and holidays and during rush hours.

One difficulty with Buchanan's conception of marginal cost is the assumption that maintenance cost is the relevant marginal money cost. This eliminates construction expenditure from the purview of the highway price structure. Although the cost of sunk, fixed or previously committed resources is not marginal (11), it does not follow that construction cost is without significance to highway pricing (12). Expansion and contraction of the highway plant through variations in construction expenditure is a daily occurence. Although such expenditures become sunk costs, new construction expenditures are continually being made and, therefore, are marginal. To have any real significance, marginal cost must refer to those resources which are currently available for other uses and which management may or may not choose to appropriate. In a similar vein, Lerner maintains that marginal costs "are costs the incurrence of which is in question" (13).

"Costs the incurrence of which is in question" are found in the program or plan of the authority. The program is continually in question and represents both production and planning (short and long run) costs; it does not include costs that have been incurred previously. If the program is well conceived, it is geared as evenly as possible to the demand that is expected to present itself at a series of future dates. If the demand develops as anticipated, the highway plant will operate as near to the optimum as possible. From time to time the program will be revised in response to changes in the outlook, and program cost will either be increased or decreased. If demand declines and additional construction is not required, program cost will decline to the level of maintenance; if demand increases, program cost will increase so as to include the cost of added capacity.

The difficulty with program cost is obvious. It is a valid interpretation of marginal cost only on the assumption that the program refers to an optimally adjusted plant. This assumption may be questioned. Particular roads or the system as a whole may be characterized by congestion (excess demand) or under-utilization (excess supply). In the event of under-utilization, additional traffic can be handled at a very low additional cost. On the other hand, congestion creates a situation which is characterized by high marginal costs some of which are exceedingly difficult to measure. Such conditions may arise because of (a) short run or temporary excess supply or demand (b) indivisibilities, that is, the physical impossibility of adjusting the plant and (c) peak load. Although these conditions are closely interrelated, each may call for a particular kind of price policy.

Before examining these situations it may be helpful to distinguish between "temporary" and "permanent" indivisibilities of the highway plant. Temporary indivisibilities are those that can be eliminated by increases or decreases in demand or supply. For example, additional lanes are added in anticipation of the demand a few years hence. There is excess supply of a temporary nature because of the inability to make frequent and small adjustments. Permanent indivisibilities appear on secondary roads. Typically, such roads have excess supply because of an inadequate demand coupled with the fact that roads must have certain minimum design features to withstand the elements and to provide a reasonable minimum quality of service. In the ensuing discussion, permanent indivisibilities (secondary roads) are treated separately. However, temporary indivisibilities are treated as a short-run maladjustment.

Short Run Excess Supply or Demand

If there were no peak load problem or permanent indivisibilities, excess supply or excess demand could be removed through appropriate adjustment of the plant. However, the plant cannot be adjusted immediately. An attempt to eliminate congestion or excess capacity immediately through price variations involves difficult administrative problems. Moreover, it is possible to maintain that price discipline is not a necessary condition for effective short run utilization of the highway plant. An adjustment to temporary excess capacity or congestion occurs more or less automatically because traffic has a tendency to distribute itself so as to reflect marginal real cost. Congestion raises real cost to the motorist; excess capacity reduces such cost. The motorist, in reducing real cost, will attempt to select that time and route which has the lower marginal real cost. Of course, this automatic adjustment for excess capacity and congestion is limited, especially in rural areas, by the number of alternatives available to motorists. Another aspect of this adjustment is the fluctuation in user tax earnings. If user tax rates are established on the assumption of optimal operations, congestion will result in "profits" to the highway authority while excess capacity will lead to "losses." The accumulation of profits may be interpreted as a reflection of rising marginal cost while the incurrence of losses may reflect declining marginal cost.

The adjustment described above may also be interpreted as a reflection of the intimate relationship between the volume or density of traffic and the quality of service. Although rates are not varied, the motorist receives a lower quality of service on a congested highway and a higher quality of service on a highway which has excess capacity. The effect is much the same as that which would be obtained if the quality standard were maintained and price variations were used to adjust the volume of traffic. Instead of price variations, the adjustment may occur partially through quality variations which are "built-in" to the system.

