Toward Rational Road-User Charges

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This paper considers how to set road-user taxes most efficiently within the constraint that user payments must cover road expenditures. The charges levied on different vehicle classes are required to cover at least the maintenance expenditures incurred because of use by those classes. Four policies for determining an extra charge or markup sufficient to balance the budget are evaluated—the vehicle-kilometer proposal, the ton-kilometer proposal, the imputed-gross-revenue proposal, and the inverse-elasticity proposal. For 1969, the vehicle-kilometer proposal suggests the least change from present policy, followed by the ton-kilometer, the imputed-gross-revenue, and the inverse-elasticity proposals respectively. The inverse-elasticity basis suggests especially higher payments from heavy vehicles than were collected. The inverse-elasticity proposal uses estimated responsiveness of demand to price changes to place heavier burdens where the reduction in use would be relatively less. The other three methods refer to various output measures for apportionments of tax burdens among vehicles. On the criterion of efficiency, the proposals are ranked inverse elasticity, imputed gross revenue, ton kilometer, and vehicle kilometer in descending order. However, on the criterion of availability and quality of information required and difficulty of implementation, the proposals are ranked in the opposite order. Consequently, the radical revision in payment structure suggested by the inverse-elasticity proposal should be regarded only as a desirable direction of change. Much more precise analysis would be necessary to suggest a detailed structure for tax revision.

A review of the legislative history of the federal-aid highway program suggests that one of the principal concerns of the U.S. Congress in providing for the financing of the program was with equity. It was deemed desirable that the road system should be paid for by its users and that each particular user should shoulder a fair share of the burden. In practice, the latter requirement was interpreted to mean that each user should pay enough to cover the costs occasioned by his or her use of the highway system. A number of studies were commissioned by Congress and by the U.S. Department of Transportation to measure these costs (1,2,3).

A recent reexamination of these issues has indicated that, for the road program as a whole, these concerns with equity have not been met (4). Payments by road users have fallen short of total road expenditures. For particular classes of users, however, the picture is different. All vehicle classes have paid enough to cover the costs occasioned by their use of the road system, although the difference between costs and payments has varied enormously from one class to another.

Some insight into the nature of this somewhat contradictory result may be gained by pursuing an analogy between the road system and an industry that must simultaneously serve the demands of several classes of customers. The decision that must be made is whether to provide separate facilities for each or to produce for all classes in combination. The crucial factor here is the relative costs of joint versus separate production.

For the road industry, the current cost advantage is strongly on the side of joint production. The road system in this country had its beginning long ago and was already highly developed by the post-World War II period. The length of roadways constructed since that time is very small in relation to what was then in existence. Separate provision for different vehicle classes in, say, 1956 would have entailed large expenditures to build new systems

of adequate coverage and quality. These would have greatly exceeded the payments made by any vehicle class. In the absence of a massive reallocation of tax responsibility, joint production of roads for the several vehicle classes must be considered beneficial to all.

Once the decision is made to produce jointly, the problem of assigning costs to the different classes of customers becomes very difficult. Under these circumstances, it is highly probable that much of the total cost will be common to all classes of users and impossible to assign in any but an arbitrary way.

This appears to be the case for the road system. In the study cited above, attempts were made to assign cost responsibility to various classes of road users. In none of the schemes considered were total occasioned expenditures more than about 25 percent of total program expenditures. The requirement that each vehicle class cover these occasioned expenditures says nothing about how the remaining 75 percent of costs (those that are common) might be met. Answering this question requires the introduction of additional criteria, either implicitly or explicitly.

This paper considers the question of what these criteria should be. Although some historical evidence is examined, the perspective is essentially forward looking. Several possible methods for meeting the requirement that payments match expenditures are considered. These methods suggest ways for revising user-charges policy.

FACTORS IN ROAD PLANNING

A rational scheme of road-user charges must take into account the technology and cost structure for providing road services. As far as possible, one would like information about how such costs are likely to vary with differences in vehicle type and frequency of use. Our investigations disclosed important gaps in knowledge of this relationship.

