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Pricing as a Tool in Coordination of Local Transportation

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Use of pricing as a means of obtaining improved utilization of transportation facilities within metropolitan areas has hardly been an outstanding success in the past and, with the increasing share of this function now taken by the private automobile, pricing in recent years has been pushed even further into the background. Yet, now more than ever before, with increasingly vast sums at stake and even the whole pattern of our metropolitan areas likely to be radically affected by the manner in which transportation facilities are to be provided and used, it is becoming essential that the full potentialities of the pricing instrument be developed. That instrument is needed as a means not only of improving utilization of existing facilities in the short run, but also of developing the data essential to intelligent planning for new facilities.

A number of factors conspire to distract attention from the possibilities of using pricing for these ends. One factor is the frequent practice of discussing the subject in terms of aggregates and averages that mask sharp differences in costs and benefits. The differences are particularly sharp in the context of urban transportation, in that important time peaks compound their effects with locational peaks and with wide differences among individuals in the marginal significance of different uses. Another factor has been the relatively high cost and irksomeness of the methods hitherto employed for the direct pricing of specific transportation services. In the absence of reliable data or estimates of elasticities and cross-elasticities of demand, there has been a tendency in transportation planning to ignore price elasticities and to assume that past trends will continue, regardless of what might be done with suitable pricing policies. Particularly with respect to the pricing of roadway use, a long history of relative absence of direct charges, plus a genuine lack of functional need of such charges for use of facilities with a low level of utilization and hence low marginal cost, have tended to cause the potentialities for improvement in this direction to be overlooked. Given only a modest amount of ingenuity, however, it is not too much to say that few significant refinements in the pricing of transportation are now actually beyond reach on purely mechanical grounds.

Estimates of the costs involved in the use of urban streets and highways by private automobiles vary widely. In most cases, not enough firm data are available to pin costs down with great accuracy, but enough is known to indicate that they can reach very high levels, and that fairly drastic pricing procedures could be justified. G. J. Roth (Department of Applied Economics, Cambridge, England) estimates that an optimum tax rate to apply on the basis of traffic data for Cambridge would range from 10 to 21 shillings per hour, or 7 to 22 pence per mile. M. Bruce Johnson (University of Washington) has presented figures suggesting that tax rates of about 5 cents per mile would be appropriate for what are vaguely described as urban arterials at levels of traffic 75 per cent of "mean practical capacity," with sharply higher rates applicable to conditions of heavier traffic. Price tags attached to alternative plans for the Washington, D.C., area for 1980 indicated that, for each additional car brought into the central business district during the rush hour, capital investment in highway facilities, not including parking, would tend to increase by $23,000. In Los Angeles where, among the larger cities, conditions might be thought most favorable for freeway construction, costs of providing for peak traffic range from 3 to 12 cents per vehicle mile. While estimates of this kind vary widely and are all subject to wide ranges of error, they indicate costs sufficiently higher than vehicular charges cover to warrant serious exploration of ways and means of bringing this cost home to the individuals whose choices of transportation patterns give rise to the costs.

Suggestions that drivers on city streets should pay for them on the basis of specific trips have usually been rejected out of hand on the ground that the collection of such charges would be too costly and would cause too much interference with the flow of traffic. Even where tolls are collected for use of bridges, tunnels, and the like, suggestions of adjustment of tolls according to the degree of congestion and the time of day have been rejected, partly because of familiar and established patterns, and partly on the ground that such variation would tend to produce confusion causing further delays at toll-collection points. Recently, however, a number of alternative schemes have been proposed for the collection of such charges, any one of which would perform the job at modest cost and with practically no interference with traffic flow.

One type of system would involve equipping each vehicle with an identification unit which can be scanned by roadside equipment located at zone boundaries so that, whenever a vehicle passed from one zone into another, a record would be made of the identity of the vehicle and the time. The records taken to a central data processing unit for assembling data on particular vehicles would be the basis of billing the owners of vehicles periodically. Bills could be readily itemized to whatever extent the owner requested, so that, if he is a regular user of the highways of an area, he could modify his pattern of highway use according to the charges. In addition, current charges could be indicated by roadside notices or publicized in other ways. A number of different techniques of identification are available, some of which are actually in use for railway, bus, and other kinds of carrier. They include electronic response blocks energized from a scanning beam, small code-signal transmitters connected with the car's ignition switch, reflectorized panels scanned by photoelectric equipment, sequences of slots in an iron bar to be scanned by radar, or photographs of modified license plates with subsequent conversion to digital records by scanning equipment at the central processing bureau. There should be no difficulty in developing one or more of these methods to a satisfactory level of reliability and at reasonable cost.

Another major type of system requires a meter on the car, in most cases, arranged to display a signal visible from the outside to indicate the manner in which it is functioning. In some versions, the meter runs down at a time rate that can be varied according to traffic conditions. In one form, the driver is responsible for setting the meter to a rate indicated by wayside signals, according to time of day or traffic conditions. A slightly more elaborate form of meter would change the rate automatically in response to signals emitted at zone boundaries. Another version could be a meter running down in response to pulses or signals emitted from wayside apparatus, either in the form of pulsed signals blanketing an area or propagated from cables laid lengthwise in the road, or sequences of signals from crosswise antennae or cables. Various ways of resetting the meters can be devised, but perhaps the simplest would be resetting them by the insertion of destructible tokens purchased at service stations. Meters at an attractively low cost have been devised in England, where pricing of highway use has aroused considerable interest.