In passing, another implication should be noted. The addition of a vehicle imposes additional "real" costs on other vehicles, although the additional money outlay of the highway authority is quite low. These "real" costs may be measured by considering the impact of the vehicle on the "practical" capacity of the highway. Practical capacity has been defined in the Highway Capacity Manual (14) as: "the maximum number of vehicles that can pass a given point on a roadway or in a designated lane during one hour without the traffic density being so great as to cause unreasonable delay, hazard or restriction to the drivers' freedom to maneuver under the prevailing roadway and traffic conditions." Every diminution of available capacity can represent an increment of cost imposed on other vehicles. Thus, the marginal cost imposed by each vehicle is a function of vehicles inconvenienced or even displaced (reduction in capacity). Since every vehicle is marginal, prices could be established on the basis of relative capacity utilized on the assumption that the more capacity utilized by a particular vehicle, the more the practical capacity is reduced. The capacity approach provides a means for translating real cost into money cost. However, if the road is capable of handling additional traffic, without any impact on practical capacity, the marginal cost can be no greater than that portion of maintenance cost which varies directly with road use.

The burden of the argument is that highway users who do not bear the brunt of high marginal costs in terms of higher user tax rates must still bear real cost in terms of delay, inconvenience and frustration. A policy of maintaining rates at the program cost level has more to commend it than the argument of administrative feasibility. Although more refined rate variations in response to temporary excess supply and excess demand would be difficult to administer, it may be desirable in some instances to add price discipline to the "built-in" adjustment already described.

Permanent Indivisibilities

Frequently it is impossible to adjust the highway plant to the demand for its use and there is a permanent condition of excess capacity. None of the possible adjustments described in the preceding section can be made. Marginal cost on a lightly traveled road is well below the unit program cost for that road. However, the marginal cost argument for low rates is not especially strong as the demand for such roads probably is relatively inelastic; therefore, the excess capacity cannot be removed through increases in traffic brought about by low marginal cost prices. Nevertheless, a formal adherence to the pricing standard requires low rates for lightly traveled roads.

Marginal cost pricing requires that secondary roads having excess capacity be operated at a "loss." In a sense this offers an excellent theoretical rationalization for a non-user share on secondary roads. The question of "losses" due to marginal cost pricing has been discussed by many writers (15). One solution to the problem is the "two-part" tariff (16). Under this proposal the consumer pays a low marginal cost price at the time of purchase. In addition, lump sum charges independent of use are employed to cover the losses that arise. An application of this idea to highway finance leads to a lump sum tax not to exceed the value-of-service to the user, combined with a low user charge based on marginal cost. The gasoline and weight distance taxes are appropriate candidates for the marginal rate while license taxes, driver's license fees, property taxes on automobiles, special assessments against those abutting property owners who use the road and many others appear to be suitable for the lump sum charge. It is felt that license taxes and driver's license fees are best suited for this purpose because their purchase is voluntary. Thus, the payment does not exceed value-of-service. Of course, this does not preclude the use of any other lump sum tax provided it is paid by the user and does not exceed value-of-service.

Peak Loads

Elimination of peak load does not involve conceptual problems that have not been described by Buchanan and others, but application to highways does involve significant administrative problems. Although there are opportunities for peak load pricing that ought to be examined by highway administrators, it is likely that the general problem is solved as well as it can be by the "built-in" adjustment. Motorists do not drive headlong into congestion unless their demand is highly inelastic; if possible, they tend to arrange their affairs in order to avoid the traffic. Reasonable rate differentials probably would have little impact on the peak load problem, although other solutions of a more general nature are possible, e.g., subsidized transit systems. In reaching this conclusion relative to the peak load problem, it is not implied that peak load pricing should be abandoned. In some instances, appropriate peak load price policy of the sort advocated by Buchanan might result in a more effective utilization of the highway system. The problems relative to peak load are administrative, not conceptual.