One major uncertainty concerns the relationship between maintenance and original capital outlay. Thicker pavements are more durable and require less subsequent maintenance. The AASHO Road Test (5,6) provided evidence of a strong relationship between initial construction standards and subsequent rates of pavement deterioration. Pavement strength was found to increase very rapidly with thickness—approximately in proportion to the seventh power (5,6,7). A small increment in its thickness can thus lead to a large increase in the durability of a pavement. From this technical point of view, the trade-off between inputs of maintenance resources and capital appears to favor a high proportion of the latter, at least under conditions of heavy axle loadings.

However, the AASHO tests provided little information about the effect of maintenance policy on pavement durability. Because their object was to test to destruction, very little maintenance was performed. This implied a rate of pavement deterioration faster than would have been experienced had regular and careful maintenance procedures been followed. Hence, we know very little about how maintenance policy influences the rate of pavement deterioration. The possibility of varying the level of maintenance provided affects the choice between initial and future inputs in a way that requires new clarification.

Determining the economic level of original capital inputs relative to maintenance activities is not simply

a matter of the technical relationships between use and wear. The relative prices of initial capital, preventive maintenance, and later reconstruction are also relevant. Regarding this point, we encountered a notable gap in the literature. First, although the AASHO tests have led to a better understanding of the relationship between highway traffic and pavement damage, the relationship between damage and the expenditures to repair it is still not clear. The record does not tell us how much of the money spent on highway maintenance has gone toward repairing damage caused by use versus how much was devoted to making good the different effects of weather, time, and other such factors. There are difficulties even in discriminating between expenditures that had an expansion component and those that did not.

Part of the answer to the question of economical construction standards depends on future trends in the real prices of inputs. Relative to original capital construction, maintenance is labor intensive. There is, of course, potential for increasing labor productivity in each form of activity, but it is clear that the relative labor intensity will remain. If labor becomes more expensive in real terms, maintenance will cost relatively more. How much, how fast, and for what kinds of maintenance and construction are open to questions.

We are thus, by these points, raising the general question of the optimal design of highways. Current road design procedures are based on the assumption of a finite expected lifetime. It is expected that traffic volumes and patterns as well as road service standards will change over time and that, after a number of years, it will usually be necessary to undertake major widening or reconstruction of the road regardless of the condition of the pavement. Given this, it is usually thought that the most efficient design procedure is to build the pavements strong enough, but no stronger than that, to last the required number of years—about 20. An examination of the trade-offs indicated might well lead to different and more variegated design standards. We suspect that, if these economic factors were to be taken explicitly into account and an attempt made to develop designs that minimize the total lifetime cost of the highway, the results would call for thicker pavements requiring less maintenance. This would increase the share of the total road costs that are common to all users.

Design decisions ultimately depend on traffic forecasts as well as cost trade-offs. The nature of the vehicles that use the roads is another question that must be considered. Several studies have emphasized the importance of axle loads in determining the pavement damage caused by a vehicle (5,6,7). A clear implication of this is that such damage can be greatly decreased by reducing the axle loads. Vehicles could be (and indeed are being) modified by the addition of axles to spread masses and reduce loadings for a given vehicle capacity. The effects of the heavy-vehicle fleet on highway pavements could be substantially altered in these ways. Policies to encourage use of vehicles that have better mass-transmission characteristics hold substantial promise as a means of reducing pavement damage and extending the lives of existing roads. These might involve, for example, encouragement of those toll highways that now charge by number of axles to set toll rates on a transmitted-mass basis instead. We could not find any satisfactory exploration of these possibilities despite their obvious relevance to debates about causation of expenditures.

These issues regarding the relationships between vehicle design and pavement damage and between damage and maintenance are all the more important given the changing pattern of highway expenditures. Capital expenditures have been declining as a proportion of total road expenditures since 1963 and in absolute terms since 1968. In contrast, maintenance expenditures have risen steadily for the past 2 decades and, in the period of the 1970s, have come to absorb an increasingly large share of the total road budget. The opinion of highway engineers seems to be that these trends will continue and, if anything, intensify (8). Secretary of Transportation Brock Adams has stated, in a speech to the Annual Meeting of the Highway Users Federation, October 27, 1977, in Washington, D.C., that it is essential that the federal government "start the shift that is necessary toward resurfacing, restoration, and rehabilitation to protect the large investment we have made in our national highway system." If, in fact, maintenance does become an increasing problem, these questions surrounding the determinants of maintenance costs and the ways of minimizing them take on an added significance.

