Methodology for Evaluating Costs and Benefits of Alternative Urban Transportation Systems*

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•INCREASING traffic congestion, growing inadequacy of parking space, and problems of urban blight which can be solved only through wholesale rebuilding are combining in cities all over the world today to focus attention, among other aspects of urban planning, on the role of transportation systems. The physical means of getting people to and from work, school, stores, health, recreational facilities, etc., as well as the means of delivering and dispatching goods to and from factories, warehouses, retail outlets, and final consumers, both individual and commercial, is increasingly coming to be recognized not only as an accessory service somehow to be grafted upon city plans, but as an organic factor in determining the design, character, and rate of a city's growth. More than that, transportation is also being increasingly recognized as one of the factors in urban living that carries with it some of the largest costs, both tangible and intangible as well as correspondingly large potential for economic and social benefit. It is no wonder, therefore, that engineers, economists, and city planners are increasingly being called upon to give systematic consideration to the question of how new transportation systems may be designed—and old ones revamped—to provide the maximum in benefit at the minimum in cost.

ALTERNATIVES, SOLUTIONS, AND GROUPS AT INTEREST

Nature of the Alternatives

The basic alternatives which are provided by present-day technology are not too numerous. Private automobile, bus, and truck traffic moving over city streets and highways is the most widespread type of movement. Rail rapid transit (subway, surface, and elevated) is fairly common in large cities. Limited-stop rail commuter service, either self-propelled or locomotive-drawn, is also to be found in many large metropolitan regions. And in a few places, aerial service (by helicopter or other aircraft) has also appeared.

For most cities, the practical choices are limited. Air service, for example, can make little practical dent on the mass transportation problem. Suburban commuter lines are of possible interest only for areas which have a string of suburbs. And such high-investment facilities as subway and elevated lines may be rejected a priori where there is no potential for very high passenger volumes.

Yet even where the basic choices are limited, there is a large number of alternatives for the analyst to contend with. Take automotive traffic alone, for example. There is the question of balance between public and private vehicles. There is the question of whether the public vehicles should be large (buses), small (jitneys), or available for

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charter hire (taxies). There is the question of which and how many routes should be served and of whether (and where) the public vehicles should sometimes have their own rights-of-way. There is the question of what motive power should be used (electricity, gasoline, or diesel) and of whether the public interest requires the use of anti-pollutant devices. There are questions of fares to be charged, and of frequency and hours of service. There is the question of the street and highway capacity to be provided—how many vehicles it should be designed to move, at what speed, and with what "delay" (e.g., entrance queuing) time. There is the question of whether construction designs should lean toward high-investment, low-maintenance alternatives or toward low investment with high maintenance, of what weight-loads they should be built to carry, and of what adversities of rain, snow, and storm they should be able to withstand.

As if it were not enough to face this multiplicity of subalternatives, there is the fact that within any one city, and frequently within any one traffic "corridor" of any one city, two or more of the principal alternatives, as well as all manner of subalternatives, may be combined in an infinite number of proportions.

Nature of the Solutions

Conceptually it should be possible, for any given city (or for any given "detachable" sector) to work out a "minimax" solution for the total transportation question, i.e., to minimize all things bad ("costs") and to maximize all things good ("benefits"). Despite the problems of finding common denominators for tangibles and intangibles, the problems of dealing with benefits to some that are costs to others, and the problems of allowing suitably different values for current, deferred, and "sunk" costs and benefits, as well as the sheer mathematical problem of combining all relevant elements into a single matrix, we do not doubt that some day the efforts that are being made here and there to arrive at an adequate comprehensive logical solution will bear fruit, and that eventually (with the help of modern computers) the models will be both solvable and sufficiently pragmatic to be believable. Until that day, however, we are forced to fall back on the method of instinct (or experience), practical parameter (political judgment), and trial and error.