THE FRAMEWORK OF APPLICATION

It has been suggested that a highway user tax structure consistent with the marginal cost standard might be based on program cost. Temporary congestion and excess capacity are eliminated partially by a "built-in" adjustment described earlier. If such conditions persist for any length of time, they will have an impact on program cost and will lead either to higher or lower rates until the plant is adjusted. If it is practical, a system of peak load and short-run prices may be incorporated into the financial structure. Modifications for lightly traveled roads which have high average program costs but low marginal costs are also required. After all adjustments have been made, the revised price structure may deviate considerably from the initial price structure based on program cost.

The basic element in the establishment of the price structure will be an incremental allocation of program cost. The usual incremental cost allocation involves a direct assignment of special cost to vehicle classes along with an apportionment of common cost among all vehicles. To have empirical validity, these cost assignments usually are based on engineering design criteria. These "design-cost" assignments or "cost responsibilities" must be converted into economic cost-price relationships. Finally, cost-price relationships must be combined with administrative relationships in order to provide a workable solution. The problem is largely one of arranging various categories into a single framework that integrates the factors impinging on the total highway program. The relationships that shall be considered fall into three classes:

1. Design-Cost—Cost of supplying highway services determined from highway design criteria.

2. Cost-Price—Prices for highway services determined in accordance with the marginal cost criteria.
3. Price-Administrative—Collection of prices in accordance with administrative criteria.

Design-Cost Relationships

All variations in highway design due to variations in either traffic volume or to the size, weight and performance of vehicles can be related either to pavement requirements or to geometric design. Pavement design refers to pavement characteristics—surface, base and subbase; geometric design deals with length, width, curvature, gradient and alinement. Fundamentally, the geometric design of a highway is a function of (a) the volume of all classes of traffic, (b) the dimensions and speeds of vehicles and (c) the quality of service (speed, ease of driving, risk, etc.) that has been selected. Assuming given soil and weather conditions, pavement design is a function of the axle load of vehicles and, possibly, of the number of repetitions of the axle load (volume of particular weight classes of traffic).

Volume relationships relevant to the geometric design have been established by studies of highway capacity (14). These relationships are not so "lumpy" as one would suppose. When a two-lane highway becomes congested, the jump to a four-lane highway is not inevitable. The two lanes may be widened, grades and curvature may be reduced and many other elements of geometric design may be varied in an attempt to adjust the geometric design to the traffic. Of course, the possibility of adjusting the plant on the drawing board is a different problem from adjusting the plant in an economic sense. Moreover, the possibility of making adjustment in the geometric design is severely limited with regard to facilities which carry a very low volume of traffic because of the minimum design form necessary to provide a reasonably satisfactory service.

Volume or quantity relationships for pavement thickness are not as well established as those for geometric design. The pavement thickness, for example, may be affected by the number and frequency of repetitions of a particular axle load. However, pavement design does not consider this relationship in a manner such that a definite relationship between number of repetitions and pavement thickness can be determined (17). The chief difficulties in isolating weight related pavement costs appear in the low-volume roads which are not designed for "infinite" repetitions of a maximum permissible axle load (17). As a result of these problems, different methods and a considerable amount of judgment are required in order to isolate weight-related costs for a highway system having both high and low volume roads. In order to simplify the discussion, it will be assumed that the system of highways is composed of two classes of road each designed in accordance with the following standards, limitations and assumptions:

1. Primary or high-volume roads are designed for an infinite number of repetitions of a legally permissible maximum axle load. Incremental weight costs can be calculated and assigned to the various weight classes using the road (18).
2. Secondary or low-volume roads are designed to the higher of two standards: (a) To withstand the elements over a given period of years or (b) to withstand the maximum axle load which appears with a sufficient frequency to affect design standards. Secondary road pavements are capable of handling mixed traffic in proportions that are not known. Provided they appear in "limited" numbers, heavy vehicles do not impose measurable incremental weight costs (17).