TOWARD A REVISED CHARGING SYSTEM

If capital expenditures are actually declining, it becomes reasonable to consider what can be done, within the constraint imposed by a requirement to raise payments from road users equal to road expenditures, to set prices in such a way as to ensure the best use of the roads. Attention is confined here to the problem of balancing the monetary budget. Nonpecuniary costs such as congestion or pollution are not considered explicitly, primarily because of the difficult problems associated with their empirical measurement, as discussed at length elsewhere (4).

In a context in which the basic decisions about the size and quality of the road system have already been made, the function of prices (or taxes) is to ensure that road-users' decisions about use will be guided by the continuing expenditures made on their behalf. In practice, this means ensuring that charges are at least enough to cover the maintenance expenditures incurred as time goes by. Short-run decisions to use roads continue to be made, and the value to users of these trips should at least be sufficient to cover the value of resources used up by them. So long as this condition is fulfilled, the greater the output of road services, the better. Thus, as a first principle, the charging system should maximize the output by the various classes of road users while covering those short-run variable expenditures clearly occasioned by them.

These short-run variable costs of road use consist principally of expenditures for pavement and shoulder maintenance. As we have observed, there are gaps in our knowledge that make it difficult to determine exactly how these costs should be assigned. The problem of determining these costs associated with road use is important enough to warrant further attention but, in the meantime, one must proceed on the basis of such knowledge as is available. At present, the most appropriate basis for determining these costs is the frequency of application of various axle loadings because this, as we have seen, governs the rate of pavement deterioration.

These costs fall short even of the noncommon [that is, the small proportion of capital costs that were estimated to be occasioned by various vehicle classes (4)] costs that can be attributed to particular user classes. Thus, setting user charges equal to short-run variable costs provides even less of a solution to the problem of how to finance the road system than does the criterion of equity. What should be done if the constraint to raise enough revenues from users to equal total road expenditures is imposed? The problem becomes one of ensuring that the money is raised with the least reduction in road use. Any charge (tax) in addition to the charge for maintenance will reduce this output. We wish to minimize these losses.

A theoretical solution to this problem results in

what economists term the inverse-elasticity rule (9, 10,11,12) (proposal A). This formula states that the price charged to each class of user should be marked up from short-run marginal costs in proportion to the inverse of the price elasticity of demand of that class. In essence, this amounts to charging whatever the traffic will bear. Vehicle classes that have extremely inelastic demands are charged quite heavily, and other classes are made to carry a much lighter burden so that they are not priced off the road.

Theoretically, this scheme is very appealing, because it is derived from a straightforward application of the aim stated above. However, there may well be practical snags in applying it that imply that it is not necessarily the dominant solution. Beyond theoretical considerations, it is also necessary to consider the accuracy of the information on which the extra charge or markup is based; the practicality of the whole scheme and its likely cost to operate as a system; and (not least) how far it will be seen to be fair by the users, which depends primarily on how radical a departure from current methods of raising road taxes is implied. For these reasons, we shall also appraise three other possible reforms of the current methods. The possibilities are

1. Proposal B: charging in proportion to vehicle kilometers traveled,
2. Proposal C: charging in proportion to gross ton kilometers carried, and
3. Proposal D: charging in proportion to the imputed gross revenue each vehicle class generates.

The first two proposals are based on simple output measures. They are included because of their simplicity and because they have in the past been proposed as methods for determining user-charge levels. The third represents an attempt to base charges in an approximate way on benefits received.

A proposed change in any tax system must consider the difference made to activities by the proposed reform. It is important, then, to fix at least the approximate incidence of the several possibilities on vehicle classes and to see what magnitude of changes in behavior are implied. To do this, it is convenient to focus on 1969, a recent year for which relatively complete data are available.

Payments and expenditures are computed for two breakdowns of vehicle class. In the first, light vehicles (automobiles and two-axle, four-tire trucks) are compared with all others. In the second, heavy vehicles [semitrailer and full-trailer combinations that have registered gross masses exceeding 27 000 kg (50 000 lbs)] are compared with light- and medium-mass vehicles. User-charge payments for these classes are taken from the estimates developed by Bhatt and others (7) and shown in Table 1. Pavement and shoulder maintenance and resurfacing expenditures are taken as the short-run variable costs of running the roads that we require each class to cover. These are assumed to be equal to short-run marginal costs and are allocated to the vehicle classes in proportion to relative amounts of pavement damage, as measured by the equivalent-axle-kilometer method described by Bhatt and others (7). The results are shown in Table 2.

