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URBAN TRANSPORTATION improvements, be they roads or transit, produce benefits and incur costs. Who receives the benefits and who pays the costs is important to policy makers and their constituents.

There seem to be two main issues here: First, how does one determine who benefits from and who pays for urban transportation improvements? This is primarily a problem of technical economics, and it turns out that one needs to know considerably more than who travels and who pays the bills. Both benefits and costs are diffused throughout the urban area by changes in prices of land and other goods and services. Economic parameters such as demand and supply elasticities influence who finally receives benefits and costs, regardless of the initial impact. The second issue is, how can information on the incidence of benefits and costs be used to formulate better urban transportation policies? This is treacherous ground for the analyst, because analysts are not supposed to determine policy goals, especially goals for equity in the distribution of real income. Such goals are based on moral, ethical, and political grounds. Nevertheless, the technical analysis must pay attention to ethical matters, if only to make sure that the right questions are being answered.

ASSESSING THE INCIDENCE OF COSTS AND BENEFITS

Finding out who benefits and who pays starts, of course, with discovering who uses the transportation facility and who pays the bills. This is not an easy task. But even the casual observer recognizes that benefits and costs go beyond the traveler and the bill payer. For example, cheaper and speedier urban travel benefits commuters in the first instance, but may also benefit employers who find it easier to attract workers for any given wage and landlords who are able to command higher rents for offices or dwellings which are now more accessible. Owners and employees of stores, customers of freight haulers (and their customers), vehicle manufacturers and dealers, transit equipment suppliers, transit unions, construction interests, and many others seem to believe that their welfare is connected to transportation improvements, beyond the direct benefits enjoyed by them as transportation users. Similar statements could be made about charges or taxes levied for transportation improvements. Benefits and costs are diffused widely throughout the economy by the price mechanism through changes in prices and quantities of many goods and services.

I do not think anyone yet knows how to comprehensively determine the incidence of benefits and costs of an urban transportation improvement and its financing. Some of the diffusion mechanisms are known, however. These can be illustrated by several parables, each of which has a lesson or two about where to look for receivers and givers. Although the parables are based on well-known models, the implications of the models for the distribution of benefits and costs are not commonly exploited in urban transportation studies.

PARABLE 1: THE COMPETITIVE MARKET

Figure 1 diagrams the competitive market for a hypothetical commodity. Demand is given by curve D (ignore curve D′ for the moment). Supply is initially S_O, resulting in a competitive market equilibrium at price P_O and quantity Q_O.

Now suppose there is a transportation improvement which reduces the producers' cost of shipping the commodity by $2.00 per unit. Assume that there is no other change in the market. From the perspective of buyers and sellers of the commodity, this productivity improvement is analytically equivalent to

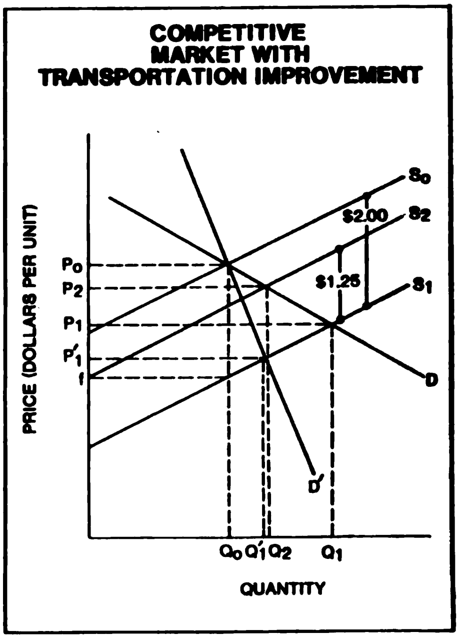

FIGURE 1

Benefits and Costs of Urban Transportation: He Who is Inelastic Receiveth and Other Parables

*by J. Hayden Boyd**

a subsidy of $2.00 per unit, paid to the manufacturers of the commodity. But, it would be incorrect to say that the manufacturers benefit by $2.00 per unit produced.

