PRICING AND RESOURCE ALLOCATION IN TRANSPORTATION AND PUBLIC UTILITIES

PRICING IN URBAN AND SUBURBAN TRANSPORT

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I will begin with the proposition that in no other major area are pricing practices so irrational, so out of date, and so conducive to waste as in urban transportation. Two aspects are particularly deficient: the absence of adequate peak-off differentials and the gross underpricing of some modes relative to others.

In nearly all other operations characterized by peak load problems, at least some attempt is made to differentiate between the rates charged for peak and for off-peak service. Where competition exists, this pattern is enforced by competition: resort hotels have off-season rates; theaters charge more on weekends and less for matinees. Telephone calls are cheaper at night, though I suspect not sufficiently so to promote a fully efficient utilization of the plant. Power rates are varied to a considerable extent according to the measured or the imputed load factor of the consumer, and in some cases, usually for special-purpose uses such as water heating, according to the time of use. In France, this practice is carried out logically by charging according to season and time of day for all consumption but that of the smallest domestic consumers; rate changes at the consumers' meters are triggered by a special frequency signal actuating a tuned relay which connects or disconnects auxiliary registers. But in transportation, such differentiation as exists is usually perverse. Off-peak concessions are virtually unknown in transit. Such concessions as are made in suburban service for "shoppers tickets" and the like are usually relatively small, indeed are often no greater than those available in multitrip tickets not restricted to off-peak riding, and usually result in fares still far above those enjoyed by regular commuters who are predominantly peak-hour passengers.

In the case of suburban railroad fares, the existing pattern is even contrary to what would be most profitable in terms of the relative elasticities of demand. Both on a priori grounds and on the basis of the analysis of the historical experience recently made by Elbert Segelhorat in a forthcoming Columbia dissertation, it is clear that the price elasticity of the off-peak traffic, at current fare levels at least, is substantially higher than that of peak-hour traffic. If, for example, the average suburban family spends $300 per year for commuting and peak-hour trips and $50 per year for occasional off-peak trips and the commutation fares were increased by 5 per cent, causing a 1 per cent drop in this traffic, while off-peak fares were reduced 40 per cent, with a 30 per cent increase in traffic, gross revenues per commuting family would go up from $350.00 to $350.85, with operating costs if anything reduced slightly, since nearly all costs are determined by the peak traffic level. The riding public would on the average be substantially better off: the above typical family, if it maintained the same pattern of usage, would pay only $315 + $30 = $345 instead of $350 as formerly, and any adaptation that it chose to make to the new rates would represent a further benefit, since the alternative of no change would still be open to it if it preferred. Things may not work out quite this neatly in practice, but the potential for substantial gains from even more drastic revisions in the rate structure is certainly there.

Fare collection procedures are sometimes urged as an excuse for not going to a more rational fare structure, but here there has been a deplorable lag behind what a little ingenuity or modern technology makes possible. There would be relatively little difficulty in devising apparatus for collecting subway fares on as elaborate an origin, destination, and time basis as might be desired, simply by dispensing a coded check at the entrance turnstile against the deposit of an interim fare, this check being deposited in an exit turnstile which will then either refund any excess or release only on the deposit of the remainder of the fare. Bus fares represent a problem that has yet to be satisfactorily solved, but considering the vast waste of the time of operators and passengers through delays caused by present fare collection methods, a concerted attack on this problem should yield high dividends. For commuter railroads, the possibility exists of issuing machine-readable subscriber's cards, with passengers making a record of their trips by inserting the card in a register at the origin and destination stations and being billed according to the time, origin, and destination of the trips actually made by the subscriber, his family, and guests. Something like this seems to be in the offing for the new San Francisco system, which in many respects is more of a commuter service than an urban transit system. Actually, it is not even necessary to enclose the stations in order to use such a system: proper registering at the stations can be enforced by dispensing a dated seat check to be displayed during the trip and deposited in registering out at the destination.