The present concern is to fix the total payments implied by the various proposals. Accordingly, short-run variable costs are assigned to the appropriate classes. The remaining expenditures are then allocated to the vehicle classes in four ways, corresponding to the four charge schemes, according to the methodologies described by Bhatt and others (4).

For the vehicle-kilometer and ton-kilometer allocations, this involves a fairly straightforward application of readily available data. The other two allocations are based on much cruder information. The imputed gross revenue calculation uses estimates of revenue per passenger kilometer and per ton kilometer derived from intercity bus and common-carrier freight data. The inverse-elasticity estimates depend on estimated values of the price elasticity of demand for fuel by various classes of users. The results of these calculations are shown in Table 3, and the details of the methodology used are described by Bhatt and others (4).

Table 4 compares the apportioned expenditures given in Table 3 with the estimated total payments given in Table 1. From Table 4, it can be seen that, for all roads and the main divisions, rural and urban, the respective proposals imply an increasingly radical departure from actual payments. The vehicle-kilometer basis is least radical, and the inverse-elasticity basis is by far the most radical. This holds true whatever the combination of vehicle classes selected. The direction of change is toward charging heavier vehicles more than they have paid, except for the vehicle-kilometer basis, where little difference from present payments is implied. The inverse-elasticity basis suggests especially higher payments from heavy vehicles than were actually collected. Taking the most notable changes within each proposal, we find the following highlights:

1. For the vehicle-kilometer proposal, the relief for light vehicles on secondary urban roads and the very much increased charges for heavy vehicles on other rural roads;
2. For the ton-kilometer proposal, the similar relief for light vehicles on secondary urban roads and the increased charges for heavy vehicles on other rural roads;
3. For the imputed gross-revenue proposal, the decreased charges for light vehicles on Interstate rural roads and the increased charges for heavy vehicles (again) on other rural roads; and
4. For the inverse-elasticity proposal, the relief for light vehicles on the Interstate system (both rural and urban) and the increased charges for heavy vehicles (yet again) on other rural roads.

To get an indication of how the relationships between these proposals and existing payments have changed over time, user-charge payments under the various schemes were calculated for several different years. Data permit only rough comparison between payments and apportioned expenditures; however, the analysis indicates that the degree of change implied by the proposals has decreased over time (4). This is especially true of the inverse-elasticity proposal, where, for both the heavy and the medium plus heavy classes, the ratio of apportioned expenditures to actual payments decreased markedly. This was due to both a decrease in apportioned expenditures and an increase in actual payments.

EVALUATION OF POSSIBLE CHANGES IN
PAYMENT REQUIREMENTS

The first criterion suggested for comparing the approaches was the relative impact of each on the use of the road by the different vehicle classes. Only one of the approaches--the inverse-elasticity rule--is explicitly designed to encourage optimal patterns of use. As noted above, in this case, the estimated responsiveness of demand to price changes is used to place heavier burdens where the loss of benefits is relatively least (in economic parlance, where the elasticity of demand for trips is lowest). In this case, the markup above cost is proportional to the inverse of the own-price elasticity of demand for road use by each vehicle class. The other three approaches are alternative methods of taxing the activ-

ities of the various vehicle classes, but refer only to various output measures. The relative sizes of output as determined by the three measurements—vehicle kilometers of travel, gross ton kilometers hauled, or total (imputed) revenue—determine the apportionment of payments above short-run marginal costs among vehicle classes. Because the inverse-elasticity rule takes the likely loss of benefits into account, we can regard this rule as a benchmark. There emerges a clear ranking of the approaches on this criterion. The inverse-elasticity approach is, by definition, superior, and the others are, in ascending order, the vehicle-kilometer, ton-kilometer, and imputed-gross-revenue approaches, which is closest to the benchmark.

Each approach, however, has relatively better features for some of the different types of roads than does the present payment scheme. For example, an outstanding common feature relative to the existing payment scheme was the indicated increased charge for heavy vehicles on other rural roads.