The effect of the productivity improvement is to shift the supply curve of the commodity downward by $2.00, as shown by the curve S_1. The effect of this increase in supply is to cause the price to fall by something less than $2.00, to P_1. Quantity produced and sold increases to Q_1. Part of the reduction in unit cost is passed forward to consumers in the form of lower prices.

The final incidence of the benefits of the transportation improvement does not depend on whether the customer pays for the transportation or whether the manufacturer pays for the transportation. In either case, the benefit from the unit cost reduction will be distributed in exactly the same way between producer and consumer.

Curve D′ hypothesizes a less elastic demand than curve D. The same $2.00 productivity increase leads to a greater price reduction, to P_1'. Producers get less, and consumers get more, of the benefits. In general, the less elastic is demand, relative to supply, the greater will be the portion of the benefit which will be acquired by the consumer. This suggests that if one wishes to find the final resting place for a benefit (or for a cost), one should look for inelastic demands and supplies. A place to start would be rents to land, since land is the classic "fixed" factor. (I will return to this subject below.) Other candidates could include "essential" travel, specialized labor and capital equipment, etc.

The analysis can be extended beyond the producer and consumer which are a party to the transaction represented in Figure 1. Benefits accruing initially to the producer will be distributed backward along the supply chain among land, labor and capital resources. Benefits accruing to consumers may similarly be shifted. In each case, one would want to look for significant inelasticities along the chain which would progressively siphon off benefits until they decay into significance.

The curve S_2 shows what happens to benefits in our hypothetical market when a user charge equivalent to $1.25 per unit of the commodity is levied on the transportation improvement. From the perspective of producers and consumers of the commodity, the gain from the transport improvement is less than the gain without the user charge. (Of course, the rest of society gains from the user charge revenue.) The reduction in benefits, i.e., the user charge, is distributed between producers and consumers in exactly the same proportion as the original benefits. This result has an important equity implication: even though benefits from transport improvements are diffused widely throughout the economy, user charges on transportation improvements are also distributed in precisely the same proportion throughout the economy. It is not necessary to levy special charges on secondary and tertiary beneficiaries in order to get them to "pay" for "their share" of the transportation improvement.

The same type of model can be used to analyze the shifting of taxes levied to finance mass transportation or highway improvements, such as taxes on property or income. In each case, the ultimate incidence of the tax rests with supplies or demands which are relatively inelastic.

User charges for transportation improvements have efficiency implications as well as equity implications. That is to say, they influence not only who gets the benefits and who pays the costs, but also how large the net benefits are. This issue is illustrated by the next parable.

PARABLE 2: ROAD PRICING

The road pricing model is well known, and need not be developed in detail here. (Excellent expositions of the basic theory are contained in Mohring and Harwitz [7] and Walters [8].) It can be shown that, under conditions typical of urban roads, establishing a price or

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toll on users discourages trips whose value is less than cost to society at the margin, thus increasing the total net benefits from the road. From the increased net benefits must be subtracted the costs of administering and collecting the toll. A more efficient collection mechanism than toll booths, such as automatic metering devices or special area licenses, seems to be necessary to realize the benefits of road pricing.

The revenues from the toll can be conceptualized as consisting of two parts. One part pays the road wear and tear costs, the pollution, noise and other disamenity costs. The remainder is a quasi-rent or return to capital invested in the road. It can be shown that this quasi-rent can be more or less than the amount needed to pay interest and amortization on capacity, depending on whether there are economies of scale in the provision of capacity and depending on whether capacity is larger or smaller than the optimum. [7]

Efficient prices for roads, sometimes labelled "congestion tolls," are controversial, and the distributional consequences of the tolls are a cause for much of this controversy. We would normally expect such tolls to make travel in congested urban areas more expensive, although there is the special case of hypercongestion. In this case, demand for travel is so high relative to the capacity of the road that the road becomes clogged, actually passing fewer slow moving vehicles than its maximum capacity, and it is in principle possible for optimal tolls to reduce the price of travel by speeding up traffic and increasing traffic volume. It is worth noting, however, that even for the "normal" case, the efficient toll would be less than the discrepancy between marginal cost and average variable private cost calculated at current levels of traffic. This is because imposition of the toll reduces vehicle miles of travel.