Such meters have the further advantage of adjustment to function as parking meters; as such, they are more flexible than fixed meters installed at the curb, in that payment is determined ex post and can be more directly apportioned to the time the parking space is occupied. Moreover, it is possible to vary the charge by time of day and even permit vehicle owners, presumably at their own expense, to attach devices which adjust the meter charging rate when a car is left parked over periods covering more than one rate of parking charge.

The cost of even the more expensive of such charging systems should be only a minor sum relative to the cost of the facilities to be controlled. Even for the systems using identification and central processing, the capital cost of the scanning and processing equipment should not come to more than about $20 per car for a moderately large metropolitan area. The identification unit carried by the car may involve a roughly comparable cost. The cost of processing and billing would be roughly comparable to that of accounting and billing for telephone or electric power service. Probably the greatest difficulty would be initial and simultaneous equipment of all cars that use the streets of a particular area more or less regularly.

If granted that some such scheme is a feasible possibility, what would it mean for the coordination of local transportation? The possibilities are indeed far-reaching. The most obvious immediate impact to be expected is a more economical distribution of traffic between the various modes. The imbalance between public transit and private automobile is much greater than would appear from a superficial comparison of over-all costs, and introduction of a flexible pricing system capable of differentiating between peak and off-peak usage can accomplish more than might at first appear. The reason is that public transit usage is much more sharply concentrated in the peak hours than vehicular traffic is, so that if no differentiation between peak and off-peak charges is made for either facility, public transit makes an unduly poor showing. It could be regarded as a form of "cream skimming" on the part of the private automobile.

In extreme cases, failure to distinguish rush-hour and non-rush-hour traffic can completely invert the cost comparison. As a somewhat oversimplified example, suppose a facility of type *M* attracts rush-hour and non-rush-hour passengers at the ratio of 1 to 4, and costs $1.00 for each rush-hour passenger provided for and 20 cents for each nonrush-hour passenger. Suppose also the costs of facility *T* are uniformly 25 per cent less, or 80 and 15 cents, respectively. If costs are figured on an over-all average basis, *M* has a cost of \$1.00 + 4(\$0.20)/5 = \$1.80/5 = \$0.36; for facility *T*, the average cost is \$.075 + \$0.15/2 = \$0.90/2 = \$0.45, on the assumption that for *T* one-half the total traffic is rush-hour traffic. The planner pointing to that calculation might ask why inferior transit service should be provided at a higher cost than the preferred private automobile costs. Transit service is cheaper, however, by 25 cents in the rush hour and 5 cents in the non-rush hour, as appropriately differentiated charges show. If differentiation by time of day is impossible, it would be desirable to have the relative charges on the two facilities at least reflect the direction of the specific cost differentials at the specific times. That could be done by raising the charges on *M* to, say, 45 cents as compared with costs of 36 cents on the average basis, while using the excess revenues to subsidize *T* and make it self-liquidating by lowering the charge to 35 from 45 cents. Ruling out special charges for peak use thus creates an impressive argument for subsidizing public transit at the expense of private vehicular traffic.

One effect of such charges for street use would be to change the relative attractiveness of different forms of mass transportation. Under present conditions, buses are often entangled in the same congestion as private cars are and are further handicapped by their inferior maneuverability. Bus service, then, is not sufficiently convenient relative to use of private cars to attract the volume of traffic required for satisfactory frequency of service and a desirable variety of routes. In the absence of pricing, some form of reserved right-of-way or priority arrangement becomes necessary. In some cases, it is possible to provide a lane reserved exclusively for buses, but usually such a practice encounters difficulties in dealing with intersections and pickup points, and often leads to underutilization of the reserved lanes, since it is seldom possible to schedule just enough bus service for a whole lane of capacity. At best this is only a partial solution. Difficulties with bus service sometimes provide strong arguments for the greater expense of a rail rapid-transit system to provide higher-speed service, even where the volume of traffic might not justify such a facility.

With street use controlled by pricing, however, it is possible to insure that the level of congestion be kept down to the point at which buses will provide a satisfactory level of service. Exclusive rights-of-way, whether reserved lanes or rapid-transit tunnels, need then be provided only where they are genuinely warranted by the high volume of traffic.

Specific charging for street use can also provide conditions more conducive to better adjustment of utilization within modes as well as between modes. For example, much sporadic effort has been spent on promotion of staggered working hours to relieve peak-hour congestion on transportation facilities. However, except in particularly favorable circumstances where governments or a few dominant employers agree to maintain staggered hours, exhortation seems doomed to only partial success unless backed up by some kind of fare differentiation. In the absence of some such mild incentive, so soon as the peak-hour congestion is reduced to moderate levels by staggering, individual employers and employees tend to drift back to the more popular hours, until at least some degree of congestion is re-created. Off-peak fare differentials, even if not sufficient of themselves to initiate any marked degree of staggering, may prove essential to make whatever staggering is achieved by other means stick. In the absence of discriminating pricing applied to private automobiles, however, it may be difficult to raise public transit fares significantly during peak hours without undue increase in use of private automobiles—a situation, worse rather than better. There are thus severe limits to what can be done with peak–off-peak differentials in transit fares in the absence of a corresponding degree of differentiation in highway-user charges.