What we discuss in this paper has to do with only a limited aspect of this last-described method, the manner of conducting the trial. Boiled down to its essentials, the method involves hypothesizing two or more alternative solutions to any given transportation planning problem. Initially, these solutions will be designed out of the accumulated experience of the planners as to which are the prime purposes to be met and which is the most economical, adequate way to meet them. The solutions will also be so designed and delimited that it may reasonably be assumed that, sooner or later, those who have the power to do so will wish to put them into practical effect. At this point, the cost/benefit analysis described in this paper takes over. Its principal purpose is to set forth, in systematic fashion, the costs and benefits of each given alternative to each of three major elements in the community. By thus detailing who is hurt and who benefited, in what respect and in what amount, by each of the alternatives, it permits at the very least an immediate choice among them, based on whom the choosers would most care to favor. More importantly, however, it gives clues (and the more numerous the alternatives the better it can do this) as to how to hypothesize better alternatives. Conceivably it might also point to the approach which clearly produces the most for all at the least cost to all, but barring a rare homogeneity of community interest, this is really too much to be hoped for.

The Groups at Interest

For the same reason that the sum total of workers, consumers, investors, etc., in a community adds up to far more than 100 percent, so the total of the three major groups with an interest in the solution of urban transportation problems also is more than 100 percent; however, it does not quite reach 300 percent. For the sake of simplicity, we refer to these groups, respectively, as "users," "operators," and the "general public." Defining their deliminations is anything but simple, however, and even more so is defining the character of their interests.

Users. —Who is a transportation user? Clearly, anyone who stirs outside of his abode, even if it is only a public walkway which is his transportation facility. True enough, when we examine the costs and benefits of "Transportation Alternative A" we are concerned primarily with the users of the facility or facilities specifically described therein. But we cannot stop there. If the facility were of a slightly different character, perhaps more people would use it, or less. Or it may produce benefits for users of a different facility, by relieving some of the strain upon it. In short, we cannot define the user group for Transportation Alternative A without expressing that alternative in terms of a transportation purpose to be served, rather than in terms merely of a set of facilities. And we must compare all of the alternatives under examination upon the same basis. For example, if the comparison is between different means, say a road and a rail line, for transporting "x" number of persons from A to B, we must examine each of the alternatives in terms of all of the persons traveling from A to B, whether they use either of the means specifically described, or neither.

Some of the problems of defining the user group for a specific comparison are immediately apparent. One alternative may have wider repercussions than another. If the transportation goal being served is defined too narrowly, conclusions may be vitiated by the user interests omitted. If it is defined too broadly, it may comprehend the interests of users on whom one or more of the alternatives may have no effect.

The circumsciption has to be at once geographical, functional, and seasonal. Here is where instinct and experience first come in. The greatest single transportation need in any large city is that of the daily journey to work. Provide for it, and in nearly every case you have provided more than adequately for all other transportation purposes, even if only by relieving the strain on otherwise-oriented facilities. Ascribe all costs to it, and you have allocated costs where there is the clearest benefit.

Singling out the daily journey to work automatically leads to the choice, for analytical purposes, of the days and the seasons of most "normal" travel. The problem of choosing which journeyers to work still remains. For some purposes, and to some extent for all purposes, the planner will wish to examine the effect of a set of transportation alternatives on the journey to work of all inhabitants of a city or metropolitan area as a whole. But the initial practical approach, in most cases, has to be in terms of a major pathway of movement, as defined by empirically determined volumes of movement and as shown graphically by the thickest lines on a traffic flow map. In the typical city, with its one strip or core of major employment concentration, these lines are like rivers flowing down to a sea, each with its own "watershed." By the thickness of the streams, one may identify the "natural" boundaries between watersheds. Each such watershed, or transportation "corridor," then becomes a basis for comparison among the present and proposed transportation alternatives that are hypothesized to serve it. The erratic streams that cut across "divides" will also have to be considered in due course, but the corridor is almost always the logical starting point.

Operators. —The role of operator is not always a clearly identifiable one. Take a private busline, or a self-supporting public one, and there is no difficulty: the operator is the entity that makes the outlays, collects the revenues, and pockets the difference. Suppose, however, the general public is involved, either marginally (as when a facility such as a rapid transit system is to some extent subsidized) or fully (as in the case of a public highway); who then is the operator?

For our purposes, we need a generic definition. The operator is that entity or conglomeration which pays the money costs attached to any given facility and which pockets any directly allocable revenue. Users of a particular facility may also, in another guise, be operators, and the two kinds of costs they bear must be distinguished one from the other. For example, the user of a city subway will pay a fare, which is his cost qua user; at the same time, part of his taxes may go to make up the current deficit, and this is his cost qua operator.

