A New Approach to the Evaluation and Construction of Highway User Charges

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I. *Principles of Highway Finance*

I.1. *Introduction*

The argument has been made many times and on many grounds that road users need not pay for the full expenditure on roads—indeed that efficiency requires otherwise. This reasoning has sometimes been applied to total expenditure for all users, and sometimes to the cost shares imputed to individual user classes or sub-classes, where cost shares are taken to be proportional to vehicle-miles or ton-miles. (In this paper the word "proportional," unless qualified, will always be used in this sense.) In what follows, I will attempt to develop the principles for efficient user charge policy by analyzing the traditional arguments for less-than-full cost pricing. These can be classified under six headings: 1) income distribution, which would be directly frustrated by seeking full cost recovery; 2) national security; 3) declining average cost of highways, in which case a subsidy is required from society as a whole; 4) the joint nature of the highway facility, requiring disproportionately large contributions from automobile users; 5) the inability, because of the prohibitively high costs, of discriminating among users, creating externalities in land rents which can subsequently be tapped for road contributions; and 6) timing—road investment is made to-day, but the road lasts a long time. Analysis of these arguments will show that the ton-mile share or vehicle-mile share approach for the road as a whole for most components will indeed be inefficient, since ton- or vehicle-miles do not reflect either the road cost structure or the demand patterns of the user classes. On the other hand, it will be possible to define principles for the allocation of most of the expenditure components and to allocate them according to discernible cost and demand relationships. These will be called "true cost shares."

Part II of the paper applies the principles developed in Part I to analyze the Yugoslav user charge and highway financing structure.

I.2. *Income Distribution*

Many income distribution goals can be handled through the road sector. The most obvious example in developed countries is the complementarity to school provision in rural areas, permitting the next generation an income advantage over what it would otherwise be given. In underdeveloped countries, or in low per capita income regions of advanced economies, income distribution aims are more direct. Here, road construction can enable the generation to grow an exportable surplus which could not itself cover the cost of a road over its lifetime. A government may wish to pursue such a policy in preference to resettlement and retraining. In these two cases, the part of the road program in question should be isolated for separate support from the central budget. In North America, many writers handle school support income distribution by deducting some percentage, e.g. 30 percent, from the cost of the secondary or rural road system. The second case can be allowed for simply by leaving out of the road account to be charged to road users in general those expenditures which are known to relate to poor areas.

I.3. *National Security*

A road network permits more rapid military mobilization, and indeed, some networks, such as the prewar German autobahn network, were built with little else in view. Therefore, it is argued, road construction costs should be recovered at least in part from society at large since the entire population benefits. But there is another alternative, which is to price all users, including the military, according to the same standard principles, as students of public finance have frequently urged.[1] In this way, the public can know better what it is spending for security and reach more intelligent budget decisions through the polls.

I.4. *Declining Cost on Uncongested Roads*

This justification is undoubtedly the one most often invoked by economists for general public sector support of the roads. According to one recent statement of the problem,[2] marginal cost is taken to be the same as incremental maintenance cost, with the annual "fixed" maintenance cost (see below), as well as the construction cost, coming out of general budget. Even within the framework of a single road, I believe that the answer cannot be so straightforward and in reality two cases must be distinguished: (a) a road already built, where sunk costs need not be recovered, and (b) a new road where the incremental or marginal cost to society is the cost of building the road, in which case the price to the users in the area should reflect this cost. Now a single road, by definition, stands alone i.e., it is not part of a network. Therefore, full or nearly full cost recovery in case (b) is possible through a two-part tariff structure for the users, who can be isolated (they *are* isolated!), and no inefficiency need result. Moreover, the single road declining cost model fails to take account of the external costs which occur when increasingly sophisticated highway engineering design denies the opportunities for budget allocations to altogether different sectors of the economy.[3]

In any event, the single road framework cannot be readily generalized to include a growing network and dynamic and heterogeneous traffic patterns. What is marginal cost in the network framework? The cost of an additional ton-mile per year? The cost of allowing larger trucks to use the present network (which may or may not involve higher ton-mileage)? The cost of improving the network to allow larger trucks to use the network? The cost of building a new link on arc AC in a network? The cost of allowing an

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[1] See e.g. O. H. Brownlee and W. H. Heller, "Highway Development and Financing," *American Economic Review*, May 1956, p. 236.

[2] Alan Walters, *The Economics of Road User Charges*, John Hopkins University Press—IBRD, 1968.

[3] See my "Theory of Multi-Product Output and Pricing Under Joint Costs and Variable Technology," *Journal of Political Economy*, July/August 1970, for an attempt to incorporate this aspect of highway cost.

extra automobile to travel on the existing network? Etc.? Output then, has no simple definition.[4] It follows, then, that the marginal cost of output is an extremely ambiguous concept and the invocation of marginal cost-price equalization gives the spurious impression that agreement on what *should* be done can easily be reached, once we are given the accounts of any particular highway authority.[5]

Although the marginal cost-pricing rule cannot be applied to a network since marginal cost is an indefinable category in the highway network context, we can realize the spirit of marginal cost-price equalization. The marginal cost-price dictum is based on the notion that output should be increased as long as the extra cost imposed on society is less than the utility which some member of society (and, therefore, society) receives from consumption of one more unit. In the next section we will argue that each incremental component of a highway technology, such as the reduction in maximum grade from eight percent to five percent, should be paid for by all the user groups according to their demand for that component and not just by the vehicle classes whose expected use of the network prompts the move to the more stringent standards in the first place, and that, correspondingly, maximum grade should be reduced as long as the benefit arising in grade reduction exceeds the cost of reduction. If a budget constraint is imposed, the highway authority can discriminate among users to recover either all of this cost, or, if perfect discrimination is not possible, a good deal more of it, at least, than would be possible through proportional pricing. If complete recovery is not possible, it will be argued in Section I.6, the shortfall should be borne by local sources.