It should be noted that these standards, limitations and assumptions will vary depending on the state of engineering knowledge. Although a more sophisticated series of design relationships could be derived, those that have been presented are sufficient for the analysis which is to follow. It is also worth noting that geometric design creates highway capacity while pavement thickness creates the ability to bear loads. Since highway capacity is created on behalf of all vehicles, geometric design may be interpreted as imposing only common cost. Interpreted in this manner, the geometrics of the extra foot or two ordinarily associated with truck traffic is a common, not a special cost, because the additional capacity is available to all vehicles. If the available highway capacity is either increased or decreased, the conditions under which all vehicles operate are changed because of the effect on congestion. This does not hold for pavement thickness which imposes special cost. The removal of an increment of weight or axle load (size, speed and volume of traffic remaining constant) reduces highway cost, but does not affect the conditions under which all vehicles operate.

Assuming that the pavement of primary highways is designed to withstand "infinite" repetitions of a maximum axle load, the marginal cost of pavement is zero because the addition of one more vehicle does not increase the total cost of pavement. On the other hand, if a continuous relationship is established between the numbers (and frequency) of a particular axle load and the pavement requirement, marginal pavement cost can be determined by evaluating the impact of an additional vehicle on the pavement thickness requirement. The ensuing discussion proceeds on the assumption that a continuous relationship between repetitional loading and pavement thickness has not been established. However, the implications of this possible relationship will be noted in the course of the discussion.

With this background it is possible to establish a series of tentative relationships around which a system of highway finance may be constructed. The relationships described below are of two sorts—geometric and pavement; they are deduced from the assumed criteria for highway design.

A. Geometric Relationships

1. Geometric design provides capacity.
2. Capacity is utilized by all vehicles. Therefore, geometric design imposes common cost.
3. Changes in geometric design create marginal costs which do not include incremental (special or weight-related) pavement costs.

B. Pavement Relationships

1. Specific or finite changes in volume of traffic are not considered in the determination of the pavement structure.
2. Because of "infinite" design, the marginal cost of pavement structure is presumed to be zero on primary roads. However, large increments of pavement can be assigned to all weight classes below the legal maximum on primary roads.
3. Increments of pavement structure cannot be assigned on secondary roads where heavy vehicles appear in "limited" numbers. Insofar as design is concerned all costs on such roads are common costs.
4. The pavement structure (but not the geometrics) of a secondary road is equivalent to the pavement structure of a primary road designed for the same weight class of traffic..

These relationships provide the basic ingredients in the development of a marginal cost system of highway finance. By relating the system to highway design, the problem is placed in an empirical or applied setting.

Cost-Price Relationships

The starting point in an analysis of cost-price relationships is the segregation of special pavement cost. One may assume that this special item has been segregated in accordance with the usual incremental cost procedure. With the elimination of special pavement cost, the simplified highway network under consideration is designed for a single weight class of traffic, although it still considers differences in dimensions and speeds of vehicles. The pavement is designed either to withstand the elements or to withstand infinite repetitions of the first or lightest vehicle class. With this "basic" structure, the limits which have significance to both design and economic analysis are geometric in nature. These geometric relationships have a special significance to highway pricing.

The marginal cost basis for the allocation of common or geometric cost by evaluating the impact on practical capacity was described earlier. An additional increment of traffic on a fully utilized facility diminishes its practical capacity and requires improvements in the geometric design. Since every vehicle is marginal, marginal cost is the cost of improving the geometric design, that is, adding capacity. Capacity relationships are ideal for marginal cost pricing. The elimination of one unit provides capacity for all other units; the addition of one unit displaces others. Marginal cost of a particular use can be determined by evaluating these displacements.