Special problems attach to the situation, normal in the United States, where the costs for some facilities are shared by a number of jurisdictions and the revenue collections are attached in varying degrees to the individual facilities. Who are the operators of facilities which are financed in whole or in part out of general revenues and/or out of gasoline taxes? In appraising the costs and benefits of a particular community's project, is it legitimate to consider only the costs and benefits to the taxpayers of the community itself, or should one take a geographically broader class of taxpayers into account? Are highway fund dollars allocated to a particular transportation project, a cost thereof, or a benefit?

The Community. —It should be apparent that wherever public expenditures and revenues are involved, there is a large measure of identity between operator interests and the community's interests. Unless taxpayers and community are to be regarded as one and the same, however, the identity is not complete. The community is no less diverse a collection of interests for transportation purposes than it is for any other, and the only real solution for cost/benefit analysis is to describe which community elements are either hurt or benefited, in what manner, and in what degree. It is for policy makers, not analysts, to determine the desirable mixture of pain and profit.

The questions of "who" and "in what degree" are complicated by the fact that much of the impact of transportation alternatives is either difficult or impossible to measure in dollars and cents. For example, while some monetary cost may be ascribed to air pollution, how is one to value permanent lung damage, and is one person's lung damage more costly than another's? How does one take account of the progressively lighter (generally) incidence of air pollution as one moves out from the center and form the major highways? Is a 50-mph broad expressway better or worse than a 30-mph narrow road with trees? How many million dollars of alternative construction costs equate with the nuisance value of a mile of elevated monorail? Difficult as it may be, giving form to intangibles like these is an essential part of cost/benefit analysis.

Even where quantitive values may more readily be attached, the impact on the community must still be defined in terms of specific groups. A new highway or a new subway raises land values along its route, but what does it do to values in areas not so favored? Is it a benefit to those who have to pay higher rents? How does one deal with the differential impact of alternative transportation designs on density of residence and consequently on cost of water and sewerage installations; is this a benefit to water-users (assuming a charge is made) or to the community at large? It is easy, in cost/benefit analysis, to gloss over distinctions like these.

TIME, COSTS, AND OPPORTUNITY

We have discussed the nature of the groups at interest. We have referred to the fact that comparisons of costs and benefits, with respect to any one of these groups, must relate to the identical transportation service for each of the alternatives (e.g., the weekday journey to work) if the comparison is to be valid. We come now to the central questions of the meaning of "cost" and of "benefit."

It is in the decision on what costs and what benefits are relevant, and by what yardstick to measure them that, in the minds of the authors, much cost/benefit analysis goes astray. At the risk of appearing elemental, therefore, this section devotes some attention to fundamental concepts of economic measurement. The sections that follow will go more specifically into the costs and benefits of particular relevance to users, operators, and the community at large.

It is hardly revolutionary to state that the real measure of cost (and frequently of benefit) is "opportunity." A cost is an opportunity foregone; a benefit may be a cost avoided. A benefit may also be measured in terms of income, or contribution to income; that increment of income to which the transportation source is essential is a measure of its opportunity value. Cost, conversely, may be a benefit foregone.

Measures such as these are neither easy to apply nor easy to communicate. However, even if deviation is expedient from time to time, the opportunity concept is the best single guide to sound analysis.

One of the most fundamental guidelines that flows from the opportunity orientation is that all cost/benefit analysis should be incremental analysis. We must start from what exists. The costs and benefits of alternative proposals are not the total operating costs or the total current benefits of those proposals, but what those proposals will add or subtract.

A corollary concept is that of sunk costs. Build a bridge, for example, and its costs go on forever. They are terminated neither by the final amortization of the bond issue that financed it nor by the physical demise of the structure. Only to the extent that there is some final salvage value can it be said that any part of the cost ceases.

What, then, is the proper cost measure for a proposed capital expenditure? Not the interest on the corresponding debt. Not the estimated annual physical depreciation. And certainly not, although one may find numerous examples of such "costing," total debt service and depreciation combined. The cost can be measured, in fact, only by the cost of money to the entity who pays it, and it is a cost which goes on year after year, ad infinitum, unless and until the physical capital can be sold and some part of the cost thereby recovered.