I.5. *The Joint Nature of the Network Components*

Many writers and interest groups have argued that the road network is a joint product which should be priced according to demand elasticities of the various user classes. Thus, this is an argument for more- or less-than-proportional cost imputation to individual user classes and need not imply advocacy of less-than-full cost pricing for the facility or network as a whole. The argument is valid as it applies to those portions of the project which are fixed, such as land acquisition, basic grading, etc. This rule can even apply to some portions of the investment which are nominally undertaken for certain classes of traffic only; for example, low maximum grades may be imposed by engineering rules in recognition of the heavy traffic expected, but cars do, in fact, also benefit and a greater social benefit

[4] Of course, there are also many marginal costs in the single road framework as well, but as suggested, this problem can be resolved by a discriminating monopolist using a two-part tariff with variation of each part according to different use dimensions.

[5] Indeed, even following the same approach and using essentially the same accounting information, it is possible to reach very different recommendations on the level of marginal cost and the actual price to charge. Walters for example, estimates the annual fixed maintenance cost as the intercept in a linear regression in which expenditure is taken as a function of average daily traffic (ADT). (*op. cit.*, pp. 194–199.) Suppose, instead, one went behind the annual data to the original field accounts. Maintenance on any road would actually be performed in one or a few months (if it were performed continuously throughout the year one could hardly speak of a fixed annual component). Suppose, for simplicity, that maintenance on any road in the network is all performed in a single month. On each road, there will then be one positive expenditure observation and 11 zero expenditure observations (with traffic fluctuating seasonally and stochastically about the annual ADT for that road.) A regression line fitted to these observations would then have a slope which would almost surely not differ significantly from zero, a very low correlation coefficient, and a fixed monthly maintenance expenditure (*Y* incercept) somewhat greater than one-twelfth of that in the first regression. In this case we would have to conclude that the marginal cost of the highway network was zero. Obviously, however, this fluke arises simply through reorganization of the data and can say nothing about the underlying technological or economic relationships.

can usually be achieved by discriminatory pricing of such components of the project.

The definition of the components of the project which should be treated in this manner itself varies. In the mountains of Slovenia, a one-meter sub-base may be required to offset the effects of ground freezing to provide *any* good paved-surface road, and discriminatory pricing may be efficient for this base, while elsewhere the sub-base relates primarily to the expected load. Evidently no absolute classification of components can be given. *A guideline is that any part of the road should be considered a joint component for those user groups whose demand for those components is positive.*[6]

The pricing of the part of the project which is variable—the pavement depth and design, for example, must be priced to the user groups according to the cost imposed.[7] Here the basic relationship, which was analyzed under controlled conditions most exhaustively by the AASHO road test, shows increasingly severe damage per ton-mile with increasing weight;[8] the burden imposed, as measured by the number of repetitions to achieve a given unserviceability level in most situations, rises up to twenty times when doubling the axle load from 5 to 10 tons. (The precise relationship depends on type of pavement and number of axles.) The relationship is, of course, difficult to determine by observations of actual everyday situations owing to the great variability of climate, traffic mix, and road type.

I.6. *Inability to Discriminate*

Inability to discriminate among users is another frequent justification for less-than-full cost pricing. Thus, even if the relationship between vehicle damage and weight can be determined, in practice it is very costly to try

[6] This approach does not even rule out the possibility that automobiles may, quite rationally, appear to be paying for part of the incremental specifications of the pavement and sub-base required to support heavy trucks. Suppose that heavy trucks represent a net addition to traffic, rather than a consolidation of smaller loads, and that they would not have appeared without the higher specifications. Assume that there are two road designs called "sophisticated" and "elementary", and that the latter represents an indivisible minimum road required by the car and small truck traffic. The sophisticated technology represents increments to the design. In this case the heavy-truck demand for the fixed components of the elementary road will be zero, but the demand for the same components when the road design is increased to the sophisticated version, will be positive. In this case, the small traffic would be willing to pay some part of the incremental design in order to shift the big truck demand curve for the elementary road fixed components. For example, if small vehicles contributed $1,000,000 to the incremental specifications, the big truck traffic demand for the elementary fixed road components would shift and the big trucks might now be willing to contribute $1,500,000 for the elementary road fixed components. But a moment's reflection will show that this is all consistent with what has been said about discrimination based on elasticities, rather than use shares. The problem of empirical determination of the demand functions remains. In practice, however, the heavy truck demand most probably will represent a consolidation of smaller loads, except in countries where cars and very small trucks comprise the total traffic, due to strict administrative controls on trucking. In such countries, relaxation of these controls would probably see immediate shifts from rail to road of large volumes which are suitable for large trucks. In the general case, therefore, there would be positive demand for all the fixed components of the elementary road by the potential large truck traffic. Moreover roads are not so neatly classified into elementary and sophisticated; rather than the single basic indivisible road hypothesized here, there would be a wide range of designs varying with traffic density and vehicle size even for smaller vehicles.

