Principles of Urban Transportation Pricing

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•THIS PAPER discusses some of the fundamental economic principles that underly the pricing of urban passenger transportation services. This is done primarily in the context of private automobile transportation, although many of these principles relate as well to the problems of mass transit. Throughout, abstracts are drawn from all those practical problems, which are admittedly both important and intractable, that arise when one attempts to implement any general set of guidelines governing the appropriate pricing of transportation services, especially the difficulties of measuring the appropriate magnitudes for tolls and roadway expenditures as well as the difficulties of collecting tolls that should in principle vary with time of day and the particular point of travel. Thus, the subject is restricted to what might be called the "pure" theory of transportation pricing.

In developing a pure theory, one abstracts from a great variety of realistic detail. For that reason, the current analysis invokes what would ordinarily be called "models" of transportation pricing situations, a model being a highly simplified representation of the reality with which one wants to deal. But, because the particular artificial problems chosen for consideration are not purported to capture even all of the more important aspects of reality, there has been a reluctance here to write of "models." The artificial cases considered are each selected to illuminate some particular aspect of real-life problems with the purpose of illustrating some single principle. For this reason, reference has been made elsewhere (1) not to "models," but to "parables." This latter term suggests more accurately the concern mainly to tell some simple stories, involving a good deal of make-believe, each of which contains some "moral" regarding transportation pricing. Systematic economic analysis of urban transportation problems seems not yet to have advanced beyond the level of what is essentially a paradigmatic treatment, and one must at present be content to improve the artful exercise of the urban planner's judgment by such useful insights as can be gotten from considering various grossly simplified situations.

A pricing mechanism in urban transportation, as in other parts of the economy, is called upon to solve several different problems at the same time, and much confusion about pricing principles arises when those problems cannot all be solved by the same price structure. One problem (the investment problem) is to determine the kinds and amounts of resources that society should fix in particular uses for fairly long periods of time or, more specifically, to determine how much land, concrete, etc., should be invested in a given road network. Once these decisions about road locations, road widths, interchanges, bridges, etc., have been made, there then arises the further problem (the rationing problem) of how they should be used. Who should make what trips and when? The main reason for not permitting unrestricted and unlimited use of an existing road network is only in part the increased wear and tear on the roads themselves from greater use, but more significantly the problem of congestion. The essence of the congestion problem is that each individual's use of a road imposes certain costs or disadvantages on others who use the road at the same time. These two problems, of appropriate investment and appropriate rationing of a given network among users, are interrelated in that the appropriate investment depends on how the network that is constructed will be used and the appropriate use depends on the fixed

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character of the existing network. Is there a set of prices (tolls) that will solve both of these related problems in a single stroke? A third problem (the income distribution problem) has to do with the relative importance for social decision-making of the many different individuals in the society. Are some to be allowed more travel than others or, more precisely, are the desires of some people to travel to be held in greater importance than the desires of others? Whenever a pricing system is used to solve the first two problems mentioned, it will affect what may generally be called the "distribution of income," or still more generally, "the distribution of satisfactions" among the various individuals in the economy. If one wishes to choose a pricing system so as to influence the distribution of satisfactions among different people, can the system then also be used to solve the problems of investment and of rationing? Is there a set of prices that can solve all three problems—investment, rationing, and income distribution—simultaneously?

In the private sector of the economy, investment resources are assumed to flow to those industries and uses where their expected earnings are above normal and to flow out of those industries and uses where the expected returns are negative or, at most, below normal. These forces are assumed to move the economy always in the direction of an equilibrium position where all fixed investments receive just the normal return; and it is demonstrated, under the conventional assumptions made by economists when analyzing policy problems, that in this equilibrium all capital goods would be put to the best possible use; that is, that it would not improve economic welfare to shift any resources from one industry to another. The earnings on capital, of course, depend on the structure of prices; not only the prices of goods and services that are produced at the end of the production line, but also on the prices of those services of production factors that enter as inputs in the production process. To rely on a profits or earnings motive to guide investment in the long run then requires a price system that will bring about this equality of returns throughout the economy. In short, the proper level of investment of fixed resources in any particular use must be expected at prevailing prices to just pay for itself, yielding just the normal return to the investors. If this same rule were applied to the pricing of highway use, the structure of tolls would need to be such that the appropriate expenditure incurred in constructing and maintaining the road network would just equal the sum of all toll receipts paid by all users on all roads. Indeed, this condition should be satisfied not simply for the entire network, but separately for each and every inch of highway construction. A price system for road use that does not lead to the "zero-profit" condition (where by profit is meant any return in excess of the normal return on capital) would seem to be other than optimal. If profits were positive, this would appear to be a signal that further investment is needed, and if profits were negative, a signal for reduced investment. If a set of prices exists so that there will be zero profits when just the right road network has been constructed, that set of prices will have solved the optimal investment problem.