Deferred Costs

Fortunately for getting bridges and highways built, the practical man is quite aware that a dollar spent tomorrow has less value than a dollar spent today, so that even infinity has a practical limit. Aside from their irrevocability, the continuing interest (or imputed-interest) costs on today's expenditures are of a piece with the repair and maintenance and other current operating costs implied by any capital expenditure. The more that any of these costs may be deferred into the future (by postponing the expenditure) the less of a cost it becomes. How much less depends upon the opportunity cost of money in the area and to the operator who makes the expenditure.

Interest rates in a particular area become a doubly important factor, therefore, in decisions on whether to adopt a capital-intensive or a deferred-expenditure solution to any transportation problem. Not only do interest rates determine the continuing level of sunk-cost expense, but they also determine the extent to which far-future costs may be equated with near-future costs. Considering the former effect alone, Lang and Soberman (1) calculated in one example that the difference between a 4 and a 5 percent interest rate raised the unit cost per passenger mile of a rapid transit system by 7 percent. For a system with triple the construction cost, the unit cost increase of 1 percent higher interest was more than 14 percent. When this effect is coupled with the fact that

TABLE 1

COMPARATIVE OUTLAY OVER 20-YEAR PERIOD
(Data in tens of thousands of dollars)

Year	$100,000 Facility						$50,000 Facility					
	Interest on Sunk Costs		Current Maint., Etc.[a]		Total Fixed Cost		Interest on Sunk Costs		Current Maint., Etc.[a]		Total Fixed Cost	
	Current Value	Year "0" Value	Current Value	Year "0" Value	Current Value	Year "0" Value	Current Value	Year "0" Value	Current Value	Year "0" Value	Current Value	Year "0" Value
1	10.0	9.1	1.0	0.9	11.0	10.0	5.0	4.5	5.0	4.5	10.0	9.1
2	10.0	8.3	1.5	1.2	11.5	9.5	5.0	4.1	5.2	4.3	10.2	8.4
3	10.0	7.5	2.0	1.5	12.0	9.0	5.0	3.8	5.4	4.1	10.4	7.8
4	10.0	6.8	2.5	1.7	12.5	8.5	5.0	3.4	5.6	3.8	10.6	7.2
5	10.0	6.2	3.0	1.9	13.0	8.1	5.0	3.1	5.8	3.6	10.8	6.7
6	10.0	5.6	3.5	2.0	13.5	7.6	5.0	2.8	6.0	3.4	11.0	6.2
7	10.0	5.1	4.0	2.1	14.0	7.2	5.0	2.6	6.2	3.2	11.2	5.7
8	10.0	4.7	4.5	2.1	14.5	6.8	5.0	2.3	6.4	3.0	11.4	5.3
9	10.0	4.2	5.0	2.1	15.0	6.4	5.0	2.1	6.6	2.8	11.6	4.9
10	10.0	3.9	5.5	2.1	15.5	6.0	5.0	1.9	6.8	2.6	11.8	4.5
11	10.0	3.5	6.0	2.1	16.0	5.6	5.0	1.8	7.0	2.5	12.0	4.2
12	10.0	3.2	6.5	2.1	16.5	5.3	5.0	1.6	7.5	2.4	12.5	4.0
13	10.0	2.9	7.0	2.0	17.0	4.9	5.0	1.4	8.0	2.3	13.0	3.8
14	10.0	2.6	7.5	2.0	17.5	4.6	5.0	1.3	8.5	2.2	13.5	3.6
15	10.0	2.4	8.0	1.9	18.0	4.3	5.0	1.2	9.0	2.2	14.0	3.4
16	10.0	2.2	8.5	1.8	18.5	4.0	5.0	1.1	9.5	2.1	14.5	3.2
17	10.0	2.0	9.0	1.8	19.0	3.8	5.0	1.0	10.0	2.0	15.0	3.0
18	10.0	1.8	9.5	1.7	19.5	3.5	5.0	0.9	10.5	1.9	15.5	2.8
19	10.0	1.6	10.0	1.6	20.0	3.3	5.0	0.8	11.0	1.8	16.0	2.6
20	10.0	1.5	10.5	1.6	20.5	3.0	5.0	0.7	12.0	1.8	17.0	2.5
Totals	200.0	85.1	115.0	36.2	315.0	121.4	100.0	42.4	152.0	56.5	252.0	98.9

[a]Including additions and improvements.