Even short of such mechanization, existing ticketing arrangements are needlessly clumsy, involving in many cases a duplication of effort between station agent and conductor and fairly elaborate accounting and auditing procedures. The New York Central has recently taken a step forward in this respect by arranging to mail monthly commutation tickets to patrons and receive payment by mail. Gross delinquency appears to be running appreciably less than the saving in ticket agents' time, and the net credit loss is undoubtedly much less than this, since many who fail to return or pay for their tickets in fact do not use them, as when they die or move away. Another wrinkle worth trying would be the use of a universal form of multiride ticket, to be sold by ticket agents or conductors at a flat price of $5.00 or $10.00, validated for bearer and those accompanying him, with a liberal time limit, for a number of rides or trip units depending on the stations between which it is designated to be used by appropriate punches at time of sale. An off-peak differential could be provided in conjunction with this type of ticket by providing that two units would be charged for an off-peak ride as against three units for a peak-hour ride. The ticket itself, for a typical suburban route, need be no larger than an ordinary playing card. Accounting would be greatly simplified, conductor's cash fare transactions would be both simplified and greatly reduced in number, and the use of the service would become much more convenient for passengers. Such a ticket would provide a more effective off-peak differential than the shoppers' type of ticket, since those who are either going or returning during the peak or are returning at a later date cannot usually avail themselves of such tickets.

But while suburban and transit fare structures are seriously deficient, the pricing of the use of urban streets is all but nonexistent. Superficially, it is often thought that since reported highway expenditures by the state and federal government are roughly balanced by highway tax and license revenues, the motorist is on the whole paying his way. But what is true on the average is far from true of users of the more congested urban streets. Much of the expenditure on such streets is borne by city budgets supported slightly if at all by explicit contributions from highway sources, in most states. More important, much of the real economic cost of providing the space for city streets and highways does not appear in the accounts at all, being concealed by the fact that this space has usually been "dedicated" to the public use at some time in the past. It is extremely difficult to make close evaluations from the scanty and scattered data available, but very roughly it appears to me that if we take the burden of all the gasoline and other vehicular taxes borne by motorists by reason of their use of city streets, this amounts to only about a third of the real economic cost of the facilities they use. In current terms, the high marginal cost of increased street space becomes painfully apparent whenever a street widening scheme is evaluated. Even in terms of long-range planning, urban expressways cost many times as much as expressways in rural areas built to comparable specifications, and while the flow of traffic may be greater, this is not enough to come anywhere near amortizing the cost out of the taxes paid by the traffic flowing over the urban expressways. Even when tolls are charged in conjunction with special features such as bridges or tunnels, these seldom cover the cost of the connecting expressways and city streets. And except where the street layout is exceptionally favorable, such tolls usually have an unfavorable effect on the routing of traffic.

The perversity of present pricing practices is at its height, perhaps, for the East River crossings to Long Island and Brooklyn. Here the peculiar political logic is that the older bridges are in some sense "paid for," and hence must be free, while tolls must be charged on the newer facilities. The result is that considerable traffic is diverted from the newer facilities that have relatively adequate and less congested approaches to the older bridges such as the Manhattan and the Queensboro bridges, which dump their traffic right in the middle of some of the worst congestion in New York. The construction of the proposed expressway across lower Manhattan from the Holland Tunnel to the Manhattan and Williamsburgh bridges would be at least less urgent, if not actually unwarranted, in view of its enormous cost, if, as would seem possible, traffic could be diverted from the Manhattan Bridge to the Brooklyn-Battery tunnel by imposing tolls on the Manhattan and other East River bridges and reducing or removing the toll on the tunnel. The delusion still persists that the primary role of pricing should always be that of financing the service rather than that of promoting economy in its use. In practice there are many alternative ways of financing; but no device can function quite as effectively and smoothly as a properly designed price structure in controlling use and providing a guide to the efficient deployment of capital.