Regarding the private sector, it is also thought that prices should be set so as to bring about an equality between the extra cost entailed in the production of a bit more of any commodity and the extra satisfaction that someone can gain by consuming that incremental amount of that commodity. The concept of cost that is relevant here relates ultimately to (a) the loss of satisfaction that the buyer of the incremental output must incur for having to accept slightly less of other things in order to make that incremental production possible. It also incorporates (b) any reductions in satisfaction imposed on others by virtue of the slight redeployment of resources that are involved in the shift of production that would occur. In the case of road use, it may be said that the extra satisfaction that a particular motorist derives from an additional trip (per unit time, for example, per year) on a given road must be just equal to (a) the loss of satisfaction he incurs by having his consumption of other goods and services reduced as may be necessary to divert resources for the increased upkeep of the road required by the greater wear and tear that his additional trip creates plus (b) the loss in satisfaction incurred by his fellow motorists because his additional use of the road increases the congestion that they experience and to which they object. When this delicate "balancing at the margin" is achieved throughout the society, it may be said that the rationing problem has been solved. The question, therefore, is: "What set of prices, including road tolls, will induce people to travel on different routes with just that frequency so that this balancing at the margin is everywhere achieved? If there exists a set of prices that will do this, those prices may be regarded as optimal because they solve the rationing problem.

What is disconcerting is that the set of prices, including tolls, that may solve the rationing problem might be different from those that solve the investment problem. Now, one of the achievements of economic analysis is to show under what idealizing assumptions regarding the nature of people's preferences, the nature of technology, and the nature of the organization of firms within the industries of a free enterprise economy, the very same set of prices will happen to solve both problems at once.

Suppose a set of prices has been found for all commodities, including transportation services, so that both the investment and rationing problems are simultaneously solved. That set of prices will also dictate a distribution of income or welfare for all individuals in the economy: some will be poor, others will be rich. Some will consume little and others much. Is the distribution that results liked, or is it regarded as unfair or even as politically dangerous? Unless one is prepared to accept whatever distribution of income happens to result from the use of the price mechanism to solve the investment and rationing problems, he may prefer a distribution different from the one that actually ensues. It should be clear, therefore, that there is a very real danger that in asking for a single set of prices to solve all three of these problems the price system is being called upon to do more than it can.

There are easy ways in which the economic analyst can avoid the problem presented by considerations of an ethically appropriate distribution of income. One way is to suppose that any distribution of income is ethically as good as any other, so that the problem is essentially ignored. Another solution, differing only subtly from the first, is to suppose that there are both good and bad distributions of income but that whatever distribution is generated by a price system that solves the investment and rationing problem, is the best one. A third device for avoiding the problem is to assume that the distribution of income can be altered without tampering with the price mechanism. This is conceptually possible. One could imagine that there is a Robin Hood who will, every period of time, steal just the right amount of income from those who are thought to have too much and dole it out in just the right way to those who are thought to have too little. This must be done in such a sneaky fashion, however, that no one is ever aware that his earnings or expenditures will ever affect his treatment at the hands of Robin Hood. Otherwise, he has an incentive to behave differently (for example, to work more or less) in order to alter the way in which Robin Hood treats him. What Robin Hood in effect does is to impose a system of head (or flat) taxes and subsidies that may differ from person to person, that do not affect the terms on which anyone believes he can exchange one commodity for another or exchange labor for commodities, so as to bring about just that distribution of income that is desired. Such a system of head taxes and subsidies is not feasible, either politically or administratively; in reality, if it is wished to alter the distribution of income in the economy it must be done by interfering with the price mechanism. But, in a long (though much too honored) tradition, let it be supposed that Robin Hood can and will do one's bidding, or that head taxes and subsidies can always be imposed and collected in just such a way as to bring about any particular distribution of income that might be wanted. Thus, the remainder of this discussion, essentially abstracts from the demand placed on the price system to solve the distribution problem.