Note: Minor discrepancies in addition are due to rounding.

maintenance, repair, and improvement costs generally start low and then trend upward over the life of a given facility, the desirability of low-investment solutions in a high-interest country becomes quite apparent.

One hypothetical example may serve to illustrate. Assume that the same transportation purpose will be equally served by a $100,000 facility with a scale of annual expenditures for maintenance, repairs, and improvement trending upward from $1,000, and by a $50,000 facility with annual maintenance, etc., trending, more flatly, upward from $5,000. Assume also an interest rate of 10 percent. Over 20 years, the comparative outlay would be approximately as given in Table 1.

In Table 1, the 20-yr crude total of the first alternative is 25 percent higher than that of the second alternative; it would appear to take an interest rate of as little as 3 percent to make the first alternative the cheaper. On a discounted cost (present-value) basis, the table shows very little difference overall: the first alternative is, for a 20-yr projection, 23 percent more costly. However, on the latter basis it may be calculated that approximately a 4 percent interest rate is the approximate indifference point. Change the configuration of maintenance and improvement costs to one in which the high-investment alternative gave even greater benefits in deferred maintenance and the low-investment alternative required a more rapid expenditure for improvements (e.g., addition of lanes), and an even higher prevailing interest rate would equate the two.

Table 1 is actually incomplete. For by the same token that the original capital expenditure is a sunk cost which involves a continuing "interest" burden, so is every subsequent cost, including the accrual of interest costs themselves. Each year's cost, in other words, should be compounded. In this particular instance a rough calculation suggests that the refinement would have no significant effect upon the relative costs of the two alternatives. Similarly, although the calculated totals would be different for a period of 30 years, or 40, instead of 20, the outlook again is for no substantial effect upon the relative standing of the two alternatives. Thus, in carrying out cost/benefit comparisons along these lines, the analyst will in each case have to decide—largely by inspection and by trial and error—how much refinement is necessary to a valid comparative conclusion.

As a practical matter, the usual way in which such a table would be set up is by time periods, say, of 5 or 10 years each, for comparison with the basic benefits to be secured (a certain level of a specific kind of transportation service) during each of these periods. Both costs and benefits would be calculated on either an average or an aggregate basis for each such time period.

GOALS AND INSURANCE

We have stated that alternatives should be compared for an identical transportation service, for example, a certain volume of journey-to-work traffic. Establishing this goal is one of the major elements in cost/benefit analysis and crucial to its validity.

Planners are well aware of the fundamental fact that transportation plans are not devised for today's traffic requirements, but for those in the future. It is not infrequent, however, that a single target date is picked as the measure of the requirement, and all design and comparisons based on that. Moreover, that single date may have attached to it but one projection of the potential demand, with no indication of how reliable the estimate and the quantitative range within which it may err. In cost/benefit analysis, this can lead to serious error.

As a practical matter, it is not possible to attach any mathematical probability to projections, for one can know neither the degree of validity of the hypotheses nor the extent of dependence or interdependence of each of the chain of factors leading to the final results. As a substitute, however, one can follow out the implications of several sets of hypotheses, each designed to give a plausible, but different result. It is particularly useful to work with a medium, high, and low. All of these should be well within the range of substantial probability, and the high should be as nearly equal in probability with the low as judgment can make it. The high and the low, compared with the judgment, or medium projection, then become rough indicators of the direction and extent of possible error.

Just as important as having a range is to have projections not just for one specific target date, but for each of a series of successive subperiods which add up to the total period of time—20, 30, 40, etc., years—in respect to which the competing alternatives are to be judged. It is only by thus setting up our analysis that we can begin to evaluate an important aspect of costs and benefits, namely, the "premium" cost of insurance against error and the corresponding benefit in terms of elimination of risk.

Premiums and Risk

Let us suppose that we have accurately added up all of the tangible and intangible costs of putting into effect a given transportation alternative, and that we have also accurately added up all of the benefits over and above meeting the assumed transportation service objective. There is still one important omission—the costs or benefits of having provided for a service objective which is either too high or too low. Since high-investment, long-life facilities have differing degrees of overprovision, period by period, from lower-investment, more flexible alternatives, it is only by taking successive readings that we can ascertain the true costs.