Of course, conclusions about the approaches depend heavily on the way in which levels of user charges are estimated. The second criterion for judging these schemes is, therefore, the quality of information on which proposed changes are made. In all cases, information is relatively sparse, although its quality and quantity vary from one to another. The inverse-elasticity method uses values derived from estimates

Table 1. Payments by user class and type of road: 1969.

	Payments ($ millions, current prices)			
Type of Road	Light Vehicles	Medium and Heavy Vehicles	Light and Medium Vehicles	Heavy Vehicles
Federal aid				
Interstate rural	1 075	889	1 476	488
Interstate urban	1 002	408	1 231	179
Primary rural	2 002	1045	2 535	512
Primary urban	1 718	424	1 993	149
Secondary rural	1 352	595	1 798	149
Secondary urban	665	141	771	35
Nonfederal aid				
Rural	1 087	421	1 438	70
Urban	3 567	664	4 120	111
All rural	5 516	2950	7 247	1219
All urban	6 952	1637	8 115	474
Total	12 468	4587	15 362	1693

Table 2. Short-run variable costs by vehicle class.

	Expenditures ($ millions, current prices)			
Type of Road	Light and Medium Vehicles	Heavy Vehicles	Light Vehicles	Medium and Heavy Vehicles
Federal aid				
Interstate rural	12	63	2	73
Interstate urban	7	22	0	29
Primary rural	80	247	3	324
Primary urban	31	39	2	68
Secondary rural	277	377	13	641
Secondary urban	16	19	1	34
Nonfederal aid				
Rural	465	335	24	776
Urban	289	196	20	465
All rural	834	1022	42	1814
All urban	343	276	23	596
Total	1177	1298	65	2410

Table 3. Apportioned expenditures by vehicle class and proposal: 1969.

	Expenditures ($ millions, current prices)															
	Light Vehicles				Medium and Heavy Vehicles				Light and Medium Vehicles				Heavy Vehicles			
Type of Road	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Interstate rural	4	1 749	670	350	2 138	393	1472	1 792	21	1 884	960	610	2 121	258	1182	1532
Interstate urban	0	1 841	1086	651	2 032	191	946	1 381	12	1 942	1 406	1 019	2 018	90	626	1013
Primary rural	6	2 085	1073	571	2 660	581	1593	2 095	135	2 303	1 573	1 111	2 531	363	1093	1555
Primary urban	4	1 313	932	617	1 468	159	540	855	54	1 407	1 182	953	1 418	290	519	519
Secondary rural	25	1 975	1330	777	2 806	856	1501	2 054	440	2 409	2 071	1 769	2 391	422	760	1062
Secondary urban	2	356	274	207	409	55	137	204	30	388	349	329	381	23	62	82
Other rural	45	2 025	1528	1009	2 953	973	1470	1 989	810	2 636	2 453	2 324	2 188	362	545	674
Other urban	32	2 382	1993	1445	2 945	595	984	1 532	674	2 765	2 617	2 464	2 363	212	366	573
All rural	80	7 834	4601	2707	10 557	2803	6036	7 930	1406	9 232	7 057	5 814	9 231	1405	3582	4823
All urban	38	5 892	4285	2920	6 854	1000	2607	3 972	770	6 502	5 554	4 705	6 120	390	1338	2187
Total	118	13 726	8886	5627	17 411	3803	8643	11 902	2176	15 734	12 611	10 519	15 351	1795	4920	7010

Note: A = inverse-elasticity proposal; B = vehicle-kilometer proposal; C = ton-kilometer proposal; and D = imputed-gross-revenue proposal.

Table 4. Apportioned expenditures as a percentage of payments by vehicle class and proposal: 1969.