The underpricing of highway services is even more strongly pronounced during peak hours. Even if urban motorists on the average paid the full cost of the urban facilities, rush hour use would still be seriously underpriced; moreover, this underpricing would be relatively more severe than for transit or commutation service. This is because off-peak traffic on the highways and streets is a much larger percentage of the total than is the case for either transit or commutation traffic; and therefore in the process of averaging out the costs, much more of the costs properly attributable to the peak can be shifted to the shoulders of the off-peak traffic than can be thus shifted in the case of transit or commutation service. The effect of this is that while the commutation fare problem is chiefly one of the overpricing of off-peak travel, and to a minor extent if at all one of underpricing of peak travel, the problem of the pricing of automobile travel is chiefly that of remedying the underpricing of peak travel, and to a relatively minor extent if at all of the overpricing of off-peak travel. These two relationships combine to give the result that even if motor traffic and commuter train traffic each on the whole fully paid their way on the basis of a uniform charge per trip, the proportion by which the peak-hour motorist would be subsidized by the off-peak motorists would be far greater than the proportion by which the peak-hour commuter is subsidized by the off-peak commuter.

A quantitative indication of the seriousness of the problem of peak-hour automobile traffic is derivable from some projections made for Washington, D.C. Two alternative programs were developed for taking care of traffic predicted under two alternative conditions, differing chiefly as to the extent to which express transit service would be provided. The additional traffic lanes required for the larger of the two volumes of traffic would be needed almost solely to provide for this added rush hour traffic, the less extensive road system being adequate for the off-peak traffic even at the higher over-all traffic level. Dividing the extra cost by the extra rush hour traffic, it turned out that for each additional car making a daily trip that contributes to the dominant flow, during the peak hour, an additional investment of $23,000 was projected. In other words, a man who bought a $3,000 car for the purpose of driving downtown to work every day would be asking the community, in effect, to match his $3,000 investment with $23,000 from general highway funds. Or if the wage earners in a development were all to drive downtown to work, the investment in highways that this development would require would be of the same order of magnitude as the entire investment in a moderate-sized house for each family. It may be that the affluent society will be able to shoulder such a cost, but even if it could there would seem to be many much more profitable and urgent uses to which sums of this magnitude could be put. And even if we assume that staggering of working hours could spread the peak traffic more or less evenly over three hours, this would still mean $8,000 per daily trip, even though achievement of such staggering would represent an achievement second only to the highway construction itself. At 250 round trips per year, allowing 10 per cent as the gross return which a comparable investment in the private sector would have to earn to cover interest, amortization, and property and corporate income taxes, this amounts to over $3.00 per round trip, or, on a one-hour peak basis, to $9.00 per round trip, if staggering is ruled out. This is over and above costs of maintenance or of provision for parking. When costs threaten to reach such levels, it is high time to think seriously about controlling the use through pricing.

It is sometimes thought that pricing of roadway use would apply chiefly to arterial streets and highways and that it would have no application to streets used mainly for access, which should allegedly be paid for by property taxes on the abutting property to which access is given. But the relevant criterion is not the function performed, but the degree of congestion that would obtain in the absence of pricing. To be sure, there would be little point in levying a specific charge for the use of suburban residential side streets or lightly traveled rural roads, since the congestion added by an increment in traffic is virtually nil in such circumstances and the wear and tear usually negligible. In effect, at these levels of traffic the economies of scale are such that marginal cost is only a small fraction of the average cost. But this does not hold for roadways used for access at the center of a city. A truck making a delivery on a narrow side street may cause as much congestion and delay to others as it would in many miles of running on an arterial highway. Even in the case of a cul-de-sac that is used exclusively for access and carries no through traffic, a firm with frequent deliveries will make access more difficult for his neighbors; only by specific pricing of such use can the firm requiring much access be differentiated from firms requiring relatively little, and encouraged to locate where its activities will be less burdensome to the remainder of the community; or to receive and ship goods at times when less congestion is generated. Some of the worst traffic congestion in New York occurs as a result of the way access is had to firms in the garment district; restrictions on truck size and exhortations have produced only minor improvement. It seems likely that a suitable charge for such use of road space would be more acceptable than an arbitrary and drastic ban, and that with a definite financial incentive methods might be found to avoid the creation of congestion.