The price of transportation will be increased more for those travelers who place a low value on their travel time. This fact has led some to conclude that congestion tolls would be regressive. There are offsetting factors, however, such as probable improvements in bus service through faster schedules and more frequent service as some drivers change from automobile travel to bus travel [5]. A more complete analysis of the forward and backward shifting of these tolls would have to be performed, along the lines suggested in the first parable above, in order to establish the net incidence of the tolls. It seems likely, however, that the distribution of the revenues, whether through providing additional government services, reducing other taxes, or increasing transfer payments, would largely determine who actually enjoys the efficiency gains from the toll.

Road pricing should have implications for both transit usage and the pattern of urban development, both of which in turn have their own effects on the distribution of real income in the city. It is the longer run effects which are most controversial. Transit advocates seem to believe that increased prices of automobile travel relative to transit travel would stimulate not only more transit use in the short run, but also future urban development oriented more toward transit. Goldstein and Moses [3] have argued the reverse, that higher prices for auto travel in heavily congested areas (where the private cost of travel is further below the social cost of travel at current charges) would increase the comparative advantage of low density areas relative to high density areas. They see higher charges for road use accelerating the decentralization of cities which causes transit to be at such a disadvantage.

I would conjecture that Goldstein and Moses' result depends on the implicit assumption that the congestion toll revenues are dispersed away from the congested areas where they are collected. If there are efficiency gains from proper pricing, and if these gains are not dissipated to other areas, then congestion pricing may increase the comparative advantage of the priced areas. It should be emphasized, however, that the efficiency and distributional implications of congestion tolls may be different from those of other policies to restrain urban travel by private automobile, such as parking taxes or automobile-free zones.

There are strong reasons to suspect that much of the benefits of reductions in the full cost of transportation accrue ultimately to landowners. The next parables deal with some of the effects of transportation on location rents.

PARABLE 3: THE VON THUENEN MODEL

Von Thuenen developed his model in the 19th Century to explain the value of agricultural land, but the same model applies as well to a city dominated by its core. [4] The central business district, where everyone is assumed to work, is represented by a point, with residences distributed around it. Each residence is assumed to occupy a given amount of land, and the only thing that distinguishes one location from another

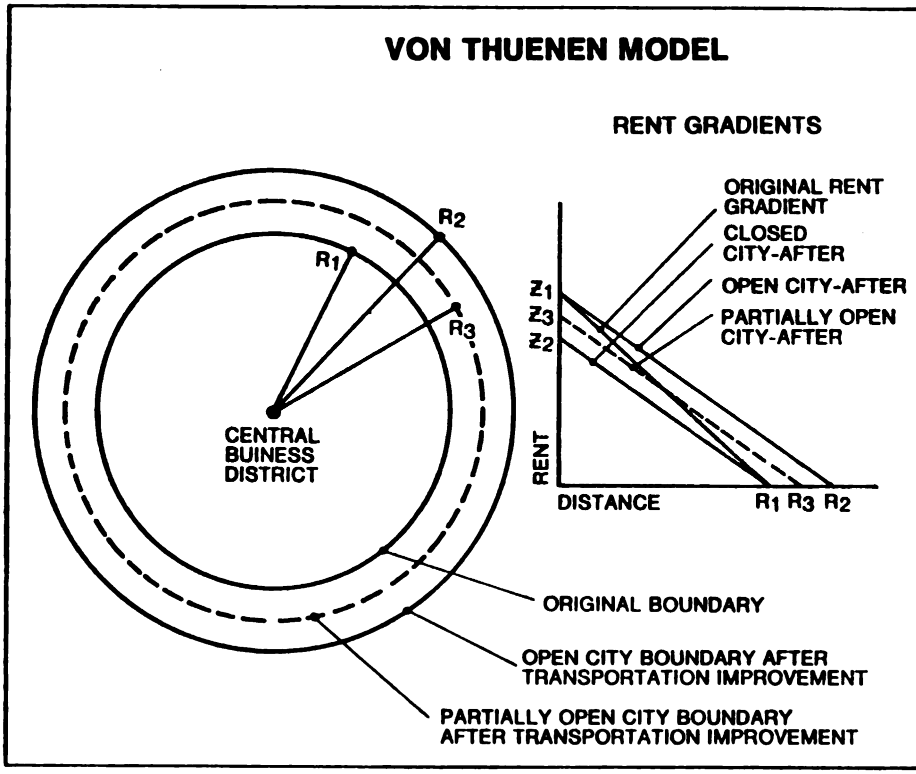

FIGURE 2

is distance and hence transportation cost to the central business district. The resulting city will be circular, as depicted in Figure 2, with a radius of R_1.