Suppose the same set of prices cannot solve both the investment and rationing problems. Then what is to be done? Part of the answer is that the problem of inconsistency between prices that solve the investment and those that solve the rationing problem simply does not arise except under special and uncommon circumstances. The main concern is with whether there are decreasing, constant, or increasing returns to scale in production with respect to some set of factors of productions. By decreasing returns, reference is made to the case where if the factors of production are increased in equal proportion, the amount of product yielded will be increased in a smaller proportion. Increasing returns to scale is the contrary case where product increases in greater proportion than the given equal proportional increase in the factors of production. And constant returns to scale occurs when product increases in the same proportion in which the factors are increased. By "factors of production" is not meant absolutely everything that can effect output, but only those things that are economic goods, which means that it must be possible to identify them, to claim ownership rights in them, and to choose among alternative uses for them. It is because some things that effect production through the technology exist in limited supply and cannot be increased in equal proportion with other factors that there may be diminishing returns to scale. If there are influences present that operate negatively on the production process and cannot be removed, but do not themselves increase as the factors of production are increased, then there may be increasing returns to scale. Even if such impediments to production, however, can be identified and could be owned, no one will claim ownership rights in them. Fixed factors of production that contribute positively to the production process will generally be "owned" by somebody and that owner, if able to withhold those factors from a particular use, is able to command a certain return for letting them be used. This return is an "economic rent," and will be included in the cost of production. But if there are fixed impediments to production, no one will claim to own them and, though from the social point of view they "earn" a negative rent, there will be no one willing to collect that negative rent, and so the socially appropriate deduction from other production costs accounted for by these impediments will not be deducted in the calculations of the private marketplace.

It is in this case of increasing returns, which can be interpreted as the case where there are present one or more impediments to production, that the solution to the rationing problem defines a set of prices at which profits will be negative. The solution to the rationing problem then yields prices that will not solve the investment problem. In this case, the standard answer is that government must subsidize investors, in effect collecting what may be regarded as the negative rents that no one in the private sector will voluntarily collect. The proceeds for these government outlays in subsidizing industries of increasing returns are in turn to be collected from the private sector in the form of head taxes, thus not interfering with the price mechanism used to solve the rationing problem.

It remains an open question whether the technology of urban highway transportation is such that government must collect negative rents (i.e., subsidize the road network). It is also an open question whether the technology of urban road transportation is such that, even if there are diminishing returns to scale, it is possible for private individuals to collect the positive rents whose payment, as a cost of production, reconciles the pricing solutions to the investment and rationing problems. These questions are examined in the parables studied (1) and reported on here.

The first and simplest of these parables considers a society with a fixed number of individuals, each of whom has a definite set of preferences among alternative combinations of (a) the number of round trips that he is able to make from Here to There and back again along a given road, per unit of time, the quantity of other goods that he is given to consume per unit time, and the degree of congestion that he encounters on the road while traveling. Other goods are represented by a single commodity, called "bread." It is assumed that the individual prefers more trips to fewer trips, other things being the same, and that there is a common measure of congestion that can be used in defining the preferences of different individuals. Other conventional assumptions about the nature of the preference structure of the individual are also made. But at this point, as in much of what follows, the reader can only be referred to the previous paper (1) for a more precise listing of the various assumptions employed. The production of the representative other commodity, bread, is assumed to occur under conditions of either constant or diminishing returns to scale, so that there are no serious problems there. The society, however, is assumed to have only a fixed quantity of productive services to use in each period of time and these must be allocated between two different uses: one to produce bread and the other to "produce" the road. The resources to be used in producing the road each period of time (say each year) would in fact be represented by both maintenance expenses and interest expenses on any capital expenditures that would occur irregularly over time. Though not descriptively realistic, it may be simplest to think of the road as something that wears out and must be replaced each unit of time. This kind of abstraction does little harm because, in any case, only the long-run equilibrium (steady state) solution to the problem of the optimal road is being considered.

There must also be a production function reflecting the road technology, and this is a relationship defining the degree of congestion as a function of the annual expenditure of productive services on the road and of the total volume of traffic (that is, the total number of trips made on the road per unit time). It is also imagined that the flow of traffic, whatever its level may be, is at a steady rate, with no hourly or daily variations. This function may be expressed as

$$d = D(\Sigma_i t^i,\ E) \tag{1}$$

in which d is the measure of congestion, E is the annual expenditure of resources on the road, and $\Sigma_i t^i$ is the sum over all individuals, i, of the number of trips made by these individuals, t^i, $i = 1, \ldots, I$.