[7] An exception which may or may not be consequential, depending on the traffic mix, arises in the fact that construction of deeper pavements and encouraging larger vehicles, will permit consolidation of some traffic, reducing the number of vehicles, and probably speeding traffic flows. To the extent that this is important, it should be discriminatorily priced.

[8] *AASHO Road Test, Proceedings*, 1962, pp. 415–425. The AASHO test is undoubtedly the most extensive controlled experiment to determine the relation between pavement deterioration and road traffic. Different rigid and flexible pavement designs were subjected to repetitions of different vehicle size and design to derive road performance curves, relating traffic to terminal serviceability.

to charge each vehicle precisely on the basis of this relationship. Constant supervision would be necessary, assisted by scales, toll booths, and limited access roads, all of which impose costs in terms of personnel, capital and driver and vehicle delay. Even to charge each vehicle on the basis of its average load (to allow for partial returns) would be difficult, since this would require that a use charge be keyed to each specific vehicle, or, if a grosser tax is accepted, to each vehicle class. Some price-cost deviations begin to intrude even at this point, although even this would be too costly to administer. On the other hand, an annual tax by itself would have the effect of encouraging heavier utilization and cause distortions. Ultimately, therefore, one accepts the notion of a fuel tax coupled with an annual fee as a tax structure which does not impose too high collection costs, and which could follow the basic cost patterns of vehicle use, the fuel tax proportional to the mileage of any given vehicle class, and the license fee proportional to size. Since, moreover, vehicle size and annual mileage tend to increase together, this combination of taxes could yield a rising user charge revenue per ton-mile. However, in imposing such a combination of taxes, it may occur that units of some kinds of traffic will be unable to pay the price demanded by the average relationships for that traffic. For example, if a high annual fee for large trucks is based on an assumed 100,000 kilometer annual run, it could not be paid by a truck driving 50,000 milometers a year. To charge the higher rate would force some of the traffic out and might reduce the benefit substantially. To allow for this, the unit charge may have to be lower than the average true truck related cost for the class in question; for other truck classes, e.g. small trucks carrying valuable cargoes which benefit through reduced congestion on higher grade roads, the price may be higher, i.e., it may be efficient to allocate some of the true truck related cost share discriminatorily among the truck classes. For some large truck users—especially in minerals and building materials—the user charge will be almost equal to the benefit originating in the traffic, while for others—some farmers, manufacturers, and marketing organizations—external benefits will develop, i.e., they would be willing to pay more than the price being charged them directly for their use of the road and in the absence of the higher prices, their incomes are higher. Part of this externality could be tapped to close the revenue gap through voluntary or compulsory contributions which can be imposed by the abutting communities in which the external beneficiaries live. This argues, then, for local rather than centralized supplementary contributions.

I.7. *Timing*

A sixth justification offered in support of less-than-full cost user charges is the question of timing. The facility will last for many years. Why should it be paid for in a single year?

Evidently, this argument applies to the question of annual expenditure, not cost, i.e., a proponent of this view could agree that users should pay their true cost shares (where cost is the investment expenditure transferred into an annual amortization stream, plus annual maintenance, evaluated in terms of variable and joint component principles presented here, rather than their share of the investment expenditure as it occurs). This could be acceptable, if a way could be devised to generate the revenues in later years. Apart from toll roads, I know of no case where such a financing policy has been implemented, and popular attitudes regarding road investments are so "sunk-cost" oriented that it is very difficult to imagine that the sector would ever organize itself to repay such loans.

There is, on the other hand, one persuasive argument that justifies the current investment expenditure as the target revenue to be recovered from users. Consider the following.

When the investment is used to expand the existing network through the construction of parallel roads on congested links, realignment or grade amelioration, or additions of lanes, users on the entire network benefit. There will be benefits to users on the network who are not using the new road itself since some of the traffic will divert to the new or improved link (or, at least, traffic will not increase as fast on the unmodified links). The benefit can be assumed to decrease with distance from the expanded segment.

Owing to transaction costs, the pricing mechanism is necessarily somewhat gross, as discussed earlier, and it is impossible to price precisely according to the demands on the various segments of the network (although some approximation to it is possible through regional differentiation of fuel and registration tax rates). All users on the network will therefore contribute towards the construction of the new facility. This should create no problem since in some future year, even if not immediately, the user of today's old road will have a new road that he can use, paid for in part by the tax contributions of the trucker who is the immediate beneficiary of the road being built today. In other words, we can imagine "loans" within the highway sector, from users in one area to those in another, both in a fairly homogenous region, as the road program develops. This, of course, is a very different situation from a penetration road policy where roads are built by fuel tax transfers from local areas to regions far removed, or a policy of general budget support of penetration roads, such as the situation in Brazil several years ago which had a very large road program at the federation level with a large mileage of penetration or "development" roads. It is also very different from the US interstate highway system where a large part of the financing of high grade roads originates in a non-related use—fuel consumed in cities.[9]