It appears that data are available for establishing prices consistent with the view that has been presented. According to the Highway Capacity Manual (14): "approximately the same operating conditions will prevail on an expressway through rolling terrain when there are 1,500 passenger cars per lane per hour as when there are 115 trucks and 1,040 passenger cars per lane." Thus, 115 trucks displace 460 passenger vehicles. In this particular case, passenger vehicles are responsible for about two-thirds (1,040/1,500) of total common (geometric) cost, while commercial vehicles are responsible for about one-third (460/1,500). This is an "opportunity cost" basis for the determination of marginal cost. The addition of a single commercial vehicle displaces capacity for four passenger vehicles. Such ratios are available in the Highway Capacity Manual which lays the foundations for the marginal cost pricing of highway services. In addition to the common costs described above, commercial vehicles will receive an assignment of special pavement cost to be defrayed either through lump sum or use taxes depending on the relationship between pavement thickness and number of repetitions of the axle load.

There are many elements of cost that are not considered in highway design. Thus, design provides almost no empirical basis for the allocation of cost of administration and maintenance. However, these costs may be either special or common and they may or may not vary with incremental additions of traffic. To the extent that these costs do vary with traffic, they may be added to the marginal costs implied by design criteria in order to arrive at a total price to be charged on the basis of use. To the extent that they do not vary with incremental additions to traffic, marginal cost is zero and "losses" will have to be covered through lump sum taxes.

The relationships described above do not hold when there is a significant amount of under-utilized capacity. In such instances an additional vehicle will have no measurable impact on the practical capacity or design of the highway. However, it might be held that any increase in traffic imposes marginal "real" costs on other traffic even if it does not affect highway design or practical capacity. Since workable distinctions of this sort are difficult to maintain, the ensuing discussion of secondary road finance adheres to a money cost interpretation.

The determination of marginal money cost on secondary roads which have excess capacity raises difficult problems. An additional vehicle has no impact on highway design, although it might have some impact on maintenance. In short, marginal cost is far below design cost. Although marginal cost would be exceedingly difficult to calculate in such situations, adherence to the pricing standard requires that these roads be operated at a "loss". An examination of applied marginal cost pricing proposals reveals that the so-called two-part tariff includes a variable or marginal charge based on operating expense (maintenance cost) and a fixed charge based on overhead (19). Strictly speaking, maintenance expense is not a marginal cost. But this seems to be the only interpretation of marginal cost that can be applied realistically in excess capacity situations. A more satisfactory term for this concept is "out-of-pocket" cost. All serious attempts at realistic applications of the marginal cost standard rely on the out-of-pocket concept. This is not acceptable under increasing cost situations, but it probably comes close when there is obvious permanent excess capacity. One now has two crude, but workable, marginal cost standards for two types of road. These are summarized below:

1. Program cost (exclusive of special weight cost) represents an approximation to primary road marginal cost. If the road is fully utilized, this cost may be allocated among vehicles on the basis of the proportion of capacity utilized by each vehicle.
2. Maintenance cost represents an approximation of secondary road marginal cost.

The two standards suggested above determine two extreme points on the traditional marginal cost curve; one for a "high" volume road, the other for a "low" volume road. Highway financial analysts are not without experience in "smoothing out" or "filling in" the missing links. Meanwhile, the discussion is based on the extremes.

It is necessary now to consider the pricing criterion to be employed for vehicles which impose special pavement costs. The special weight cost applicable to a given weight class is a common cost with respect to the vehicles in that class and other heavier weight classes. On the assumption that these weight costs do not vary with the number of repetitions of load there is no justification for penalizing additional use of these pavement increments. Insofar as the marginal cost standard is concerned, the use of such increments by heavy vehicles should be encouraged through low prices. (Of course, any encouragement that this might offer for increased use of the highway may be offset by the impact of additional heavy vehicles on congestion, that is, geometric requirements.) Pursuit of a low or zero price policy for the pavement component would involve "losses" due to economical or marginal cost pricing. These losses would be equal to special pavement cost. If the service is to be continued, beyond the design life of such highways, these losses must be recouped. The losses on each increment may be recovered from the operators of the heavy vehicles requiring such increments, through the use of lump sum charges.