	Expenditures (percentage by class)															
	Light Vehicles				Medium and Heavy Vehicles				Light and Medium Vehicles				Heavy Vehicles			
Type of Road	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Interstate rural	0	163	62	33	240	44	166	202	1	128	65	41	435	53	242	314
Interstate urban	0	184	108	65	498	47	232	338	1	158	114	83	1127	50	350	566
Primary rural	0	104	54	29	255	56	152	200	5	91	62	44	494	71	213	304
Primary urban	0	76	54	36	346	38	127	202	3	71	59	48	952	44	195	348
Secondary rural	2	146	98	57	472	144	252	345	24	134	115	98	1605	283	510	713
Secondary urban	0	54	41	31	290	39	97	145	4	49	45	43	1089	66	177	234
Other rural	4	186	141	93	701	231	349	472	56	183	171	162	3126	517	779	963
Other urban	1	67	56	41	444	90	148	231	16	67	64	58	2075	191	324	516
All rural	1	142	83	49	358	95	205	269	19	127	97	80	757	115	294	396
All urban	1	89	62	44	419	61	159	243	9	80	68	58	1291	82	282	461
Total	1	110	71	45	380	83	188	259	14	102	82	68	907	106	291	414

Note: A = inverse-elasticity proposal; B = vehicle-kilometer proposal; C = ton-kilometer proposal; and D = imputed-gross-revenue proposal.

of short-run price elasticities of demand for gasoline and diesel fuel by trucks and for gasoline by automobiles (13). It was assumed that such elasticities would be the same for any change in input costs and that the reaction to any tax change could therefore be computed from these elasticity estimates. But their use in this context clearly involves extrapolation. Considerable aggregation was also necessary. Values for gasoline-powered and diesel-powered trucks had to be combined. Light trucks were assumed to be like automobiles and buses like trucks. The only variability over road types was due to different proportions of gasoline-powered and diesel-powered heavy vehicles, because elasticity estimates for gasoline and diesel trucks differed substantially. The elasticity measures aggregate over market conditions; for example, surely the elasticity of demand for use of some road types by heavy trucks would be considerably lower than for others. It is also clear that, given price changes of this magnitude, elasticities will change as adjustments to new price levels proceed. The effect of this among vehicle classes is unknown, yet it is relevant to policy because a move to a new taxation system has a long-lasting effect.

Presumably these estimates could be refined through the use of more precise elasticity estimates and a more appropriate disaggregation of markets. The analytical requirements would be substantial, however. This charge scheme remains very information intensive.

The vehicle-kilometer data are relatively the simplest to measure and quite easily predictable. Gross ton kilometers are somewhat more difficult to estimate because of variations in loadings. In this scheme, passengers are treated in the same way as freight. The imputed-gross-revenue apportionment was derived for passenger vehicles from the average revenue per intercity bus passenger kilometer traveled by applying this figure to all passenger travel. Values for freight were similarly derived from freight revenue divided by ton-kilometers carried, converted to a vehicle-kilometer basis, and extrapolated to private freight carriage. Thus, the estimates of imputed gross revenues are again based on few observations and much averaging.

In terms of the information criteria, we find the ranking of the charging schemes reversed. The more radical the proposal, the less secure is the information that it requires. Regarding the practicality and cost of operating the different proposed schemes, it is worth noting that the means of payment can only be approximately accurate. A vehicle-kilometer base can be reflected, reasonably but not entirely, by a fuel or a tire tax. Further accuracy would require monitoring odometer readings and would considerably increase the costs of collection and enforcement. A ton-kilometer base brings in the extra dimensions of goods carried and amount of empty running. New effort would be required to measure these factors. An imputed-gross-revenue base would imply collection of data on revenue earned as well as information on private carriage for which no revenue is generated. It would be difficult to devise a base applicable to both types of operation. The information base for the inverse-elasticity method appears formidable indeed. Much more study of activity at a disaggregate level would appear necessary to establish reasonably accurate elasticity estimates by road type and vehicle class.

Common to all policies under consideration is the need for a more complete methodology for the attribution of variable expenditures among vehicle classes and road types. The assumption of year-by-year proportionality between pavement damage, as estimated by axle loadings, and short-run variable expenditures deserves much closer scrutiny than it has, to our

knowledge, been given. Individual road segments are not on maintenance schedules that guarantee that damage caused in a given year is repaired that year. But no information is available on the nature of the lag structures involved. Furthermore, our research has not considered differences due to frost damage, nor have we been able to find information on road deterioration due to time and weather alone, independent of axle loadings. Thus, more precise relationships between road damage and pavement and shoulder maintenance expenditures would be needed to develop more precise proposals regarding vehicle classes and road types than the aggregations considered in this paper.