To approach pricing in the manner just described does not guarantee that the current expenditure will be covered—the "intra-network loans" which are related to the demand of user groups for roads should cover cost shares over time (if they do not, the road should not have been built) but not necessarily the expenditure in each year. Whether they do or not depends on the size of the annual program in relation to the network and to demand factors. If the expenditure is small, it will probably be covered; if it is large, it may not be. In Yugoslavia, this network modification is relatively small: the present road network is around 25,000 paved kilometers. The investment program (modernization, reconstruction and new construction) will be around 2,000 kilometers a year, of which probably no more than 300 kilometers will be completely new construction (and much or most of that parallel to existing roads, i.e. there will be little in the way of penetration roads). If the network is growing much faster in individual regions, the existence of administrative sub-divisions allows for some user charge variation.

The subsidy could, in principle, come from anywhere. However, this presupposes a level of skill in project evaluation far beyond what is possible with present techniques; in spite of the recent advances in project appraisal, many problems remain in the comparison of e.g. an irrigation project in Macedonia, an aluminum plant in Serbia, or a road project in Slovenia. One of the problems is the irreconciliability of the benefit measures which are usually employed—a consumer surplus measure in a road investment versus national in-

[9] In an attempt to incorporate other non-related tax revenues, the US highway lobby in 1971 tried to get Congress to earmark a portion of the alcoholic beverage tax. The Senate approved the Bill, which was later killed in joint House-Senate Conference. ("Light in the Tunnel", *N.Y. Times* 12/20/71, p. 31.

come generation in an export industry. To put the latter on an equivalent basis would require that a labor supply or disutility function for the new employment be introduced into the calculation. Moreover, even comparison between two roads may rely on different criteria since penetration roads are usually evaluated in terms of national income generation.

Finally, discrepancies arise in the comparison of consumer surplus measures between full-employment and unemployment regions. While this problem is generally acknowledged, lack of consensus on how to deal with it in practice raises serious doubts about the ability of a central planning board to allocate investment interregionally. Coupled with the frailty of intersectoral comparisons, this suggests that local jurisdictions are in the best situation to assess their investment needs since they can draw upon non-market ballot box information from the local constituency, whereas this information could be transferred to the central planning board only with considerable accompanying noise.

I.8. *Summary of Principles*

Before evaluating the Yugoslav user charge structure, it will be useful to summarize the principles which have been elaborated.

1. Support for roads from outside the road sector may be based on income distribution considerations. In this case no attempt is made to recover the expenditure from users or beneficiaries. Ideally, such transfers should be made from the general national budget to the poor region in question for subsequent efficiency-evaluated allocation within the poor region. They should not emanate from a national earmarked road fund. Such road projects should be isolated from the road program itself (hereafter called simply the road program).

2. A joint component is a component for which several classes have a positive demand. This is a general classificatory criterion which will have very different implications in actual application as we showed by the following examples:

   i) It is most probable that the incremental design specifications associated with heavy vehicle classes, e.g., low maximum grades, will have joint demand, since the lighter vehicles will also benefit through their execution;

   ii) It is possible for a component to be joint in some geophysical situations while size-variable in others (e.g., the sub-base);

   iii) It is even conceivable that the basic road, which is usually a joint component for all the traffic classes, can be a non-joint component demanded exclusively by cars if the heavy truck traffic which requires incremental design specifications represents new shipments (e.g., transfers from railroads) rather than consolidation of existing shipments.

3. User classes should contribute to the road according to both their demand elasticities for the joint components and the specific costs which they impose.

4. Although automobile demand might be inelastic enough to pay for the entire road expenditure, it should not be asked to do so because many parts of the road are truck-variable, i.e., they deteriorate differentially under use by different vehicle sizes or, conceivably, are demanded exclusively by trucks.

5. What has been said of costs can be applied to the annual expenditure for the road program (i.e., that part of total road activity which is viewed as improvement of the network in built-up areas). This probably relates to most of the road activity.

6. Outside support of the road program may be justified when discrimination is inefficient, i.e., when to discriminate would imply a foregone benefit of unrealized traffic. Outside support is likely to be more efficient when provided by local communities rather than by centralized sectoral or regional transfers, owing to the imperfections of project evaluation techniques.

II. *Evaluation of the Yugoslav Structure*

Between the foregoing statement of principles and the final evaluation, however, there are many decisions to make in the determination of demand, the definition of size-variable components, the estimation of present user contributions, and so on. In assessing the results of this investigation, any reader will be able to find something to object to—some number or the treatment of some relevant factor. The latter I have tried to explain carefully where important decisions are made, as in the treatment of sales taxes, to try to help the reader appreciate the special conditions at play in Yugoslavia. Quite different treatments of the variables may be justified in other countries, and some possibilities are indicated in the course of exposition. For example, in other countries different weights will surely be assigned the different traffic classes, which, of course, does no violence to the essential principle that the true joint components must be priced according to demand. This point has been stressed repeatedly and is offered now as an added caution lest the reader attempt indiscriminate translation of the numerical estimates derived here to some other country. Nor have the weaknesses of the data base escaped the author's notice. But in spite of their shortcomings, the available Yugoslav data are in many ways more complete and suitable for purposes of this analysis than is the information which is available in many other countries, probably most developing countries at any rate. Therefore, it will be more fruitful to use Yugoslavia as a study to illustrate the implementation of the principles of Part I to evaluate a user charge structure, and to show some of the kinds of compromises which inevitably must be made in evaluating user charges according to these (or, indeed, any) standards. Such compromises necessarily reduce the efficiency of the final estimates of the warranted user charges. But to abandon the attempt to make such estimates simply because they are somewhat imperfect and to settle instead for the far less perfect pricing systems in effect in most countries today, which, when evaluated at all, are usually analyzed, essentially, in terms of total revenue from all user sources vs. total expenditure and which undoubtedly contain a large urban subsidy to interurban users, could scarcely be construed in the next best alternative.[10]