But talk of direct and specific charges for roadway use conjures up visions of a clutter of toll booths, an army of toll collectors, and traffic endlessly tangled up in queues. Conventional methods of toll collection are, to be sure, costly in manpower, space, and interference with the smooth flow of traffic. Furthermore, unless the street configuration is exceptionally favorable, tolls often contribute to congestion over parallel routes. However, with a little ingenuity, it is possible to devise methods of charging for the use of the city streets that are relatively inexpensive, produce no interference with the free flow of traffic, and are capable of adjusting the charge in close conformity with variations in costs and traffic conditions. My own fairly elaborate scheme involves equipping all cars with an electronic identifier which hopefully can be produced on a large-scale basis for about $20 each. These blocks would be scanned by roadside equipment at a fairly dense network of cordon points, making a record of the identity of the car; these records would then be taken to a central processing plant once a month and the records assembled on electronic digital computers and bills sent out. Preliminary estimates indicate a total cost of the equipment on a moderately large scale of about $35 per vehicle, including the identifier; the operating cost would be approximately that involved in sending out telephone bills. Bills could be itemized to whatever extent is desired to furnish the owner with a record that would guide him in the further use of his car. In addition, roadside signals could be installed to indicate the current level of charge and enable drivers to shift to less costly routes where these are available.

Other methods have been devised in England, where the country can less well afford the vast outlays demanded by our rubber-tired sacred cow, and where street layouts are such as to make provision for large volumes of vehicular traffic both more costly and more destructive of civic amenities. One scheme suggested for use in a pilot scheme for the town of Cambridge involves the use of identifiers to actuate a tallying register, the rate of tallying being governed by impulses the frequency of which would vary according to the degree of traffic congestion existing in the zone in which the car is reported to be. Another extremely simple and low-cost but less automatic device would consist of a meter installed in each car so as to be visible from outside, which could be wound up by the insertion of a token sold at an appropriate price—the token being subject to inspection through a window and being destroyed when the subsequent token is brought into place. The driver can control the rate at which the meter runs down by a lever or switch which simultaneously displays a signal which will indicate to outside observers the rate currently being charged. The driver is then required to keep this signal set to correspond with the rate in effect in the zone in which he is driving as indicated by appropriate wayside signals. Extremely simple methods of varying the rate at which the meter runs down have been devised in England, which for the time being I must treat as confidential. The rate can appropriately be a time rate rather than a distance rate, since the greater the congestion the greater is the appropriate charge, so that no connection to the wheels is needed and the whole meter can be extremely compact, rugged, and cheap. The chief difficulty with this method is the likelihood that drivers will "forget" to turn the rate of the meter up promptly on entering a higher rate zone, but given a reasonable amount of policing this difficulty might be overcome after an initial period of habituation.

A slightly more elaborate version of this method would call for the changes in the meter rate to be actuated automatically in response to signals emitted from wayside equipment at the boundaries of the various zones. This would probably raise the cost to something above the level of the response block method. On the other hand, both this and the previous method are somewhat better adapted to serving to assess charges for parking as well as for moving about within an area, so that the cost of servicing and installing parking meters could be properly credited against the cost of the new system.

Another version would call for the meter to be run down by pulses emitted from cables laid along the roadway, with the pulse rate varied according to traffic density and other factors. Alternatively, the cables could be arranged to emit continuously and located across the roadway —the number of cables turned on at any one time being varied according to traffic conditions. Reliability of operation can be assured by using two alternative frequencies in alternate cables successively. The cables need not be spaced evenly, but for economy in operation may be placed in groups so that they can be energized from a single source. With either of these methods, any failure of the meter to operate could be checked by requiring the meter to be placed in plain view and arranging for a visible signal to be changed cyclically as the meter is actuated.

Adequate methods for enforcement of each of the schemes seem available which are reasonably simple, with the possible exception of the manual system, where minor negligence might be difficult to check and lead to major negligence. With identifier methods, the registering of the proper vehicle number could be checked by having a few of the detector stations equipped with apparatus to display the number being registered, which could be compared with the license plate by observers. Errors due to malfunction, as well as most fraudulent tampering, would show up as a matter of course during the processing of the records, as each record showing a car entering a zone must match the immediately succeeding record for that car leaving that zone. Cameras can also be arranged at some locations to take pictures of cars not producing a valid response signal. With meters, arrangements can be made to hold used and mutilated tokens in a sealed box; these could be inspected and their number compared with a non-resettable counter with a capacity not likely to be exceeded during the life of the car, as a part of an annual safety inspection program.