These conclusions concerning pricing for special weight increments do not hold if a relationship can be established between number of repetitions of axle loads and pavement cost. If pavement cost is a continuous function of number of repetitions, an additional vehicle will impose additional pavement cost and a price based on use should be employed. It seems possible that a relationship might be established between special weight cost and axle miles. In this event, the axle-mile standard for the inter-class allocation of special pavement cost might be appropriate. This appears to be the current practice. This is an interesting example of the relationship between the state of engineering knowledge and highway pricing. The assumption of "infinite" design leads to lump sum taxes while the assumption of "continuous" design leads to prices which vary with use such as axle-mile or ton-mile taxes.

Tentative Price-Administrative Relationships

The usual procedure in establishing the highway user structure involves the calculation of a "bill" (cost responsibility) for the motorist. Once cost responsibility is calculated, various taxes and tax rates are adjusted so that this amount is collected from each user. In attempting to administer the system of highway finance without toll gates, one may take advantage of any fortuitous relationships that will further his purpose. The ensuing discussion suggests two possible price-administrative relationships that do not have as strong a foundation as the design-cost and cost-price relationships. Nevertheless, the relationships that shall be suggested appear to have enough validity to qualify as tentative hypotheses awaiting empirical verification. The two price-administrative hypotheses are:

1. If there is but one weight class of vehicle, a single price for the use of both primary and secondary systems is more likely to conform to marginal cost principles than to full or average cost principles, that is, cost responsibility.
2. Gasoline consumption provides as adequate a measure for pricing in accordance with capacity utilized as can be had without the use of toll gates or elaborate reporting devices.

To evaluate the first hypothesis one may recall the two pricing criteria established in the cost-price section. These are: (a) Marginal cost on the primary system is determined by unit program cost, and (b) marginal cost on the secondary system is determined by unit maintenance cost. Unit program cost on the secondary system is considerably above unit program cost on the primary system. However, average maintenance cost on the secondary system is considerably below unit program cost of the secondary system. Thus, unit program cost on the primary system may have a closer relationship to unit maintenance cost on the secondary system than to unit program cost on the secondary system. If one translates theoretical cost curves into metaphor, this involves saying that the marginal cost of a small plant operating with excess capacity is likely to have a closer relationship to the marginal cost of an optimally operating large plant than the average cost of the small plant has to the average cost of the large plant. This relationship assumes that average cost declines over the range embracing the small and large plants. A graphical demonstration is not necessary to grasp the nature of the relationship between the average and marginal costs of small and large plants operating under conditions which involve a large proportion of fixed costs. This possible relationship between the two marginal costs provides a means for rationalizing the administrative problem. If it is hypothesized on the basis of the possible relationships described above that the two marginal costs are roughly equal, it follows that a single price can be charged for both primary and secondary roads in the absence of heavy axle loads.

The second hypothesis is suggested by a proposal set forth by Leland James (20). Although James' figures and theory have been questioned (20), no one appears to have disputed the existence of the gasoline consumption-capacity utilized relationship. A comparison of relative gasoline consumption and space occupancy ratios indicates that this relationship might have considerable validity. An empirical test is not attempted in this paper, although the design for such a test involves no difficulties. In order to demonstrate the possibilities, it shall be adopted as an hypothesis for administrative purposes. In addition to providing another possible tool for marginal cost pricing, gasoline consumption makes possible a significant analytical short-cut. If the relationship between gasoline consumption and capacity utilized were "perfect", the common (geometric) cost of primary roads would not have to be apportioned directly among vehicles. After special pavement cost is assigned, the task would be completed by establishing a gasoline tax rate such that gasoline tax "earnings" on the primary system would cover its common cost. It seems that there is a good possibility of achieving two ends in one maneuver: (a) Establish marginal cost rates and (b) obviate the calculation of total cost responsibility for each vehicle. Only special cost responsibility would have be to calculated. Moreover, if marginal pavement cost is presumed to be zero (because of "infinite" load bearing capacity), the problem resolves itself into the determination of a gasoline tax and the establishment of a system for recovering losses through lump sum taxes.