Much of the coordination provided by differentiated highway charges would be within the private-automobile mode, of course. Rapid vehicular transportation within congested areas—often not now available at any price—would be available for meeting emergency and high-priority needs, when the cost is justified. Even in a community where competition between mass transit and private automobiles is not a factor, pricing of highway usage would have an important function in coordinating the flow of highway traffic. For example, traffic between opposite sides of town often has the choice of going right through the center or of taking a more circuitous by-pass route—frequently competitive routes, even when one or both is not of limited-access type. Left to themselves, cross-town drivers are likely to choose the shorter route through the center, unless it becomes so congested that the longer way around is quicker. Pricing under such circumstances can be of considerable help in decongesting the center and increasing the share of traffic diverted to the relatively less congested and less costly by-pass routes, particularly during rush hours. If pricing cannot be used, the alternatives may be: (1) providing relatively costly and often unsightly facilities through the business center to take care of not only the traffic to and from the center but the through traffic as well; (2) tolerating the persistence of sufficient congestion to discourage the through traffic; (3) or possibly downgrading the design to make through trips artificially awkward, even in off-peak periods and for traffic going only part way through the center.

In the longer run, the availability of such pricing methods might have a fairly profound effect on city planning in general. Patterns of development could be projected on the basis of rational use of the facilities provided, rather than later distortion of plans to adjust to the tendency toward wasteful use of the facilities. While proper pricing of transportation services alone cannot eliminate the externalities involved in urban land use, it can reduce them somewhat. Without eliminating the need for zoning and other direct controls over land use, proper pricing would diminish pressures on determination and administration of zoning rules. Improvements in externalities, otherwise dependent on modification of zoning rules, would be absorbed through the transportation charges.

While many economists may agree that a fairly strong prima facie case for a sophisticated pricing scheme can be built in terms of broad over-all patterns, as outlined above, adoption of such a scheme will not come easily. The novelty of many of its features and the opposition to be expected from individuals and organizations strongly committed to the continuation of present trends are against it. Advocates of pricing must, therefore, spell out in considerable detail what the costs and benefits to be expected are. Such a study could be a means of securing adoption of adequate pricing methods in places like Washington and San Francisco, where pricing seems likely to be critical in determining the pattern of future growth. To determine more accurately how far it would be useful to extend such a scheme to less critical areas, such as Denver or Indianapolis, is also needed. The fact that Cambridge is being seriously considered for an experimental installation in England seems to indicate that there are at least some who feel that the scope for pricing extends to fairly small urban communities.

A more solidly based justification for sophisticated transportation pricing can be obtained only by a fairly elaborate analysis. The data for that are not yet available in the quantity or the form needed, though some information on orders of magnitude is available. In principle, the analysis would be a multistage one. The first stage would be a short-run cost-benefit analysis at the margin in terms of existing conditions; the second, a further short-run cost-benefit analysis in terms of conditions that might be generated by a system of charges at appropriate short-run levels; the third, a long-run cost-benefit analysis in terms of the roadways and other transportation facilities that would be needed without sophisticated pricing, compared with the needs indicated in the presence of sophisticated pricing. Finally, there would have to be a cost-benefit analysis in terms of comparing the cost of sophisticated pricing machinery with the benefits to be derived through more efficient utilization of facilities.

The basic question at the start is, given a system of transportation facilities, what price structure is appropriate? On general welfare-economics grounds, prima facie, the price should be made to vary as closely as possible with the marginal cost and to be at a level at least equal to marginal cost. The margin above marginal cost would be influenced by a number of factors. Among those justifying a margin of price above marginal cost are: (1) the presence of such margins in the prices of commodities and services that compete either on the demand side or on the consumption side of resources; (2) the fact that excess revenues can be used to lower the rates of taxes having a harmful effect in other sectors of the economy; and (3) the likelihood that users of urban-highway facilities during the periods of potential congestion are probably drawn from economic strata somewhat above average, so that excess charges considered as taxes would be moderately progressive in incidence. On the grounds of (3), justification of some slight discrimination in favor of public transit and commercial vehicles against private automobiles might be possible.

Measuring marginal cost of highway use under current conditions is a fairly straightforward problem, although it does involve a certain amount of evaluation of intangibles. While such items as contribution to smog, or added irritation or expenditure of nervous energy resulting from driving in congested traffic are extremely hard to evaluate in monetary equivalents, they are not likely to loom large in the total. Increases per vehicle mile in gasoline consumption, wear and tear on the vehicle, and increases, if any, in losses due to accidents may prove somewhat more amenable to pecuniary evaluation. The largest element of cost in most cases is, however, the delay suffered by vehicles and their occupants.

Measurement of the average amount of delay suffered by vehicles in a traffic stream as a result of congestion is a fairly straightforward procedure, given a well-defined objective and the resources for the necessary observations. Converting it into a pecuniary measure of cost, however, is subject to a considerable range of error. At one extreme, time may mean very little to a rider out for "an hour's spin" and caring little whether the hour covers fifteen miles or thirty, or to the unemployed bus rider with too much leisure. Vehicle time may also be relatively costless if the vehicle is used only for a fixed number of trips per day—by a commuter. On the other hand, the time of the busy executive may be worth a great deal, at least in terms of what he would pay to accelerate his trip. A reduction in time spent in the journey to work may be considered tantamount to a reduction in the gross working day and can thus appropriately be valued at a rate corresponding to the rate of take-home pay. Evaluation at the rate of pay is even more clearly appropriate for those whose travel falls within their working day, as truck-drivers, salesmen, taxi-drivers, or doctors.