Much will depend on the nature of this production function. One case arises if, when the annual expenditure, E, and the volume of traffic, $\Sigma_i t^i$, be increased in equal proportion, d remains the same. This is the case of constant returns to scale. If, however, an equal proportional increase in traffic and road expenditure increases d, this represents adverse returns to scale; and if that decreases d, favorable returns to scale. This may seem a bit different from the earlier classification of production functions into the categories of constant, decreasing, and increasing returns to scale because there the dependent variable, product, needed to increase in equal, lesser, or greater proportion than the factors of production, respectively. Here the categorization rests on whether d stays constant, increases at all, or diminishes. The conceptual difference is, however, more apparent than real. The three cases identified here could be restated as follows: if the quality of the product, d, remains the same, is it possible to achieve the same percentage increase in output, $\Sigma_i t^i$, as the increase in the input, E? If so, there are constant returns. The case of adverse returns, as previously defined, is the case where, to hold the quality of product, d, constant, the volume of output, $\Sigma_i t^i$, must be increased in lesser proportion than the increase in the input, E. Adverse returns therefore corresponds to the case of decreasing returns. By the same reasoning, the case of favorable returns corresponds to the standard case of increasing returns. (No attempt is made in this study to estimate whether constant, adverse, or favorable returns are more common in reality. A word of caution is advisable, however, against any quick presumption that favorable returns are the rule. It may be thought that this is the case because a two-lane road (in one direction) can carry more than twice the traffic of a one-lane road at the same speed. But the input, E, is not a measure of cost at constant prices; it is a measure of cost expressed in terms of foregone alternatives. Especially to the extent that land is an input in road construction, the widening of a road or the expansion within a given area of a road network entails adding land that may have increasingly greater value in alternative uses. This would work towards adverse returns to scale.)

The first question is: Suppose that the individual receives a fixed per-unit return for any of society's total factor services that he contributes to production per unit time, that he must pay a head tax or subsidy per unit time, and that he confronts a given unit price for bread and a given toll for each trip he makes on the road. How much bread will he want to buy and how many trips will he choose to make each unit of time in order that he maximizes his satisfaction as reflected by his preferences? Conditions giving the solution to this problem for each individual are then introduced as "behavior conditions" in the problem of deciding what is the proper toll and what is the proper expenditure on the road.

Subject to all these conditions, one then asks what requirements must be imposed on the prices, including the toll, and on the allocation of the productive services between producing the road and producing bread in order that it should not be possible, through any change, to move any individual to a position he prefers more without having to move another individual to a position he prefers less. A situation of this sort, where it is impossible to benefit anyone without hurting someone else, will be referred to as a pareto optimum, and there will be many such optima depending on the distribution of income, which may reflect a judgment as to the relative importance of the levels of satisfaction achieved by different individuals. Different distributions of income would be achieved by different assignments of head taxes and subsidies.

In short, it is desired to know what conditions are necessary in order that a pareto optimum can result. For the case analyzed, the following conclusions can be drawn:

1. There does exist an optimal level of expenditure on the road, but this depends on the distribution of income that is chosen to be most suitable.

2a. There does not exist an optimal toll for the use of the road that is the same for all individuals, but tolls must differ from person to person.

2b. If the further simplification is introduced that the individual does not take account of the extent to which his own use of the road affects the congestion that he himself experiences (a simplification that seems not very objectionable), then there does exist an optimum toll that is the same for all individuals and all trips.

3. Under the simplification of 2b, this optimum toll is defined in terms of economic relationships that are measurable in principle though very difficult to measure in practice.

4. Continuing under this simplification, there is no apparent market mechanism that will provide a measure of what the optimal toll should be.

5. The optimal level of expenditure on the road should exceed optimal toll receipts by the amount S/D_E, where

$$S \equiv D_{\Sigma t} \Sigma_i t^i + D_E E \tag{2}$$

and $D_{\Sigma t}$ and D_E are the rates of increase in d with respect to increases in annual traffic volume and road expenditure, respectively (partial derivatives of $D(\Sigma_i t^i, E)$).

If there are favorable returns to scale, S will be negative and, because D_E is negative, optimal road expenditures should exceed optimal toll receipts. The difference is a subsidy to be paid for the construction and maintenance of the road out of funds raised by head taxes. In the case of adverse returns to scale, S will be negative and the optimal expenditure on the road should fall short of optimal toll receipts, the excess of toll collections over road costs being returned to the public in the form of head subsidies. If $S = 0$, the road should be exactly self-financing out of toll collections.