Ultimately, one would expect that all cars in an entire country would be equipped with meters or electronic identifiers. Initially, however, it would be necessary to make some provision for cars from other areas. Cars in transit or making infrequent visits to the congested area could be given the freedom of the city in a spirit of hospitality. Cars making a longer stay or more frequent visits would be required to equip themselves—say at cordon points established along the major arteries entering the controlled area. Unequipped cars would be prohibited from using the minor streets crossing the boundary of the controlled area. Such provisions would be particularly easy to enforce with electronic identifier methods: unequipped cars passing major control points would set off a camera; unequipped cars using routes prohibited to them would set off an alarm signal, facilitating their apprehension. With a meter system, checking on unequipped cars would have to be largely a manual operation and would probably be considerably less rigorous. Actually a similar problem occurs at present in enforcing provisions against the use of out-of-state license plates in a given state for longer than a limited period.

Such charging for street use could have a far-reaching impact on the pattern of urban transportation and even on the patterns of land use, by promoting a more economical distribution of traffic between various modes, the various modes being used in accordance with their suitability for the particular trip in the light of the costs involved, instead of, as at present, being chosen to suit the preferences and whims of the individual regardless of the impact on others. Motorists will no longer be manoeuvered into the position of being forced to pay for a luxury that they can ill-afford. Mass transportation will have an opportunity to develop in line with its inherent characteristics, eventually developing a quality and frequency of service that will in many cases be preferred even to the spuriously low-priced private car transportation that might be provided in the absence of a system of specific charges. Traffic-generating activities will tend to be located more rationally in relation to real transportation costs. For example, appropriate transportation charges might have been sufficient to have inhibited the construction of the Pan-American subway-jammer over Grand Central. Rapid vehicular transportation within congested areas, not now available at any price, will be generally available for meeting emergency and high priority needs where the cost is justified. Traffic will be routed more efficiently, so as to provide a smoother functioning of the roadway system as a whole. The levels of charge required to balance marginal cost and marginal benefit in the short run will provide a much more definite and reliable guide than is now available as to where and to what extent the provision of additional facilities can be justified. One can cite, for example, the extra half hour that the airlines have to allow during rush hours for the trip from East 38th Street to Idlewild, in spite of the fact that this route is almost entirely over grade-separated expressways.

One effect of such charging would be to change the relative attractiveness of different forms of mass transportation. Under present conditions, buses are involved in the same traffic tangle as the private car and are often further handicapped by their inferior maneuverability. It is then difficult to make a bus service sufficiently attractive relative to use of a private car to attract a sufficient volume of traffic to make the frequency of service satisfactory. In order to give the transit facility a chance to compete with the private automobile, it becomes necessary to provide some sort of reserved right of way. With buses this in theory takes the form of a lane reserved for them, but in practice this faces formidable problems in dealing with intersections and pickup points, and at best means that the lanes thus provided are likely to be underutilized, since it is seldom desirable to schedule just enough bus service to fully utilize a whole lane of capacity. These difficulties provide a strong argument for going to the very substantial expense of a rail rapid transit system.

With street use controlled by pricing, however, it is possible to insure that the level of congestion is kept down to the point at which buses will provide a satisfactory level of service, and rail rapid transit systems will be required only where a volume of traffic arises that will warrant their high cost on the basis of superior service and operating economies.

But while the most dramatic impact of street use pricing would be to permit the economical allocation of traffic among the various modes, it would be of great importance even in cases where intermodal substitution is not a factor. Even in a community entirely without mass-transit service, street pricing could have an important function to perform. For example, traffic between opposite sides of town often has the choice of going right through the center of town or taking a more circuitous route. Left to itself, this traffic is likely to choose the direct route through the center, unless indeed the center becomes so congested as to make it quicker to go the longer way around. In the absence of pricing, one may be faced with the alternatives of either tolerating the congestion in the center of town, or if it is considered mandatory to provide congestion-free access to the center of town, of providing relatively costly facilities in the center of town adequate to accommodate through traffic as well. With pricing it becomes possible to restrict the use of the center streets to those having no ready alternative and provide for the through traffic on peripheral roadways at much lower cost. Without pricing, bypass routes, though beneficial, often attract only part of the traffic that they should carry for the greatest over-all economy of transport.