Such an evaluation at the rate of pay might be subject to upward or downward adjustment according to whether the time spent in traffic delays is considered more or less irksome than time spent on the job. In any case, it is the average value attributable to a given traffic mix that furnishes the basis for a charge: the joy-rider is not entitled to escape the charge merely because he places no value on his time at the moment. Another element to be taken into account is the dispersion of delays. Under some circumstances, slow-moving traffic is subject to relatively little additional delay up to a certain point, as traffic density increases; faster-moving traffic is held up most severely. On the whole, faster-moving traffic probably has a higher time value than slow-moving traffic has—a reason for using a value-per-minute of delay slightly higher than a strictly statistical average. Another factor is the variability of trip time on different occasions. If trip time is more unpredictable because of interruptions of flow due to heavy traffic, or if interruptions when they do occur are more severe, significant additional cost may be entailed in the adjustment of plans, over and above the increase in average time lost in the traffic flow itself. Individuals may have to leave their origins much earlier in order to be reasonably sure of catching a train, meeting an engagement, or the like. That time would not be indicated by a comparison of average trip times between congested and uncongested conditions. Transit operators may have to schedule longer layovers in their schedules, and passengers may have to wait longer at bus stops and transfer points. These factors only add to the difficulty of evaluation, and data permitting their specific evaluation are almost totally lacking.

All of this would pertain to traffic as currently observed. Also needed is some idea of the circumstances after an equilibrium is reached, with rates justifiable in terms of the traffic conditions generated in response to the imposition of those rates. Here we know relatively little about the elasticity to be expected, either in terms of substitution between modes, between times of day, or in terms of absolute generation or suppression of traffic. Leon Moses has made some estimates of the amount of fare differential that would be necessary to divert passengers from automobile commuting to public transit. He estimated that free transit riding would convert only one-third or less of the present car commuters to public transit riding, while an increase in the cost of car commuting by 60 cents per trip might convert about half the automobile commuters. These figures indicate that the prospects of doing very much by the manipulation of transit fares are very limited. Although the assessment of charges appropriate to the costs would not eliminate the problem, it would put a very considerable dent in the problem of rush hour congestion.

In the longer run, there is the further problem of evaluating the contribution of a sophisticated pricing system in the context of optimal adjustment of the highway and transportation system to the demand, with and without pricing. It is of course conceivable that, even though the cost of a pricing system could be shown to be amply warranted in terms of the short-run situation, it might be cheaper in the long run to construct a slightly too-large highway system than to install a somewhat less costly but essentially nonproductive pricing mechanism. But while such a situation is conceivable, it seems to be rather unlikely. It would require that the elasticity of demand for highway usage be very low at levels of traffic above the optimal but fairly substantial at levels of traffic below optimal.

A complete appraisal of the desirability of pricing requires, nevertheless, that we not only estimate the appropriate levels of charges and the consequences of levying them, in the short run with existing highway facilities, but also the appropriate levels after highway facilities have been adjusted to an optimal level. Here, we are concerned not merely with the short-run cost of additional traffic as measured by costs of congestion borne by fellow motorists, but rather with equilibrating short- and long-run costs. Long-run costs in this case are costs of construction of additional facilities, including in appropriate places, the opportunity cost of devoting land to this rather than to other uses. In an optimal equilibrium, of course, the long-run marginal cost and the short-run cost should be equal. But, since short-run marginal cost is calculated in terms of the traffic conditions at a given time of day, whereas long run marginal cost pertains to the effects of expanding a facility for use throughout the year, equality can be met only in terms of aggregating the short-run marginal cost over a year. This in turn implies use of data pertaining not only to peak-hour traffic levels but also to at least some of the off-peak levels where the marginal cost, though lower than during the peak, is still not negligible. Put in another way, if an estimate is to be made of the long-run marginal cost of peak traffic, it is necessary to credit against the cost of expansion of the facilities' capacity some allowance for benefits from such expansion accruing to off-peak traffic.

To reduce the procedure for analyzing long-run marginal cost to manageable proportions, we can use the constant-elasticity formula for congestion cost, according to which the time taken to travel a given distance is $t = t_0 + aq^k$, where t_0 is the time required to travel a given distance under conditions of very light traffic, q is the volume of traffic in vehicles per hour and a and k are constants. The average congestion cost experienced per vehicle is then $z = t - t_0 = aq^k$, and the marginal cost per vehicle trip is $a(k + 1)q^k = (k + 1)z$ in vehicle hours. Long-run optimum adjustment is then reached when the marginal cost of an addition to capacity is equal to the short-run marginal cost aggregated over all traffic, i.e., $M = \sum_i (k + 1)z_i q_i = \sum_i a(k + 1)q_i^{k+1}$. It may help to think of a "marginal cost per average vehicle,"

$$\bar{x} = (k + 1)\bar{z} = \frac{M}{\sum_i q_i},$$

which is the figure that would be obtained by dividing the cost of an increment of capacity by the total increment of traffic provided for by the increment of capacity at constant degree of congestion. A "peaking factor" can then be constructed which would be the ratio of the marginal cost of peak traffic to the marginal cost per average vehicle. Put in another way, the peaking factor would be the ratio of the proportion of total marginal cost chargeable to a given volume of peak traffic to the proportion this traffic is of the total traffic, i.e., the ratio of the marginal cost for the peak traffic to the marginal cost averaged over all traffic. The peaking factor can then be written,

$$R = \frac{a(k + 1)q_p^{k+1}}{\sum_i a(k + 1)q_i^{k+1}} \frac{\sum_i q_i}{q_p} = \frac{q_p^{k+1}}{\sum_i q_i^{k+1}} \frac{\sum_i q_i}{q_p}.$$