Individual road-user classes cannot be required to pay for all the resources they use because the amount is indeterminate. The joint production of road services makes any determination of appropriate payments by vehicle class somewhat arbitrary. Under the constraint that payments equal expenditures for the totality of all classes, the inverse-elasticity rule emerges as the most efficient way to tax vehicle classes. Our calculations for this rule using the aggregate data available resulted in an apportionment of nearly 90 percent of program expenditures to heavy vehicles. This result could not be implemented for a variety of reasons.

First, the magnitude of these payments would be such that heavy vehicles would either be redesigned or withdrawn from most or all of the road system. Surely much of the existing road system is not especially valuable for heavy vehicle use. It is very likely that operators of heavy vehicles would confine themselves to portions of the road system rather than bear this massive increase in tax burden. Second, the estimates of short-run variable expenditures by different vehicle classes and the elasticities of demand for vehicle classes are nothing more than crude averages applied across the board to different circumstances. Consequently, it seems wise to regard the payment structure suggested by the inverse-elasticity proposal as only an indication of a desirable direction of change that points to higher payments for heavier vehicles.

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Concepts, Principles, and Objectives of Economic Analysis Applicable to Traffic Accidents

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In the many years that cost-benefit analysis has been used as a management tool for decision making between different alternatives for highway improvements, a penetrating study has never been made of the factors of personal injury and fatality accidents as they relate to economy of transportation. Specifically, the economic gains and losses related to wage and salary incomes foregone because of lost work time (including death) have never been determined. This paper sets forth concepts, theories, and principles that can serve as guides in the search for dollar amounts to represent consequences of highway improvements that impinge on traffic accidents. Descriptions of 32 main consequences are given that indicate the role of each and how it could be priced for input to the cost-benefit analysis. It is proposed that these factors and others should be studied in depth by professionals from the several disciplines involved.

PREFACE

In past discussions, I have had difficulty in getting others to understand my position. It may be difficult for some persons to distinguish between making an analysis of the transportation economy of alternative investments in highway improvements and in pricing traffic accidents for other purposes or for viewpoints other than that of the economic community as a whole. In the evaluation of this paper, the differences in these two concepts must be kept in mind.

This paper takes the position that the analysis for the economy of highway transportation investments should (a) evaluate all economic factors in market dollars; (b) include all economic consequences that can be market priced and exclude economic factors that cannot be market priced; (c) exclude all factors that are not related to the conservation of resources; and (d) price highway costs, motor-vehicle costs, and accident costs in economic cost dollars and not in value dollars.

The ultimate decision maker can accord such weight to the humanitarian factors as he or she believes just and right. For calculating a benefit-cost ratio or a rate of return, however, that includes highway and motor-vehicle costs, traffic-accident costs must likewise be expressed in market price dollars that relate to economic conservation of resources.

SETTING AND SITUATION

It is encouraging to find increased use of economic analysis, or cost-benefit analysis, as a means of calculating the relative index to the transportation economy that exists between any pair of alternatives for the investment of capital in a highway improvement (whether for construction, reconstruction, or alteration of the highway structure) and traffic facilities.

There is agreement that the procedure of analysis should involve the economic costs of fatal traffic accidents; in fact, some new highway and motor-vehicle investments have had as their major objective the reduction in the number, cost, and rate of accidents that result in human death. The factor of accidents has brought new discussions, new literature, and new analysis to bear on the dollar cost of a traffic fatality. However, some of the dollar sums arrived at as costs are actually values that have been calculated without proper attention to the principles of economic analysis, the application of the results, or the role of economic analysis in the decision process.

The capital-investment analysis of any proposed highway improvement that involves the factor of fatal traffic accidents is, in reality, no different than the analysis of a proposed project that does not involve consideration of traffic fatalities. But many persons consider such a proposal to be different because of the human, emotional, and social implications. Although a fatal accident is different from a nonfatal accident because of these human and social factors, it remains equally true that the concept, principles, and theories of economic analysis do not differ. A change in concept can be injected into the analysis without changing the basic set of principles. The one significant change needed is that of separating the emotional and social factors from the highway costs, the motor-vehicle costs, and nonfatal accidents. In substance, this concept restricts the main cost-benefit analysis to strictly market-based economic-resource factors and sets aside the social and human factors for a cost-effectiveness analysis, or no analysis at all other than to be considered by the decision maker along with the other irreducible factors.