Since the only thing that distinguishes one location from another is distance from the CBD, the land market will be in equilibrium when the sum of transport costs and land rent per unit time is equalized for all locations within the city. At the periphery, land rents are zero, while at the core, transportation costs are zero and hence land commands a rent equal to transportation costs to the periphery, assumed to be Z_1. Rent declines linearly from the center to the periphery, such that the sum of transportation costs and land rent is equal to Z_1 at all points.

Suppose that a transportation improvement is introduced which uniformly reduces transportation costs. The effect of this transportation improvement on land rent depends on whether the city is open or closed. For the closed city, population is assumed to be constant, so that the demand for transportation is inelastic. In this case, the effect of the transportation improvement will be to reduce transportation costs to the unchanging periphery from Z_1 to Z_2. Thus, the land rent at the center is reduced, and land rents at every other location are also reduced, as shown by the gradient Z_2R_1. Residents (i.e., travelers) get all of the transportation benefits plus a transfer from landowners.

Suppose next that the city is open. This means that the lower transportation cost attracts population into the city in sufficient numbers to extend the radius to R_2, at which distance the transportation cost is the same as the old transportation cost to the old periphery, Z_1. Transportation demand, in other words, is elastic. Land rents at the center will be the same as before, while land rents at every other location will be increased, as shown by gradient Z_1R_2. The maximum increase in land rents occurs at the old boundary. Residents (travelers) are no better off, and the benefits accrue entirely to landowners.

A more realistic case, intermediate between the closed city and the open city, is the partially open city, represented by the dashed curves in Figure 2. The increased economic attractiveness of living in the city attracts additional population, but not enough population to force transportation costs at the periphery back to the original level. The demand for transportation is neither completely elastic nor completely inelastic. Land rents at the center and near the center are lower than before, while land rents in the outskirts are higher than before. The effect of the transportation improvement in this case is, in part, to redistribute wealth from landowners near the center to landowners further out and, in part, to make residents (travelers) better off.

The preceding analysis assumes that transportation costs the same in any direction, and that the effects of a transportation cost decrease are uniform over the area. In fact, however, transportation improvements typically reduce the cost of transportation to some locations more than to others. This is particularly true for mass transit improvements, but it is also true for road improvements. The effect of transit and highway improvements on the pattern of location rents is examined in the next parable.

PARABLE 4: ACCESS COST RENT GRADIENTS

Many discussions of urban transportation alternatives focus on differences in line-haul speed. Automobile speed might vary from 20 mph on a main street to 60 mph on an urban freeway. Transit speeds might vary from 12 mph for local buses to 18 or 20 mph for older subways to 35 to 45 mph for express bus service or new rail rapid transit systems such as BART and Washington Metro. [1,9]

Variations on the order of two or three to one are not insignificant, but variations in access speed are far greater. A person walking to or from a transit line might cover ground at 3 mph. Since urban travelers seem to value time spent walking and waiting at about three times the rate for time spent in vehicles [1], that walking speed translates to one mile per in-vehicle equivalent hour. A bus feeder might cover 12 mph, to which would have to be added time spent walking to the bus line and waiting for the bus; this out-of-vehicle time would also be valued at a greater rate than in-vehicle time. An automobile might move along surface streets at 20 or more miles per hour. Instead of the three to one variation in line haul time costs per mile, access modes might vary by 20 to one or more.

Figure 3 shows the influence of access mode on land rents. To keep the exposition simple, I have assumed reasonable numerical values for speed, etc., and have ignored other components of cost. This does not significantly affect the conclusions. Both access and egress to the freeway in Figure 3 are by automobile on surface streets. The central business district area and the residential area are each served by an interchange. The concentric circles represent isochron contours of equal access time. The CBD contours are drawn assuming 10 mph speed, while the suburban residential contours are drawn assuming 20 mph speed.