The peaking factor can then be calculated from data on the distribution of traffic flow by time of day, for any given value of k. The value of k will of course vary, being in general lower at lower volumes of traffic and approaching infinity as the capacity of the facility is approached. Data available seem to show, however, that over a range of from about 60 per cent of capacity to about 95 per cent, a fixed value of k can give a remarkably close fit, and it is presumably in this range that the major interest lies. Use of a value of k appropriate to the higher levels of traffic, for the purpose of imputing a share of the marginal cost to the lower levels of traffic, considerably overstates the share absorbed by the lower levels of traffic. Since the amounts involved are in any case very small, this is of little importance to the over-all results. Peaking factors obtained in this way can be applied to over-all incremental cost figures to obtain the appropriate level of charges in the long run.

Applying this method to hourly data for freeways in Los Angeles, New York, and Philadelphia gives values for R ranging from 2.08 to 5.57, for values of k ranging from 3.0 to 4.0, considering various durations of the peak ranging from 5 hours to 15 hours per week, in each direction. Long-range planning, however, would have to allow for the fact that pricing would of itself tend to flatten out the peak and thus substantially reduce the peaking factor. On the other hand, evaluating the desirability of applying the pricing mechanism in a given situation is in effect integrating over the interval running from the optimal situation, without sophisticated pricing, to the optimal situation with such pricing. The relevant peaking factor, therefore, may be some intermediate value between that obtaining under current conditions and that obtaining under ideal conditions, with pricing.

Evaluation of the scope for sophisticated pricing depends not only on demand patterns—both as to degree of peakedness and price elasticity—but also on the relative costs of the installation of the pricing mechanism and of additions to traffic facilities. The costs of the pricing mechanism are necessarily subject to a wide range of uncertainty—owing to almost no relevant experience. In *The Economist* for March 16, 1963, however, there is a report that a British firm has estimated the cost of a meter for a car at from £5 to £10, which certainly suggests the cost of sophisticated pricing is not the prime deterrent. The meter described appears to be operated by roadside signals, and the cost of the roadside equipment is likely to be far less in the aggregate than the cost of the meters themselves—indicating a fairly low-cost system. The question seems to be not so much whether a system exists that would be worthwhile where the need is greatest, but rather whether more highly refined and automatic systems would be worth the extra cost. Since it would be desirable to have a single type of system in operation in different metropolitan areas throughout the country, it may be desirable to have a system slightly less elaborate than would be ideal for the most severely congested metropolitan areas.

In estimating the cost of providing facilities for additional traffic, ranges are wider both relatively and absolutely. More data are available for freeway and expressway construction—where much recent expenditure has been concentrated—than for measures designed to increase the capacity of local street networks. It is somewhat easier, though still difficult, to reduce over-all costs of freeway construction to meaningful common units of measurement. Moreover, to the extent that expressways provide relief for local streets congested with a large share of through traffic, that is the relevant margin.

Costs of freeway construction vary tremendously. Additions proposed in January 1959 for the Maryland suburbs of Washington were to have cost an average of $0.54 million per lane mile; lanes projected at the same time within the District of Columbia were priced at $2.35 million per lane mile; 6.7 miles of projects in Manhatten were priced in 1958 at $38.4 million per route mile, equivalent to at least $5 million per lane mile (for an average of nearly eight lanes). If we assume a charge of 4.5 per cent on the value of the right of way and 6 per cent on construction costs for interest and amortization, and if construction costs are two-thirds of the total, then the charges become 5.5 per cent per year, or about $160 per million per day. Adding $17 per lane mile per day to cover maintenance and control expenditures, we have a daily cost per lane mile ranging from $92 (for a capital cost of $0.5 million per lane mile) to $767 for expressways costing $5 million per lane mile. If we suppose the average daily traffic to run from 5,000 cars per lane on the cheaper facilities (average conditions on four-lane freeways in California) to 20,000 cars per lane on the more expensive facilities (approaching the maximum observed on six- and eight-lane freeways), we get an average cost per vehicle mile of from 1.8 cents for the low-cost facilities to about 3.8 cents on the more expensive facilities. Applying relatively low peaking factors ranging from 2.0 to 3.0, we would get a cost of peak traffic of 3.6 cents per vehicle mile on the lowest-cost facilities, ranging up to 10.8 cents per vehicle mile on high-cost facilities.

Of course, these are average rather than marginal costs, in that we have not allowed for economies of scale in the construction of expressways. A six-lane expressway will not always cost 50 per cent more than a four-lane facility. Alternate routes often produce economies of scale, shortening travel distance and time for some users, plus relief of congestion. Such economies are rapidly becoming exhausted, however, in the New York metropolitan area. We find an extra tube being added to the Lincoln Tunnel, the Throg's Neck bridge is really not much more than a relief for the Whitestone bridge, and expansion is often in the form of additional lanes to existing facilities. Moreover, it appears that more than three lanes bring decreasing returns to scale through increased interference with traffic getting to and from access ramps. Costs increase, too, as the relatively less costly locations are used up.