Pricing of street use can in the long run have significant effects on the whole pattern of development of urban communities and on property values. While on general principles one can hardly imagine this impact to be other than beneficial, it is a little difficult to discern the net direction in which it would tend—for example, whether the concentration of activity at the center would increase or decrease. In order to gain insight into this problem I have been toying with a model which attempts to incorporate the essential element of choice of route, but in spite of drastically simplified structure and assumptions this model has so far resisted an analytical solution and will probably have to be worked out by simulation and successive approximations on a large electronic computer.

The model is a follows: Consider a community with a system of streets laid out in a circular and radial pattern; for simplicity, assume that the mesh of this network is small enough to be negligible; that is, that we can travel from any point in a radial and in a circumferential direction, but not at an angle. Thus any trip must be made up of radial segments and circular arcs. In effect, we assume perfect divisibility of road space, or that the capacity of a street is directly proportional to its width. In the neighborhood of any given point at a radius r from the center, a proportion of $w(r)$ of the area is devoted to streets, the remainder being devoted to business activities that generate one unit of traffic for each unit of net area; i.e., one unit of gross area originates and terminates $[1 - w(r)]$ units of traffic. The traffic originating at any one point has destinations distributed at random over the remainder of the business area; i.e., any tendency of related businesses to group themselves close together is neglected. The average cost of transportation per ton-mile (or passenger-mile) is given by some functional relation in which the density of traffic per unit roadway width is an argument. For example, we may put $x = A + B\ (t/w)^k$, where t is the volume of traffic in tons per hour and w is the width of the roadway in feet, A, B, and k being constants. A may be thought of as the operating cost of the vehicle, where the volume of traffic is negligible, the second term being the additional costs experienced due to delays resulting from congestion; k is the elasticity of this congestion cost, which can be thought of as being proportional to the number of added minutes required to cover a given distance as compared to the time required in the absence of conflicting traffic. A relation of this form was found to fit data from the Lincoln tunnel extremely well up to close to the point where a queue begins to accumulate, with a value of k of about 4.5, so that the marginal congestion cost is some $k + 1 = 5.5$ times the average congestion cost per vehicle. In other words, according to this data, an individual who has to take ten minutes longer to make a given trip than he would if there were no interference from other traffic causes 45 vehicle minutes of delay in the aggregate to other vehicles with whose movements he interferes. Unfortunately, comparable data for the more interesting case of travel over a network of city streets could not be found, but something of this order of magnitude is generally to be expected.

It can readily be shown that optimum allocation of the street space in a given small area between radial traffic and circular traffic calls for the space to be allocated in proportion to the traffic so that the average and marginal costs are the same in both directions. We can thus combine the circular traffic and the radial traffic and speak of the relation of costs to traffic in terms of aggregate ton-miles of traffic in both directions per acre of street area. Thus the cost per ton-mile can be taken to be $x = A + B(t/w)^k$, with x in cents per ton-mile, t in ton-miles per gross acre of land, and w the fraction of the land devoted to streets, in the particular neighborhood.

Given the density of traffic as a function of r, it is possible to determine the least-cost route for any given trip on an average cost basis in which the shipper bears only the delay costs experienced by him, and alternatively on a marginal cost basis where he must pay in addition a toll corresponding to the delay his trip imposes on others. By imposing the condition that the traffic distribution thus generated shall be one which produces the cost structure leading to the traffic distribution, one gets a differential equation which in principle can be solved to give equilibrium traffic patterns. The cost of this equilibrium traffic pattern can then be integrated over the entire area to give the total cost of transportation, and this can be done both for the marginal cost case and the average cost case to get the total saving in transportation cost over a given street network brought about by the pricing of street use.