II.1. *Size-Variable Costs*

Following the generally accepted notions of economic efficiency, the sunk cost of constructing the existing highway network will not be considered as a current cost. That part of the investment which is subject to wear and which must be replaced, chiefly the pavement and sub-base, is a current cost, however, and must be assigned to the traffic classes according to the deterioration which each imposes.

[10] The International Road Federation in its annual yearbook, for example, compares total road sector revenue to total expenditure to show that road sector is self-paying, and, by implication, efficient. Total revenue is defined to include all sales taxes and automobile fuel tax revenues, etc. Thus, the possibility that many vehicle class and urban-interurban, distortions may exist is overlooked. Moreover, total expenditure recovery from users in any one year is itself a questionable criterion. See IRF, *World Road Statistics*, 1966–1970, Geneva and Washington, 1971, pp. 152–171. The recent debate on highway economics in Canada has started from the notion that revenue-expenditure is a good approach, with the earliest papers focussing primarily on the handling of various revenue sources and expenditure items. (See M. Q. Dalvi, *op. cit.*, and D. W. Conklin, J. E. Tanner, and L. S. Zudak, *op. cit.* Finally, in Brazil, contributions originate primarily in automobile use, which is predominantly city- rather than intercity-oriented. (For discussion see Alan Abouchar, "Brazilian Highway Expenditures and the Construction Maintenance Mix," Fourth Highway Symposium of the Brazilian Institute of Road Research, Rio de Janeiro, 1968.)

The AASHO road test coefficients are undoubtedly the best measure of the deterioration imposed on different pavement designs by traffic components and we will apply them to the allocation of size-variable costs in this chapter. In the following discussion, truck designations will refer to the payload. Three truck sizes will be used in the analysis: small (4-ton load); medium (10-ton load); and large (20-ton load). The loads are converted to gross vehicle weights, which is the basis of the AASHO equivalence coefficients, by applying U.S. Department of Transport vehicle specifications as given in its publication *Road User and Property Taxes, 1970.* Metric-ton adjustments are made where appropriate.

The AASHO coefficients are calculated 1) for twelve flexible and rigid pavement designs; 2) with respect to four different levels of deterioration and unserviceability; and 3) for 40 different vehicle weights and axle designs. Accordingly, to apply them accurately requires, first, that we know the distribution of pavement designs in the network, and, if there are serious differences in the pavement distribution on sub-networks, analyze them separately. Unfortunately, no systematic and sufficiently detailed inventory of the links in the network exists. However, in fact, the relative deterioration by large and small trucks is of the same order of magnitude for a wide range of pavement designs, so that the precision that could be derived from this additional detail is not consequential. Table 1 shows the deterioration coefficients, which express the equivalence of each vehicle class to a vehicle bearing a nine-ton (single) axle load for different pavement designs. In our calculation we will assume the road stock to be distributed equally between rigid and flexible pavements, and use simple averages of the AASHO coefficients. This will make little difference in the final estimates: for example, use of the rigid pavement coefficients throughout would raise the warranted user charge of the 20-ton capacity trucks by 10 percent. The effect on smaller vehicles would be negligible.

The coefficients are calculated for two levels of unserviceability, as measured by expert evaluations. Again, the order of magnitude of the differences in the coefficients to reach any unserviceability level is fairly stable, so that the choice of one rather than another will not affect the relationship between the warranted user charge estimates for different vehicle classes. We will base our calculations on an unserviceability level of 2.0, which is the lower of the two measured, reflecting in part the need to stretch out the life of capital in poor countries.

There are also differences in the damage inflicted by single and double-axle vehicles, and some attempt should be made to weight each vehicle class by the axle distribution of the class. As Table I shows, the tandem axles inflict less damage than single axles. But information is not available to weight each class by its axle distribution. We will assume single-axle loads for small and medium vehicles, and tandem axles for the large trucks. This reflects the administrative axle-load limitations and the apparently good supervision of these regulations in Yugoslavia.