SUMMARY OF TENTATIVE RELATIONSHIPS

It is now possible to bring the relationships that have been developed into a complete, albeit speculative, system of highway finance and administration. The more important relationships are:

A. Design-Cost Relationships

1. Changes in geometric design create measurable marginal costs.
2. Changes in pavement thickness create special cost.
3. The pavement structure (but not the geometry) of the secondary system is equivalent to the pavement structure of the first increment of the primary system.

B. Cost-Price Relationships

1. Price should be established at the marginal cost level.
2. Common (geometric) cost may or may not be significant to highway pricing depending on the amount of capacity available. (a) If there is under-utilization, the economic cost of providing additional service is below the design-cost of providing additional capacity. Maintenance cost represents a reasonable approximation of marginal cost. (b) If there is full utilization the economic cost of providing additional service is at least equal to the design-cost of providing additional capacity. Program cost is a reasonable approximation of marginal cost for applied purposes.
3. Marginal cost of special pavement structure may be either zero or some positive quantity depending on the limits of engineering design.
4. Losses due to marginal cost pricing must be recovered from users in the form of lump sum taxes not to exceed the value of service.

C. Price Administrative

1. If there is but one class of vehicle, a single price charged for the use of both (primary and secondary) facilities is more likely to conform to marginal cost standards than to full or average cost standards.

2. Gasoline consumption provides as adequate a measure for pricing in accordance with capacity utilized as can be had without the use of toll gates or elaborate reporting devices.

It is important to note that the relationships are integrated. Highway design, price theory, and financial administration are now parts of a single model. The three sets of relationships described above may be arranged in whatever manner appears to suit the institutional fabric and may be extended, refined and validated through further research and testing. It is felt that they represent a reasonable application of an abstraction, the marginal cost principle, to highway design, highway pricing and highway administration. In order to demonstrate a possible application of these relationships, a provisional synthesis is offered.

A SYNTHETIC SYSTEM OF HIGHWAY FINANCE

Assume at the outset that special pavement cost, along with the axle loads to which it applies, is isolated (A2). (Notations refer to the relationships described in the preceeding outline.) Now, the pavements of primary and secondary systems are structurally equivalent (A3). Uniform rates established at the marginal cost of the primary system will result roughly in marginal cost prices on the secondary system (C1). Now, set the gasoline tax rate so that "earnings" on the primary system cover the common cost of the primary system (C2). The result is approximate marginal cost prices on all systems.

Gasoline tax earnings on the primary system will cover all but special pavement costs of the primary system. Gasoline tax earnings on the secondary system may cover maintenance costs but this is not assured. If the primary road system is congested, "profits" will be earned at the established gasoline tax rate. If highways are provided under long-run increasing cost conditions, revenue yielded at the established rate may prove inadequate for optimal expansion. In this event, (a) the gasoline tax rate will have to be raised or (b) "intolerable" conditions may persist until an adequate surplus is accumulated. If there is persistent excess capacity on the primary system, losses will occur and the plant must be contracted. Secondary roads will incur losses because of permanent excess capacity. The amount of secondary road losses will be the difference between secondary road program cost and secondary road gasoline tax earnings. Such losses will be large or small depending on the amount of excess capacity. Where marginal cost is lowest, the losses will be greatest.

Regardless of the specific conditions under which they arise, losses due to conformance with the marginal cost standard call for lump sum taxes levied on the user. These taxes cannot exceed value-of-service or the direct benefits accruing to the user. Although any lump sum tax may qualify for this purpose, license taxes are indicated. Their imposition would not interfere greatly with use and they cannot exceed value of service because they are voluntarily purchased. Since primary roads tend to operate under optimal or congested conditions, losses will be incurred on secondary roads where excess capacity is prevalent. Therefore, the license tax on light vehicles may be reserved for secondary road purposes.