The bottom part of Figure 3 depicts a mass transit line. Two stations are shown, where access is assumed to be by walking and feeder bus respectively. The feeder bus access assumes an average feeder bus speed of 12 mph and walking speed of one mile per in-vehicle equivalent hour, so that the isochron contours are lines with 12:1 slope.

A third alternative transit access mode, by private automobile, is not shown on Figure 3. The contours for transit access by private auto (park and ride, kiss and ride) would resemble those of the top panel except that time to transfer to the transit mode would have to be added. Transfer time would also have to be added from feeder bus to a line-haul mode, unless the feeder vehicle continues on an express busway for the line-haul portion of the trip.

To summarize, the rent surface for automobile access can be visualized as relatively flat. Large areas are included within, say, a ten minute contour. The large supply of accessible land makes low density development economically feasible in the residential area. It also makes low density development economically feasible in the destination area.

In contrast, with the exception of automobile access to the residential area station, the rent gradient surrounding transit stations is much steeper. This is particulary true for the CBD area, where auto egress is presumably impossible. Rent surfaces around transit stations can be visualized as being very sharply peaked, with narrow ridges running out along feeder bus lines. If automobile is the dominant mode for the urban areas as a whole, the influence of outlying transit stations on the rent gradient could be expected to be highly localized. The transit influence on land values would be manifested by sharp peaks projecting above a broader surface determined by automobile access costs. In the CBD, the rent peak could

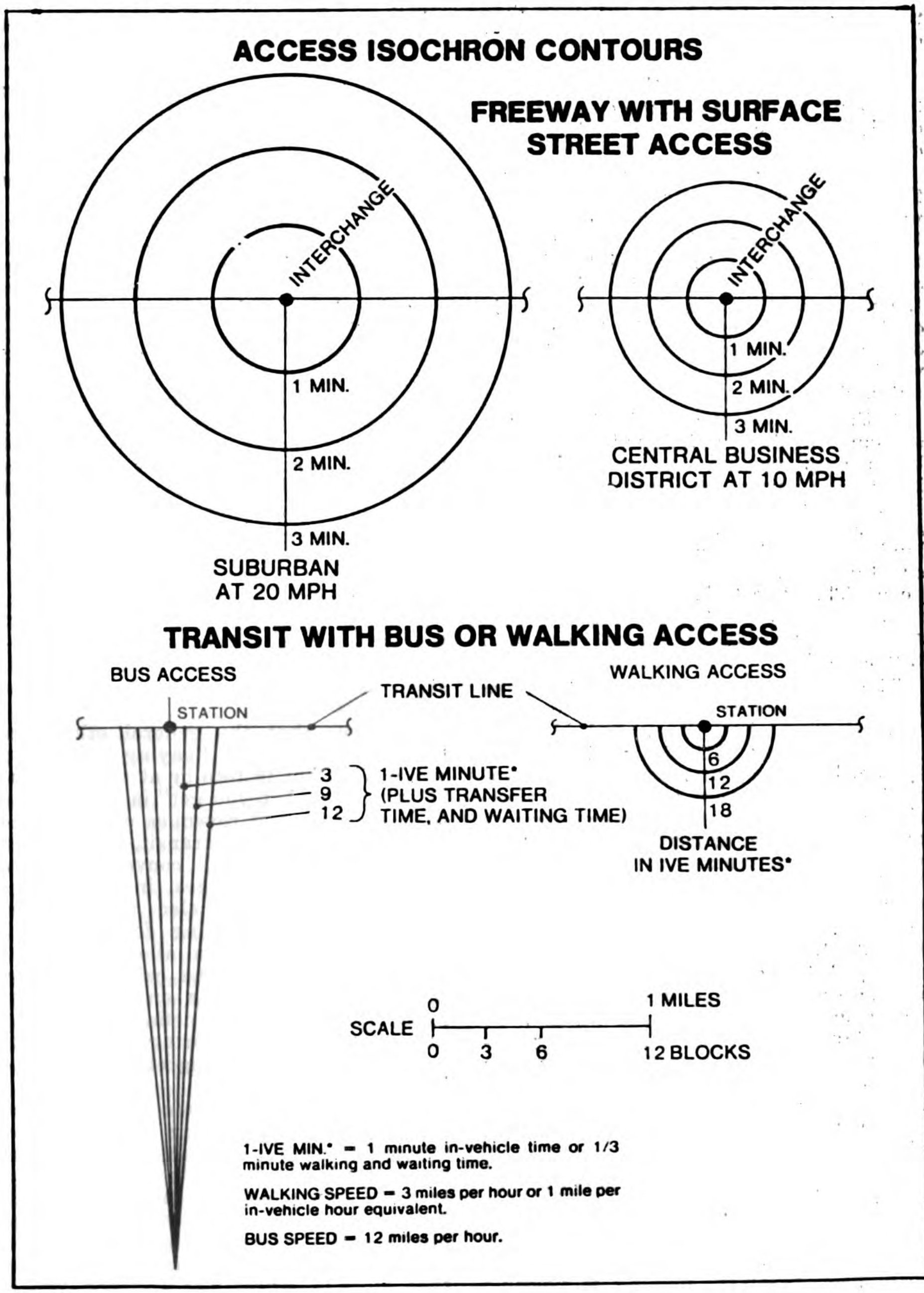
ACCESS ISOCHRON CONTOURS
FREEWAY WITH SURFACE STREET ACCESS
INTERCHANGE
1 MIN.
2 MIN.
3 MIN.
SUBURBAN AT 20 MPH
INTERCHANGE
1 MIN.
2 MIN.
3 MIN.
CENTRAL BUSINESS DISTRICT AT 10 MPH
TRANSIT WITH BUS OR WALKING ACCESS
BUS ACCESS
STATION
TRANSIT LINE
3
9
12
1-IVE MINUTE* (PLUS TRANSFER TIME, AND WAITING TIME)
WALKING ACCESS
STATION
6
12
18
DISTANCE IN IVE MINUTES*
SCALE
0
1 MILES
0
3
6
12 BLOCKS
1-IVE MIN.* = 1 minute in-vehicle time or 1/3 minute walking and waiting time.
WALKING SPEED = 3 miles per hour or 1 mile per in-vehicle hour equivalent.
BUS SPEED = 12 miles per hour.