The case of adverse returns to scale corresponds to diminishing returns in industrial production. If something is lost through the expansion of scale, this results from the presence of some fixity in the technological process. In the conventional theory of industrial production, this would be ascribed to the presence of fixed factors of production that earn an economic rent, which would be collected by their private owners. In the case of the optimal road problem, however, this fixity cannot be identified by a factor of production for whose use a charge will be made over and beyond the cost of road construction and maintenance; therefore, the road should be operated at a "profit," with toll receipts exceeding road expenditure. In the opposite case of favorable returns to scale, there is some impediment in the production process that is increasingly overcome as road expenditure increases. With an equal percentage increase in traffic, it would be found that, because of the expansion of scale, congestion diminishes. That impediment, whether or not it can be identified, will earn a negative economic rent which no one will want to collect. Hence the road needs to be subsidized (that is, operated at a loss).

The second parable is an extension of the first. Here it is assumed that there are two roads, either with the same origins and destinations or not. A remarkable fact is that this does not matter. All of the results of the first parable carry over in this case and pertain to each road independently. If the measure, S, as defined before is now replaced by S_1 and S_2, each indicating the character of returns to scale on each of the two roads, then road one should be operated at a profit or at a loss depending on whether S_1 is positive or negative, and similarly for road two. It should be stressed that this contradicts the common view that one road (or mode) should be taxed to pay for another. Whether one is thinking of roads or alternative modes of transportation, the relationship between the optimal expenditure and the optimal toll for one is independent of the optimal expenditure and toll for the other, except, of course, to the extent that all economic variables are interrelated in that some goods may be substituted in consumption for other goods and factors of production may be put to alternative uses. But there is no more reason to suppose that one mode of transportation should be taxed in order to subsidize another mode than that it should be taxed in order to subsidize the production of bread.

This analysis can also be extended to the case of three or more roads and, because it is unimportant whether they have common origins and destinations or not, the analysis therefore applies to a whole road network.

A third parable introduces a different sort of complication. Suppose that the total amount of productive services available to the economy is not given in advance but itself depends on the amount of travel that takes place. Indeed, it may now be imagined that the trips people wish to make are not pleasure trips desired as such, but are work trips desired because they add to the individual's income. This, it is discovered, makes absolutely no difference in the analysis. Whether the trip is motivated because it is enjoyable or because it leads to increased consumption of something else that is enjoyable is beside the point. The same five conclusions drawn from the first parable are valid in this situation as well.

The fourth parable introduces still a different complication in the original problem. Here it is supposed that the desired intensity of road use differs with two different portions of the day, a peak period and an off-peak period. Traffic intensity, however, is assumed to be sufficiently great so that there is a problem of congestion during both of these sub-periods. This case is very similar to the two-road case because the same route may be regarded as one road during the peak period and as another road during the off-peak period. The major difference is that these two roads are actually the common product of a single expenditure decision, so that the production relations are

$$d_1 = D(\Sigma_i t_1^i,\ E) \tag{3}$$

$$d_2 = D(\Sigma_i t_2^i,\ E) \tag{4}$$

where subscripts 1 and 2 denote roads 1 and 2, respectively. The absence of a subscript on E, indicates that the resources used to produce the first "road" are simultaneously used to produce the second. (This derives from such considerations as the possibility, for example, of heavier policing or of changing lane dividers as between the peak and the off-peak periods.) It is also noted that the function, D, is the same for both periods.

The results for this case are just like those before, except that the optimal road subsidy is more complicated. It may be expressed as

$$E - \tau_1 \sum_i t_1^i - \tau_2 \sum_i t_2^i = \frac{S^{(1)} \sum_i w^i u^i_{d_1} + S^{(2)} \sum_i w^i u^i_{d_2}}{D_E^{(1)} \sum_i w^i u^i_{d_1} + D_E^{(2)} \sum_i w^i u^i_{d_2}} \tag{5}$$

in which τ_1 and τ_2 are the optimal tolls per trip on each of the two roads, u_{d_1} and u_{d_2} are the decrements (measured as negative) to the satisfaction index of individual, i, of a unit increase in the measure of congestion on roads 1 and 2, respectively, the w^i's are "weights" reflecting the relative importance in the social judgment of the satisfaction levels of the different individuals and reflecting indirectly the decision as to the appropriate distribution of income, and $S^{(1)}$ and $S^{(2)}$ measure the adversity (or, if negative, favorableness) of returns to scale in the road technology on each "road" (i.e., for the same road for each different time of day). This analysis can easily be extended to the case of three or more periods of different traffic flow intensities.