It is also necessary to estimate the stock of the various vehicle classes and their annual runs, and, finally, the total annual deterioration. To estimate stock we proceed from the official transportation and communications yearbook (*Saobraćaj i veze*). In 1970 there were about 850,000 vehicles registered in Yugoslavia including: 720,000 cars, 120,000 trucks (including truck tractors) and 15,000 buses. The average run for trucks is 50,000 kilometers, and for buses 70,000. We will assume the average run for large trucks to be 75,000 kilometers, for medium trucks 65,000 kilometers, for small trucks 40,000 kilometers, and for cars 15,000 kilometers. A further calculation is based on an annual run of 115,000 kilometers for large trucks. We would still

TABLE 1

EQUIVALENCE FACTORS FOR TEN VEHICLE DESIGNS AND FOUR PAVEMENT DESIGNS

(Entries give number of repetitions of 18,000-lb. single axle load which damage the road the same amount as given vehicle)

	Single Axle				*Tandem Axle*			
	Rigid Pavement		*Flexible Pavement*		*Rigid Pavement*		*Flexible Pavement*	
Thickness of Surface	6″	11″	Light Duty	Heavy Duty	6″	11″	Light Duty	Heavy Duty
Weight of Vehicle Tons								
2	0.0002	0.0002	0.0002	0.0002	—	—	—	—
10	0.09	0.08	0.08	0.08	0.01	.01	0.01	0.01
18	1.0	1.0	1.0	1.0	0.14	0.13	0.07	0.07
26	4.76	5.02	5.36	4.96	0.63	0.62	0.32	0.33
40	32.18	32.57	39.57	31.25	8.36	8.79	5.10	4.83

Source: *The AASHO Road Test,* pp. 422–423. Light and heavy duty flexible pavements refer to the lightest and heaviest pavement and base combinations. The coefficients in table relate to lowest unserviceability level (2.0).

have to know the interurban shares of these mileages, as well as the detailed distribution of trucks. We will assume that the medium 10-ton capacity trucks number 40,000 and the 20-ton capacity trucks number 30,000 (the statistics list 30,500 truck tractors). This involves some simplifications, but in the absence of more complete census and sample data, there is no alternative.

There is, of course, no physical indicator of annual deterioration, and we will base our deterioration estimate on the annual financial accounts. Yugoslav road expenditure data is classified by maintenance, reconstruction and modernization, and new construction. Reconstruction is supposed to refer to improvements to existing roads, including base works, while modernization is supposed to refer to simple repaving. There is undoubtedly some overlap here, but it is unimportant because both of these activities are vehicle-size variable in the sense used here, i.e., they represent efforts to rebuild a deteriorated pavement. More important is the overlap between modernization/reconstruction and maintenance, on the one hand, and new construction on the other. It is very likely that new construction contains some blacktopping or upgrading of gravel roads, both of which are vehicle-size related. We will assume that half of maintenance and one-third of new construction are really vehicle-size related.

Table 2 shows the total average annual expenditure by category for 1969–70. It is assumed that all reconstruction and modernization, one half of maintenance, and one-third of new construction are size variable in the sense used here. Unfortunately, however, we must work with 1971 user charge data, and so it is necessary to estimate 1971 expenditures, which have not yet been reported by the federal government. To do this we project forward the 1970 expenditure by 25 per cent, a rate which is consistent with informal estimates in Yugoslavia.

To determine the size-variable cost per unit, we must first convert total traffic into equivalent traffic units (ETU) by applying the AASHO coefficients to the estimated traffic. The ETU calculations are shown in Table 3. Backhauls are assumed to be half-loads, and other procedures are explained in notes to the

TABLE 2
ESTIMATION OF EXPENDITURE CATEGORIES AND SIZE-VARIABLE SHARES, 1971

	Average Annual Expenditure 1969–70		*1971*		
	D. Billion	*% of Total*	*Estimated Expenditure D. Billion*	*Size Variable Cost Share D. Billion*	*Percent of Estimated Expenditure in this Category*
Reconstruction & Modernization	1.3	54	1.690	1.690	100
New Construction	.5	21	.660	.220	33
Maintenance	.6	25	.780	.390	50
Total	2.4	100	3.130	2.300	

Note: Total 1971 expenditure assumes 25 per cent annual growth over 1970. (1970 assumed to be D 2.500 billion). Annual 5-year plan calls for average 1971–75 expenditure of D 5.2 billion.

table. The total ETU of 5,687 million units is then divided into the total size-variable cost of D 2.3 billion from Table 2. This gives a variable cost of 40.4 paras per ETU.[11] For each class this is then multiplied by the average of the loaded and backhaul coefficients, divided by the total gross vehicle tonnage, and then adjusted to a metric ton basis. For example, for the 20-ton capacity trucks we get: 40.4 (1.92 + .42) .5 = 47.3 para per vehicle kilometer. This gives 47.3/(36 + 25) .5 = 1.55 para per ton kilometer, or 1.7 para per metric ton-kilometer.

II.2. *Demand-Related Charge*

The balance of maintenance and new construction should be priced according to demand. For new alignments, the differential price that a truck should be willing to pay is equal to the cost reduction from the new road. This can be approximated by the saving in driver time. We will assume that route rectification combined with faster hourly speeds doubles the hourly mileage calculated in terms of the old route (i.e., if on the old route 400 kilometers between points A and B could be travelled in ten hours, the journey from A to B could be travelled in five hours on the new route). The 1970 average truck driver wage was about D 1,250,[12] or D 8.4 per hour. Dividing this by the 40-kilometer per hour effective distance saving gives an average saving of 21.0 para per vehicle-kilometer. This saving per kilometer is then divided by the average gross vehicle tonnage as shown in Table 4 to get the saving per gross ton-kilometer. Since there are usually two drivers on long-distance shipments, the gross ton-kilometer saving for 20-ton capacity trucks must be doubled.