FIGURE 3

be substantial. Thus, one might conjecture that transit would stimulate high density development in the CBD, around outlying stations and, perhaps, along feeder routes, but that this effect would be highly localized and may not significantly influence the overall metropolitan density.

Property tax financing will influence the net effect of the transportation improvement on land rents differently from user charge financing. Property taxes would tend to reduce the height of the rent surface proportionally across the metropolitan area. Transit fares, in contrast, would affect only those areas dominated by transit. Road use charges would affect those areas dominated by automobile access.

Both the freeway and the transit system involve redistribution among landowners beyond the sort depicted in the third parable. The transportation improvement increases the supply of accessible land, but it also changes some land, namely land around interchanges or stations, to a more accessible category. The effect is much more pronounced for transit than for freeway, assuming roughly equivalent line-haul transportation improvements.

The highly localized benefits from transit improvements is confirmed by a study by Dajani, Egan and McElroy of the planned Atlanta rapid transit system [2]. The authors found that residents of traffic zones located near transit lines and destined for employment near the same transit line benefited relative to residents of traffic zones located away from the transit line, or who were destined to employment in locations not conveniently served by the transit line. The effect of location swamped the effect of average income in the zone. Even so, the analysis was based on averages for areas which were quite large with respect to walking distances (although not for automobile distances), suggesting that a finer-grained analysis might reveal an even stronger influence of location on benefits.

USING INCIDENCE INFORMATION TO FORMULATE POLICY

Suppose, for the sake of argument, that the formidable technical problems have been resolved, making it possible to determine grossly the incidence of benefits and costs of alternative transportation investments and alternative financing arrangements. The question remains, how does one use this information to formulate policy?