Enlargement of existing routes provides a concrete illustration of the premature expansion that may be required in the absence of suitable pricing. The scheme of commutation rates for the Lincoln Tunnel actually encouraged a type of traffic concentrated in the peak hours. If the Port of New York Authority had been willing to experiment with a more rational toll structure, postponement of construction of the third tube might have proved desirable. If, for example, the entire annual toll charges incurred as a result of the construction of the third tube were apportioned among users that could not be accommodated on the existing two tubes, selecting for this purpose the users having the least intensive demand at each time of day, the charges might have been too high for those users. If so, it would have been better to dispense with construction of the third tube, adjusting tolls to restrict traffic to the capacity of the existing tubes. Of course, given the political constitution of the Authority, charges of exploitation and failure to cater to the demands of the public would have arisen. Use of the excess revenues to provide better alternative transit service, however, would certainly have been worth considering. On the other hand, given an inability to adjust tolls as described, construction of the tunnel may have been preferable to toleration of the existing facilities.

For local streets of downtown areas, the evaluation of long-run marginal cost is much more difficult; indeed it may be impossible to arrive at meaningful figures. The long run, in the strict sense, is longer than the life of the planners, and determining the optimal street layout (starting from scratch) is only an interesting intellectual exercise with but remote implications for even longest-range policy. Costs of occasional street-widening or -straightening projects should be a stern reminder that, in certain directions, the opportunity cost of street space is very high. At the other extreme, urban redevelopment often involves closing streets and creation of superblocks. Almost every case appears to be *sui generis*, giving little guidance for long-run expectations. Perhaps costs of local street use in downtown areas may be alleviated in the long run by the competition of expressways penetrating close to the center and siphoning off some traffic from local streets.

Arguments against meaningful charges for city-street use are often based on the notion that, in the long-run, marginal and average cost should be roughly equal, and that average cost can be computed on the basis of actual cash outlays for city street construction and maintenance. Charges for a rental value of the space occupied by the streets is dismissed as either already funded through allocation of the street space to public use, or on the ground that the value of the street area is reflected in the market and tax value of the adjacent property. Let us explore in an academic vein the opportunity cost of devoting an additional quantum of land to transportation use rather than to the support of a business activity.

In a Von Thünen-Lösch type of model of spatial economics, every commodity or service has a well-defined shadow price at every point in the space, prices which never differ from one point to another by more than their cost of transport. Firms locate at points where the relation between factor and product prices is most favorable, where there is no cross-haul, and site rents reflect transportation-cost differentials for a firm located at any given point as compared to the next best location for the firm. In such a model, generally, abstracting a piece of land from existing use will cause an increase in transportation cost in conjunction with the displaced activity. The cost can be measured by the amount of rent necessary to bid the land away from the particular use. In such a model, the opportunity cost of land in a given location for use in providing transportation facilities could be determined on the basis of the market rent of the land.

Actual cities are very far from this rational pattern, however. In many economic relationships, prices tend to be blanketed over an area, costs of transportation being borne now by the seller, now by the buyer, or sometimes shared in a rather uncertain manner. A great deal of cross-hauling goes on, most importantly perhaps in moving labor; great numbers of people with comparable skills pass each other going in opposite directions, in many cases those living near the center of the city work in the suburbs. A firm contemplating a move from a low-rent location A to a high-rent location B (or vice versa) is likely to compare the rent differential with the saving in that portion of the transportation costs which is likely to be borne by the firm; this change is likely to be substantially less than the total change in transportation costs resulting from the movement of the firm. In the extreme case of a completely blanketed market and equal sharing of transportation costs between shipper and consignee (or between employer and employee, etc.), the firm would tend to take into account only one-half the saving in total transportation costs in moving from A to B. As a result, the rent differential is likely to be bid up only to half the level that would fully reflect these transportation costs. This fact may be considered as the essence of what is sometimes vaguely referred to as the external economies of the central business district.

If all businesses have roughly the same ratio of area to transportation requirements, the result would not be serious; the only deviation from theory is that rents would be lower than they should be theoretically. To the extent that businesses differ, there will be some maldistribution of business with reference to the minimum transport locations, but the deviations do not seem to be highly systematic. If one business attempts to bid land away from another at the center of the city, the expectation would be—barring wide differences in their transportation requirements—a rough balance between the resulting increase in transportation costs for one business and decreases for the other. (In neither case, however, would all these changes be borne by the firms changing locations.) When space at the center is taken over for transportation purposes and the firm formerly occupying that space is forced to move to the periphery, total costs of the transportation services required by that firm will go up by more than the saving on rent, some of them being shifted to customers and suppliers of the firm. To justify the change for the city, the reduction in costs of transportation resulting from use of more space for it must be substantially greater than the rent the city paid to bid the space away from the firm. Not only would it be proper, then, to charge users of transportation rent for the space utilized equivalent to the rent the space would command if put to commercial use, but actually more than this—in the limiting case of random interrelationships, twice as much.

A city cannot afford to charge nothing for use of central city streets on the ground that they perform an access function, paid for by owners of abutting property in property rents and taxes. It is inappropriate to levy specific charges for use of rural and suburban access streets; but this is because the low level of traffic makes negligible the marginal cost of increased traffic, and not because of an access function. A drawback in charging for use of congested access facilities through property and other taxes is lack of creation of incentive to economize in the use of the congested facility—changing the hours of use, or shifting to a less competitive location for access.