The estimated saving will be realized only by those using the new roads. If we assume that this amounts to 20 per cent of traffic in any given year, the saving must be divided by 5 to get the average saving per vehicle. We will disregard the savings accruing to vehicles on other routes as inconsequential. Also neglected is the saving through reduced fuel consumption and vehicle maintenance.

[11] 100 paras = one dinar.

[12] The average income for all truck drivers in 1969 was D 1173. Data for 1970 was not yet available. The 1970 truck driver wage is assumed to grow at the same rate as wages overall in the economic sector (six percent). See Statisticki Godisnjak, 1971, pp. 268, 270.

TABLE 3
CALCULATION OF EQUIVALENT TRAFFIC UNITS FOR FIVE TRAFFIC CLASSES, 1970

Description of Vehicle	*Load*[a]	*(1) Stock (000)*	*(2) Vehicle Avg. Wt. (tons)*	*(3) Avg. Annual Run (000)*	*(4) T-K's (bills) 1 × 2 × 3*	*(5) Percent of total T-K*	*(6) Weight per axle (000 lbs.)*	*(7) Average AASHO Equiv. Coeff.*	*ETU Veh. Kilo. (millions) (1) × (3) × (7)*	*Percent of total*
1. Cars	3 pass.	720	2.2	15	23.4	14.2	2.2	.0002	2	negl.
Trucks										
2. (Small (4-ton cap)	full	50	7.5	20	7.5	4.5	7.5	.035	35	.6
(RUP No. 5	half	50	5.5	20	5.5	3.3	5.5	.01	10	.2
3. (Medium (10 ton cap)	full	40	20.0	32.5	26.0	15.8	20.0	1.57	2041	35.9
(RUP No. 8	half	40	14.0	32.5	18.2	11.0	14.0	.34	442	7.8
4. (Large (20-ton cap)	full	30	36.0	37.5	40.5	24.5	36.0	1.92	2160	38.0
(Tandem Axle RUP No. 12)	half	30	25.0	37.5	28.1	17.0	25.0	.42	472	8.3
5. Buses	40 pass.	15	15.0	70.0	15.8	9.6	15.0	.5	525	9.2
Total					165.0	100.0			5687	100

Note:
[a] Truck capacity-loaded weight relations based on data presented by U.S. DOT in *Road User and Property Taxes*, 1970. RUP designations refer to specifications on pages 10–11.

TABLE 4

CALCULATION OF USER CONTRIBUTIONS, 1971

(all weights metric tons)

Vehicle Class[a]	Average[b] Vehicle Weight (metric tons)	Annual Mileage (000 kls.)	Registration fee (Dinars)	Fuel[c] Consump. (liters)	User Cost[d] Per Lit. Dinar	Total Fuel Cost (5) × (4)	Total User Cont. (6) × (3)	Total Ton-kils (000) (1) × (2)	Total User Contrib. Per T-K (Paras) 7 ÷ 8
Car (Medium)	2	15	170	2,160	.55	1,190	1,360	30	4.5
Trucks									
Small (4-ton cap)	5.9	40	1,725	10,620	1.2	12,740	14,465	236	6.1
Medium (10-ton cap):									
Gas	15.4	65	6,000	29,250	1.2	35,100	41,100	1,001	4.1
Diesel	15.4	65	6,000	22,500	.64	14,490	20,490	1,001	2.0
Large (20-ton cap.) Diesel									
Moderate use	27.7	75	13,500	33,750	.64	21,735	35,235	2,078	1.7
Heavy use	27.7	110	13,500	49,500	.64	31,880	45,380	3,047	1.5
Buses (40-passengers) diesel	13.6	70	2,000	25,200	.64	16,130	18,130	952	1.9

[a] See note (a) Table 2.
[b] Average of forward and backhaul, converted to metric tons.
[c] Based on DOT, RUP fuel consumption.
[d] For cars—naknada 2_a puteve only.
For trucks—naknada 2_a puteve plus turnover tax.

TABLE 5

WARRANTED USER CHARGE AND ACTUAL USER

(Contribution per metric ton, trucks only.)

	1971				
Vehicle	(1) Variable Cost[a]	(2) Demand Related Component[b]	(3) Total Warranted User Charge	(4) Actual Contrib. (Table 3)	(5) Actual Warranted
4-ton capacity	1.4	.71	.72	6.1	8.4
10-ton capacity					
gas	2.27	.27	2.54	4.1	1.61
diesel	2.27	.27	2.54	2.0	.79
20-ton capacity	1.7	.28	1.98	1.7	.85

Notes to Table 5:

[a] Variable cost is determined from the relationship P_{ETU} (1.1) $(C_L + C_{1/2})/(L_L + L_{1/2})$ where P_{ETU} = the average cost of size-variable components (Reconstruction and modernization + 1/2 maintenance + 1/3 new construction); 1.1 is a metric-ton conversion factor; C_L and $C_{1/2}$ are the AASHO coefficients for full loads and half-loads; and L_L and $L_{1/2}$ are the gross tonnages under full and half-loads. For large trucks, we have

$$P_{ETU} = \frac{2.3\ (10'')\ \text{para}}{5{,}687\ \text{mil.}} = 40.4\ \text{para.}$$

$$\text{Var. Cost} = [40.4(1.92 + .42)/(36 + 25)]1.1$$
$$= 1.7\ \text{para per metric ton-kilometer}$$

[b] Demand-Related Component is determined by dividing the hourly wage—8.4 dinar—by the increase in speed permitted by the new construction (assumed to be 40 kilometers). The saving per kilometer is then divided by the average gross vehicle tonnage (Table 4). This is then assumed to represent the saving per ton-kilometer of 20 percent of the traffic in class.