Unfortunately, the differential equation that results is of the second order and third degree, and I suspect does not admit of an analytical solution in terms of well-known functions. The next step is recourse to solution of specific cases by successive approximations.

As a by-product of this calculation, one could then also derive the equilibrium rentals that would be paid by businesses at various distances from the center, on the assumption that rental differentials would correspond to the differentials in the costs of transportation borne by the business; because of the symmetry of origins and destinations, it would make no essential difference whether shipping costs were borne entirely by shipper, entirely by consignee, or shared between them.

A further step in the analysis would be to take total cost as determined by the distribution $w(r)$ of land between business and transportation uses at various distances from the center and treat this as a calculus of variations problem of choosing the function $w(r)$ so as to minimize the total cost of transportation. In this way one could compare the pattern of land allocation that would be optimal without pricing to that which would be optimal with pricing. Considering the complexity of the problem, I hesitate to make any guesses as to the nature of this difference, except to speculate that it is likely to be somewhat surprising to many of us.

I will wind up by laying before you one final piece of unfinished business, which is the problem of developing criteria for determining how much of the area in a particular neighborhood should be devoted to transportation, given the pattern of rents in the area. Conventional cost benefit analysis, if employed here at all, would tend to take the form of comparing the rent which private business would pay for the space with the reduction in transportation cost which would result from increasing the area used for transportation and decreasing the effective density of traffic. But in connection with the present model, this rule fails to yield optimal results. Let us imagine, to make things a little more explicit, that a Comprehensive Transportation Authority stood ready to rent or lease land, to be converted from or to transportation use, to or from private business, at a price reflecting the marginal productivity of land area in a particular location in reducing the total cost of carrying out a given number of ton-miles of traffic within a given neighborood. In terms of our cost formula, the rental would be given by the partial derivative of total cost per unit area xt, with respect to changes in the proportion of total area devoted to transportation, w, the density of traffic t remaining unchanged. Thus:

$$-\frac{\partial(xt)}{\partial W}=\frac{-\partial}{\partial w}\,(At+Bt^{k+1}w^{-k})\;=\;+\,kBt^{k+1}w^{-k-1}.$$

A business will then move to a higher rent location only if the saving in transportation costs borne by the particular business is greater than the difference in rent. However, since transportation costs are in this model borne in part by the firms with which a given firm deals, only half of the change in the transportation costs of the goods he receives and ships resulting from his change in location will be felt directly by the firm making the change, so that on the whole a firm will fail to move unless the saving in the costs of the shipments to and from the firm is twice as great as the net increment in the costs of transportation resulting from the reapportionment of the space devoted to transportation. In other words, the conventional cost-benefit analysis in terms of going rents has a strong tendency to leave business uneconomically dispersed and to result in too much space in the center of the city being devoted to transportation.

This conclusion is derived from an admittedly highly simplified model, which neglects such factors as the clustering of interrelated firms, the wide variations in the ratio of land to transportation requirements of various activities, and the possibilities for creating additional space by construction of multistory buildings, or for that matter, multilevel highways. But the model can plead not guilty to the charge of having ignored the journey to work and other passenger transportation, for, input-output analysis style, we can regard labor as the product of the household sector, and, Clayton Act to the contrary notwithstanding, as an article of commerce with a peculiarly high transport cost. The essential difference between this model and classical space economics models such as those of Von Thunen is that the latter imply a well-defined shadow price for each commodity at each point in the space, with transport taking place only between points where the price differential balances the transportation cost, whereas the present model allows for crosshauling and a certain amount of particularism in the relations between economic units. The real world presumably lies somewhere in between these two extremes. Study of journey-to-work patterns seems generally to reveal a situation a fairly long way from the Von Thunen extreme, with a great deal of crosshauling of labor of roughly comparable skill. According to this, a cost benefit analysis can justify devoting land to transportation only when the savings in transportation costs yield a return considerably greater than the gross rentals, including taxes, that private business would be willing to pay for the space. This in turn means that an even greater preference should be given to space economizing modes of transport than would be indicated by rent and tax levels. And our rubber-shod sacred cow is a ravenously space-hungry, shall I say, monster?