Other proposed methods of pricing to coordinate urban transportation—among them, parking fees, cordon tolls, special licensing arrangements, and others—fail to reach the core of the problem. Its solution depends on provision of a direct incentive to the individual driver to economize in the use of high-cost facilities during periods of peak demand and potential congestion. As competition of the private automobile with other forms of urban transportation increases, a rational solution to the pricing of other competing modes depends on adoption of more rational pricing procedures for the private automobile. Without an adequate solution in this area, no fully satisfactory solution in the other areas is possible.

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COMMENT

HAROLD BARGER, Columbia University

William Vickrey throws down a double challenge: to the engineers and to the politicians. He asks the engineers to devise a plan for metering the use of city streets and he wishes to persuade the politicians to accept what must at best be a complicated and unfamiliar proposal. It seems a pity to opt for these complexities until it is shown that more conventional methods will not achieve the desired result. We have made a beginning with parking meters, but surely tariffs are not nearly high enough. We can tax cars by length and width—the relevant variables—rather than by weight. Instead of subsidizing parking garages, we can tax them. We can levy substantial tolls at the entrances and exits to cities. Finally, if the insurance companies can identify cars used in cities in order to impose higher premiums, city governments equally should be able to levy special taxes on them. The proceeds could be used to subsidize commuter railroads, and even buses and taxicabs. Until measures such as these have proved ineffective, it would appear premature to embrace the complexities of an electronic plan for metering automobile use of city streets.

BRITTON HARRIS, University of Pennsylvania

It is difficult to find any basic point of disagreement with Vickrey's analysis, as far as it goes. The fundamental principles of allocation of resources which he espouses are, quite clearly, economically sound. Considerable wind could be generated discussing his proposed methods of collecting tolls for highway utilization and his illustrative examples of facility costs. I propose rather to take these details as largely illustrative, with the qualification that the analysis and planning of transportation systems within the metropolitan system is substantially more subtle and complicated than Vickrey has suggested. I will explore certain other implications of Vickrey's position which he has, I feel, not treated adequately.

It is by no means clear that Vickrey's proposed policy would have the effects which he seems to seek. The collection of increased user charges for costly and high-grade transportation facilities would, he implies, result in a reduction in the use of these facilities because of the elasticity of demand. Such elasticity is perhaps less than imagined; but more important, any reduction of the utilization of a congested highway facility results in an improvement in the service offered by the facility, and consequently tends to restore demand to previous levels. If, following Vickrey's rigorously economic line of thought, we then extend the construction of such facilities to provide a new level of service until marginal revenue equals marginal cost, the result might be a highway system substantially more extensive than is presently contemplated in most urban areas.

This situation arises because we are presently allocating funds to urban highway construction only up to the point of rather high benefit-cost ratios. Vickrey implies that benefit-cost calculations should be converted into revenue-cost calculations. If, however, revenues are made to equal benefits, if there has been any realism in our benefit-cost analyses, and if these analyses become a guide to investment, it seems likely that Vickrey might be disappointed in the results.

In the Conference discussion following the above remarks, Vickrey conditionally acquiesced to the foregoing, stating that if this came to pass, he would accept such a verdict of consumer choice. Such acquiescence displays that curious stoicism of economists, who are willing to sacrifice personal values, however derived, in defense of a logical position. As an addendum to my discussion at the Conference, let me add a brief extension of my earlier remarks which suggest a way out of this dilemma. In placing his reliance on cost-revenue relationships for transportation alone, Vickrey is exploring the local optimum which may be reached from present metropolitan arrangements. New arrangements and new combinations of factors may have the effect of substantially reducing urban travel demands. The existence, the costs, and the benefits of such arrangements are difficult to establish, and no market for them exists which is comparable to and carries the same conviction as the market for transportation services in which people trade daily. Even more difficult to evaluate are the external effects on neighborhoods and urban life in general of any large program of construction of transportation facilities. These externalities are not negligible and are not excluded from an economic evaluation of the costs of transportation. It is therefore imperative that economists make some contribution to the valuation of such important consequences of metropolitan transportation development—consequences for which, again, no market exists.

MARTIN WOHL, Harvard University

There are many aspects in this paper worthy of discussion, if for no other reason than because they are so often misunderstood. Initially, one must be critical of the fashion in which Professor Vickrey has dealt with the problem of identifying and specifying the objective function; even a perfunctory reading of his paper reveals situations where he is anything but precise and where he intermixes social and economic objectives in a purely subjective fashion. For example, in his discussion of staggered working hours as a means of relieving peak hour congestion, he notes: "Off-peak fare differentials, even if not sufficient of themselves to initiate any marked degree of staggering, may prove essential to make whatever staggering is achieved by other means stick." Obviously Vickrey at least implies that even though economic (or social) gains of reduced congestion to riders are not sufficient to compensate them for whatever losses they must endure as a result of staggered hours, this free choice should be disallowed.

In another place, Vickrey states that it is justifiable to set prices above marginal costs in some situations and that "excess revenues can be used to lower the rates of taxes having a harmful effect in other sectors of the economy." Also, he comments that "the likelihood [is] that those using urban highway facilities during the periods of potential congestion are probably on the whole drawn from economic strata somewhat above average, so that excess charges considered as taxes would be moderately progressive in incidence," and ends by stating that "on this last ground it would probably be possible to justify some slight discrimination in favor of transit and commercial vehicles against private automobiles." Purely aside from the fact that he almost certainly is incorrect in his basic assumption about relative rider-income characteristics, it should be evident that he again is terribly imprecise, judgmental, and subjective in assessing the wisdom of *quasi* value-of-service pricing and certain income transfers.