Eq. 5 indicates that if there are adverse returns to scale, the road should be operated at a profit, toll receipts over the entire period exceeding road expenditure; and contrariwise. If there are adverse returns to scale for one sub-period and favorable returns for the other, then whether the road should be operated at a profit or a loss depends on the relative magnitudes of $\Sigma_i w^i u^i_{d_1}$ and $\Sigma_i w^i u^i_{d_2}$. The formulas for the optimal tolls, which are not presented here, are also more complicated than in the earlier parables. Each depends on the way in which the congestion level affects the satisfaction of each individual during both the peak and off-peak periods, and on the weights assigned to measure the relative social importance of satisfaction indexes achieved by different individuals.

The fifth parable is considerably more complicated than those preceeding. It introduces space explicitly in the context of a "classical" city with a "city center" to which people who reside in outlying regions, differentiated as "rings," wish to travel. Individuals' preferences rest on the same things as in the previous parables (the amount of bread consumed, the number of trips made, and the degree of congestion); but, in this parable, they also rest on the amount of square footage available to them for their residences and the distance they live from the city center. The measure of congestion must in this case depend on the residential location of the individual, being greater the farther out he lives. (Congestion is defined here as dimensionally the product of congestion at a point and distance. Thus, although congestion at a point may be less near the outskirts than near the city center, a longer trip from farther out to the center entails greater congestion because congestion in the sense used here is congestion at a point integrated over the distance of the trip.) What is considered is simply a portion of this city, with a fixed population living in a fixed area (though with no outer boundary in the nature of a city limit). All individuals in this area travel to and from the city center using the same arterial route. The individual can use his income to pay tolls, to buy bread, to pay head taxes, and to pay rent for the land that he occupies. One aspect of a pareto optimum now is that people must be allocated residentially to different parts of the city and must occupy parcels of land of different size depending on their preferences, their incomes, and the prices they confront. The individual chooses his bread consumption, the number of trips he makes to the city center, how much land he occupies, and how far out from the city center that land is. Consistent with these free market choices, the same questions are asked as before. What is of special interest to investigate, however, is whether the rent per square foot for land use in a region or ring a given distance from the city center should be the same for all individuals who live there and whether it should be a constant or should instead vary with the size of the lot. In particular, should a surcharge in the form of a land use tax be superimposed upon the land rents generated by a free market in order to raise funds for the payment of the highway? After all, the pattern of congestion will depend on the way in which people sort themselves out over the available space, and it is not evident that each in his private choices will take account of the additional congestion he imposes on others by occupying more space and thus causing his outlying neighbors to travel greater distances under congested conditions.

The result of this analysis is that the very same propositions that emerged from the first parable emerge here as well. Land rents should be those that would be determined by demand and supply in free markets, being so much per square foot regardless of quantity and regardless of renter (or owner), depending only on distance from the city center. There should be no surcharge on these land rents in order to raise funds for the cost of the road. The cost of the road, once again, should either exceed, equal, or fall short of the total receipts from optimal tolls depending on whether there are favorable, constant, or adverse returns to scale in the highway technology.

In a final parable, it is demonstrated that if account is taken of the fact that roads themselves use up space that might be devoted to other purposes, all previous results will still stand so long as the rental value of the space used for roads is included in the measured cost of road construction.

For a variety of complications, then, the central result is that (if individuals do not take account of the increased congestion that they themselves experience simply because they make more trips) there does exist a set of optimal tolls and an optimal expenditure on roads. There is, however, no evident way in which these appropriate magnitudes can be found through a market system and they are hard to measure. But the roads need not be exactly self-financing. Depending on whether there are adverse or favorable returns to scale, roads should either more than pay their own way or should be subsidized. And in comparing the case for either the subsidization or taxation of different roads or modes, there is no constraint stating that taxes (or profits) collected from some should be balanced out by the subsidies paid to others.

As an epilogue, a few remarks are in order about where this kind of analysis might lead. All of the parables here reported have dealt with the question of finding a pareto optimum in a situation where there are no practical restrictions on the collection of any scheme of tolls deemed appropriate. As a practical matter, this is, of course, grossly unrealistic. Future research might well be addressed to the problem of what tolls or other levies should be charged and what road expenditures should be if, for example, tolls cannot be varied with time of day as may be required, or cannot be varied with the distance of the trip, or must be the same for different routes, or must in other ways depart from the optimality criteria. These are the so-called problems of the "second best" in welfare economics applied to the matter of urban transportation pricing. They are more difficult problems than those here considered, but extending the present analysis to them might yield more pertinent results.

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