Special pavement costs must now be considered. In this simplified system, such costs are incurred on the primary system. The current state of engineering knowledge indicates that the marginal cost of pavement is either zero or some positive quantity. If marginal pavement cost is presumed to be zero, additional lump sum taxes may be imposed on appropriate vehicle weight classes. If marginal pavement cost is positive, axle-mile or other third-structure taxes may be indicated. It is possible that a combination of lump sum and third structure taxes may be required. To a large extent a specific solution to this problem depends on the state of engineering knowledge and on administrative and jurisdictional considerations. To summarize this synthetic system:

Primary road finance relies on gasoline taxes levied on the assumption that all vehicles are of the lowest weight class and on lump sum and/or third-structure taxes designed to recover special pavement cost imposed by heavier vehicles. Secondary road finance relies on gasoline tax earnings for all or a portion of maintenance expense and on local license taxes on light vehicles in order to recover the balance.

SOME SPECULATIONS RELATIVE TO HIGHWAY FINANCIAL POLICY

Assuming that the basic relationships on which the model rests bear the scrutiny of students and administrators, it is interesting to consider some of the possible implications to public policy. If the direct benefits to users exceed the cost of the highway program, a "user pay all" policy can be established. Surpluses, rents and other windfalls may be considered by those responsible for justice or equity in the tax system as a whole. However, as a practical matter the highway analyst may have to make the value judgment concerning the appropriation and disposition of these surpluses. If the direct benefits accruing to users do not exceed the cost of a given program, payments established on the basis of the foregoing principles will not cover cost. This does not imply that the highway system is overexpanded. However, the highway program will have to be reviewed in the light of the indirect benefits which may have played a role in the investment decision, but which have not yet played a role in the financial structure. Appropriate non-user taxes to cover the "losses" due to "social" expansion of the plant may be determined in accordance with the theory of joint demand presented at an earlier point. An appropriately determined non-user share results in an adjustment of user taxes to a level below marginal cost. To economic theorists this represents the adjustment for "external economies" or social value. In this writer's opinion this adjustment would be minimal.

The motorist or truck operator probably will pay a higher price because the bulk of the present non-user share has been eliminated. However, the non-user funds released would be available to finance other governmental programs of a more "general" nature. It is possible that the present non-user share which is devoted primarily to secondary roads will be roughly equivalent to any increase in gasoline or license tax revenue for secondary road purposes. Secondary road users might simply trade one form of tax for another. This study may lead only to a rearrangement of administrative relationships, especially those having to do with the jurisdictional distribution of centrally collected funds. The validity of such a rearrangement ultimately rests on factors other than those with which this paper is concerned. On the other hand, if the present non-user share has led, on one way or another, to a distortion of the primary or commercial rate structure, there is a possibility that the present allocation of resources is inefficient. This raises again the questions of the proper level of commercial truck rates and the propriety of utilizing rents, windfalls, and surpluses for highway purposes. Because such surpluses appear to have been restricted to secondary road finance, it is likely that the impact on the commercial rate structure may have been minimal.

Although some exceptions have been made to the analyses, procedures and techniques that are employed in the establishment of the highway user tax structure, it appears that the highway user tax structure has survived and remains a powerful tool for the attainment of economic efficiency. It is reasonable to agree with Zettel (4) that: "When we consider that user taxation was conceived in expediency, born of necessity and nurtured of politics, it is surprising that the offspring is as healthy and works as well as it does to serve sound economic objectives." The chief concern, however, is not with the decisions that have been made in the past, but with those that are about to be made for the future. A vastly expanded Federal Highway Program has been inaugurated. The means for the financing of this program are still tentative. The Congress and students of highway problems are now awaiting completion of studies undertaken by the Bureau of Public Roads. This will represent the third federal study of highway problems, and like the Coordinator's Report, probably will establish a nation-wide pattern for a host of state and local investigations. The concressional request for investigation and research is broad enough to allow for either a benefits-received or pricing approach to highway problems. If one reads between the lines of the First Progress Report of the Bureau of Public

Roads, it is possible to distinguish some disenchantment with the benefits-received approach and a renewed interest in economic efficiency. The decisions now being made will have an important bearing on the possibilities for the attainment of economic efficiency in the highway user tax structure.

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