It is useful to specify explicitly the social values or ethical norms one has in mind when one assesses the incidence of costs and benefits, to insure that the right questions are being asked. Without attempting to specify what the social ethic ought to be (for each of us has his own ideas and that debate belongs in another forum), I should like to pose a couple of examples and sketch out how one might apply the positive and empirical incidence analysis.

There seems to be general support for a system which correlates reward with effort. The concept of paying for what you get and getting what you pay for has, at least, in our society, some ethical force. User charges for transportation facilities are consistent with this ethic. Congress seems to have had this kind of ethic in mind when it commissioned the highway cost allocation studies in the 1960s, since it asked that both costs attributable to various classes of road users be calculated and that benefits accruing to users and others be assessed. (A major issue seems to have been, and still is, whether trucks were paying a "fair share" for their use of roads.) As we have seen, user charges tend to get diffused throughout the economy in the same way as benefits from transportation improvements, strengthening the case for user charges under this ethic.

I believe that the general ethic can be used to support "paying for what you get" either in toto or at the margin. "Paying for what you get" in toto means to have costs and revenues exactly balance for roads, for transit, etc. There are obvious financial conveniences in arranging user charges in this way. However, there are also well known difficulties in accounting for historical or sunk costs, and in allocating joint costs. Furthermore, the calculations in practice seem to focus on government expenditures narrowly defined and taxes narrowly defined, ignoring various externalities such as congestion and pollution.

"Paying for what you get" at the margin means assessing to the actor the social costs of his action, i.e., those costs which are borne by society if he takes a trip which are not incurred if he decides not to take the trip. Implementing this interpretation of the ethic in this fashion has the added advantage that efficient prices are charged which maximize net benefits. Problems of accounting for historical costs and allocating joint costs are, in principle, eliminated. The difficulty with this interpretation is that total costs and revenues may not balance, either for an individual mode or for urban transportation facilities as a whole.

It would be consistent with the ethic to distribute the surplus, if any, in the affected area. For example, there is evidence to suggest that congestion pricing in urban areas would yield revenues higher than at present, and higher than normally accounted government expenditures for urban roads. [6] If, on the other hand, efficient prices lead to a deficit, then the ethic would support assessing the deficit on those inelastic factors which enjoy the incidence of the benefits. For example, it seems probable that efficient prices for transit would yield revenues insufficient to cover the total costs, so that the ethic would support land taxes on the area most accessible to the transit stations.

A second ethic which seems to have a powerful influence on public policies is the ethic of distributional equity. Many policies seem to be designed to aid the poor, the handicapped, minorities which have been historically discriminated against, and others less fortunate than the average. Mass transit subsidies are often justified partially on grounds of distributional equity. In addition, measures to restrain the price of gasoline are justified as a benefit to lower income workers who would otherwise find it more expensive to drive to their jobs.

Unfortunately, when one looks closely at the market for urban transportation services, it turns out that subsidies to either highways or mass transit are poor ways to help the less well off. The policy that makes gasoline cheaper for the blue collar worker also makes it cheaper for everybody else, including affluent commuters who use considerably more of it. Transit riders, particularly patrons of suburban-CBD systems like BART, often tend not to be poorer than the rest of society. More fundamental, however, is the fact that the person who enjoys a cheaper trip is not necessarily the person who ultimately benefits from the policy. The parables above seem to suggest that this is particularly true for transit, where the steepness of the access cost rent gradient tends to focus benefits on those landowners concentrated around the stations. Thus, if income redistribution to the less fortunate as a group is a goal, there are probably better policies than urban transportation to achieve it.

The analysis could easily be extended to other ethics and other considerations. But the point is made that the incidence analysis ought not to stop with a mere listing, for a single policy choice, of who benefits and who pays and how much.

In conclusion, one might observe that the popularity of "impact studies" with policy makers is not matched by corresponding attention by economic theorists to methodology development. I believe this may be because we economists like to do what we know how to do tolerably well which, in welfare economics, means assessing overall benefits and costs. Policy makers seem to be at least as interested in who acquires these benefits and who bears the costs, and will continue to commission studies using the best available methodologies, even if the best is inadequate. Greater attention by analysts to developing and implementing better methodologies for assessing the incidence of benefits and costs ought to pay dividends in the form of more rational public policies.

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