More importantly, I should like to comment on his numerical example of rush-hour and non-rush-hour costing and pricing, and on his proposed technique for assessing peak-hour marginal costs.

The first example included the following data:

	Facility M (Auto travel)	*Facility T* (Transit travel)
Ratio of rush-hour passenger volume to non-rush-hour passenger volume	1/4	1/1
Cost per rush-hour passenger trip ($)	1.00	0.75
Cost per non-rush-hour passenger trip ($)	0.20	0.15
Average over-all cost per passenger trip ($)	0.36	0.45

Drawing upon these numbers, Vickrey then states,

If differentiation by time of day is impossible, it would be desirable to have the relative charges on the two facilities at least reflect the direction of the specific cost differentials at the specific times. That could be done by raising the charges on *M* to, say, 45 cents as compared with costs of 36 cents on the average basis, while using the excess revenues to subsidize *T* and make it self-liquidating by lowering the charge to 35 from 45 cents. Ruling out special charges for peak use thus creates an impressive argument for subsidizing transit at the expense of vehicular traffic.

That this example and Vickrey's conclusion are absurd should be evident. First, it is clear that differential pricing can easily and cheaply be instituted on transit services; such a scheme would probably divert some peak hour riders to auto (in the absence of differential pricing for autos), would probably permit transit system economies, gain considerable off-peak riders, and reduce unit costs on two counts. But this is the point; years ago transit use during off-peak hours was high, just as the auto today, and the average over-all price and cost for transit was not only low but considerably lower than auto. (In fact, the price of transit service is still usually lower than auto—in spite of Vickrey's assumed numbers—because of transit subsidies of one sort or another.) And despite the lower price of transit travel, many passengers shifted and still continue to shift from transit to auto;

they are shifting simply because of service differentials, and because of their ability and willingness to afford higher-quality service.

The absence of any discussion by Vickrey regarding service offerings or differentials leads one to assume either that he presumes that there are no service differentials (a ridiculous case) or that he presumes that the objective of the transportation expert is to move passenger volumes at the lowest total cost irrespective of the service level and aside from questions of demand and value of higher service.

Furthermore, the volume and cost data used for this example (as well as that applied in the peaking factor examples) can hardly be described as typical, and thus useful for drawing such general conclusions as Vickrey did. Briefly, the modal data which were compared are not equivalent with respect to quality of service, volume, origin-destination pattern, and so forth; thus, the assumed set of ratios and costs was not internally consistent.

As for the proposed technique for determining marginal costs for peak and off-peak travelers, a number of comments are in order. Vickrey states: "Here, we are concerned not merely with the short-run cost of additional traffic as measured by costs of congestion borne by fellow motorists, but rather with equilibrating short- and long-run costs. Long-run costs in this case are costs of construction of additional facilities, including in appropriate places, the opportunity cost of devoting land to this rather than to other uses. In an optimal equilibrium, of course, the long-run marginal cost and the short-run cost should be equal." Thus, he recommends that system capacity be expanded until (aggregated) marginal congestion costs are equal to marginal construction costs, a point of mutual agreement.

However, his technique for allocating the construction costs of additional capacity to peak-hour and off-peak-hour users does considerable violence to this economic precept. Briefly, he derives a "peaking factor" which is supposed to (but does not) represent the ratio of marginal construction costs for peak-hour users to the marginal construction costs for all users, and which is then to be applied to the average construction cost for all users to determine the price for peak-hour travelers. It is important, though, that the peaking factor which Vickrey developed (and which he then applied to some numerical examples in a later section) was based entirely on congestion costs rather than on construction costs.

To be more explicit, Vickrey defined the peaking factor as the marginal congestion cost for peak-hour travelers divided by the sum of the marginal congestion costs for all travelers using the optimum-sized facility. Since marginal construction costs and marginal congestion costs (for a particular facility) are not necessarily equal at all output or volume levels, this *congestion* peaking factor of Vickrey's bears no necessary relationship to the incidence of construction costs. As a consequence, Vickrey's peaking factor technique for allocating construction costs and setting peak and off-peak prices (to recover construction costs) can at best only be termed an approximate value-of-service pricing technique rather than a cost-of-service pricing technique.

The technique would be approximate, if for no other reason than that Vickrey, in developing his peaking factor, has implicitly assumed that congestion cost varies directly with travel time, and thus as travel time (on a particular facility) increases exponentially with traffic volume, so does congestion cost. This assumption is subject to considerable doubt.

In summary, one must support Vickrey in his efforts to improve the utilization of urban transportation facilities through the development of better pricing tools and mechanisms. At the same time, though, one cannot help but be apprehensive on examining the material presented, its technical inaccuracies, and the somewhat subjective and rather biased attitude about the use and application of these tools. In short, Vickrey has not presented differential pricing principles and techniques properly or without regard to the outcome, but has seemingly used them to achieve certain unsupported social objectives. Further, he uses volumes, volume ratios, unit costs, and other related numbers in his examples which are at best atypical and thus improper for arriving at the conclusions which then follow. And, finally, I am most critical of his failure to properly account for service differentials in examining the relative cost structure and implications for auto and transit travel and for continually referring to the development of pricing tools for long-term objectives while using factors, volume and cost data based on existing and not necessarily optimum facilities and services.