The final demand-related components for the four truck classes are shown in Table 5.

Although many assumptions have had to be made in deriving the demand-related charges, they will not affect our final conclusions significantly. These charges are small in relation to the variable cost component for the medium and large vehicles, and for the small vehicles the estimated present user contributions are already large enough to allow for large errors in calculating them, as Table V-5 shows. We now consider the present user charge pattern.

II.3. *Estimation of User Contributions and Comparison with Warranted User Charges*

Estimation of user contributions is shown in Table 4. The Yugoslav data on license fees are given in terms of truck capacity. In order to calculate contributions per gross ton, gross vehicle weights had to be derived. This was done, as before, by applying U.S. Department of Transport specifications in its publication.

The most controversial point in the user contribution calculations is the treatment of the turnover tax (*porez na promet*). Many Yugoslav observers today (including road-building agencies, road user groups, and manufacturers) believe that that part of all turnover taxes in excess of a "basic" rate should be counted a user contribution. But this conflicts with the essence of the turnover tax, as indeed, does actual tax practice. In the past the turnover tax has been levied almost wholly on final goods at rates which are progressive with respect to the presumed income level of the respective consumer classes, e.g., it is zero on food and books, and then has a basic rate of 18 per cent on some consumer goods, rising to around 35–40 per cent on luxuries. Where final goods also serve as intermediate goods, the tax is, in principle, rebated. One taxation expert from the Secretariat for Finance has expressed the belief that the rebate mechanism works effectively. In view of these characteristics of the turnover tax, it is appropriate to regard the whole of the turnover tax paid by trucks as a road user charge and all that paid by cars (about 35 per cent of retail price) as an excise. In addition, of course, we consider the narrowly defined road fuel tax (*naknada za puteve*) as part of the user contribution. Fuel consumption rates required to estimate the user contributions per kilometer are taken from the U.S. Department of Transport as indicated in Table 4.

Table 5 brings together the warranted user charges and the user contributions. Column 5 shows the user contribution relatively to the warranted charge, calculated in Column 3. The very large trucks fall short in their user contributions, as do the 10-ton capacity diesel trucks, although neither class by very much. The apparent paradox of a lower variable cost for the 10-ton truck occurs because the larger truck has a tandem axle, which is relatively less burdensome on the road per ton of gross weight than the single axle, 10-ton truck.

The discrepancies which have been uncovered are less serious than might have been expected, and it is possible that they can be explained by the roughness of the data and our need for simplifying assumptions along the way. The calculations show that all vehicle classes are paying more than their directly-variable cost, as defined in this paper, plus a demand-related contribution towards the joint component costs. Whether the excess paid is sufficient to cover the analogous costs for cities, including congestion or other externalities, would require separate study. The data for such a study in the necessary detail is, of course, lacking. It can be seen, however, that the excess of actual over warranted charge does decline with rising vehicle size. This is probably consistent with the costs that they impose in urban networks since a higher fraction of city use probably consists of small vehicle traffic.

II.4. *Supplementary Beneficiary Contributions*

The foregoing price-cost comparisons relate to the directly-variable costs and to a demand component of the true joint costs. The demand component reflects the estimated average minimum savings for each vehicle class in the entire system—on the arcs being improved (with new additions or rectifications) and on the rest of the network as well. This will not necessarily cover total expenditure in any one year and may lead to a requirement for non-user supplementary financing, which, we have recommended, should originate in the local communities. The analysis of the overall financial account of the road network shows that the communities contributed around 15 per cent of the total in 1969. As a result, around $^3/_4$ths of total revenues originated in sources which we define as direct beneficiary groups—users and abutting communities.[13] Federal participation (including army activity, grants from the Fund for Development of Backward Regions, and other unidentified federal grants) was about 12 per cent. Republic participation (around 10 per cent) is a grey area between beneficiary and non-beneficiary participation. It is not included in the estimated $^3/_4$ths direct beneficiary share, although part of it undoubtedly should be. Whether the non-beneficiary contributions were consistent with income distribution goals, or simply constituted an attempt to close the gap between desired investment plans and the capacity of the road sector to generate user-charge revenues cannot be determined.

To conclude, then, a set of road pricing and financing principles can be devised by analyzing the joint components and the directly variable costs. Flexibility in interpreting the nature of components is essential—it is impossible to state categorically that any particular physical part of roads falls under one rubric or other. It depends, rather, on the geophysical engineering and economic characteristics of the road and demand. This is believed to be more meaningful than the global financial approach for analysis of potential price distortions which can arise in the highway sector of any economy.

[13] In this estimate the turnover tax is treated as described in II.3 for purposes of calculating present user contributions, i.e., the turnover tax on automotive fuel is treated as an excise or general revenue tax, while that on estimated truck gasoline and diesel fuel consumption is treated as a user contribution.