A characteristic of alternative transportation designs that enters into the picture is their differing lead times. The system which has to be built now in terms of a given estimate of demand in 1975 is obviously more costly in this respect than the system which can start adapting to meet it in 1970. Against this must be balanced the contingent cost of adaptation or of shortfall.

When we speak, therefore, of comparing alternative transportation systems against a common standard of transportation service, we do not necessarily mean that each system must provide the identical capacity. Each type of service has its own most economical time-phasing, in terms of its flexibility and cost of upward and downward adjustment. Differing economies of construction scale and of right-of-way acquisition are among the factors to be considered. It is best to examine independently each basic alternative, in terms of its costs of achieving low, medium, and high capacities, in each of several forward time periods, selecting that progression of construction which will differ least from the costs of meeting the projected low while minimizing the contingent costs of having to adapt to the medium or, with appropriate discount, to the high.

COSTS AND BENEFITS TO TRANSPORTATION USERS

At this point we may consider some of the specific kinds of costs and benefits that apply to each of the three groups which were previously defined. The first of these is transportation users.

The principal benefit to transportation users, obviously, is the basic transportation service provided. Usually this may be considered in terms of an extension of capacity. Let us say, for example, that we are considering the addition to a particular transportation corridor of either a new, four-lane highway or a rail rapid transit system. As already suggested, the objective with which either of these has to be matched is the phased net addition of a certain amount of capacity, time period by time period. By definition, either alternative will provide the same basic user benefit. It is thus only in the quality of the service provided by each alternative and in the respective costs to the users that differential user cost/benefits are to be found. And since each kind of addition will have a different effect upon the whole complex of transportation services offered, we must look not only at the specific increment as such, but at the changes it brings about in the qualities and costs of the whole transportation service offered.

The nature of these other qualitative and cost aspects is apparent enough; their quantitative evaluation is something else again. Travel time is a cost, but is it the same cost to all users? Comfort is a benefit, but how much is it worth? For the user who pays a fare, the money cost of transportation is clear, but how about the man who drives an automobile? Should the journey to work be costed marginally or ratably? Or should it bear all of the overhead?

It is not uncommon for economists to postulate the rational man and assume that the scale of costs and benefits to transportation users can be evaluated in this light. A private transportation company would hardly take these kinds of liberties with the customers. Rational or irrational, the scale of values of each transportation user is a personal one and the cost/benefit analyst has a duty to respect it.

Before he can work with such factors, however, the analyst must know what the personal preferences of transportation users really are. Hence, the importance of suitable field surveys.

Such adverse concomitants of public transit as having to stand, bumpiness of ride, waiting, walking to transit (especially in inclement weather), and lack of cleanliness are among the factors which incline some people to use private automobiles, even if they recognize an extra cost. On the other hand, irritations due to traffic congestion and difficulty in finding parking space (which often requires the automobile rider to walk some distance to his place of work) are among factors which recent surveys have shown incline automobile riders to switch to subways or commuter trains where available. There are limits, however; at least one survey turned up 8 percent of automobile riders who would not abandon that form of transportation come what may. And cost differentials will retain some part of the market for public transit customers no matter how bad the service.

The question arises whether, in cost/benefit analysis carried on for public policy purposes, these relative traveler values are a pertinent consideration. It may well be that a minimization of the time consumed in getting to work and that a certain degree of physical comfort are both in the public interest, insofar as they tend to maximize general productivity and morale. The public measurement of the benefit may be far different from the private one, however, especially as it affects different traveling groups.

Yet the preferences of individuals, and especially their indifference points with respect to various costs and amenities, are of paramount importance to the planners of transportation systems. An alternative transportation plan which depends upon a distribution of ridership among modes in a way in which individuals with free choice will not distribute themselves is not a real alternative. Consumer preferences, therefore, really are an element in feasibility analysis. Such analysis, at least in preliminary form, should precede cost/benefit analysis and thus insure that consideration is being given to practical proposals.

One should start with a set of projections of patronage, under different assumptions of user-charge, service level, and aggregate transportation demand, for each of the specific kinds of transportation which form part of a possible transportation alternative. For tentative reasons of community interest, which can then be verified in the course of cost/benefit analysis, one can assume charges which are more or less than actual cost in order to achieve a given patronage level, but otherwise (and especially in the case of private operators) the equating of costs and charges would seem to be a priori the most desirable policy. Howsoever the pricing, the marginal user of each facility will presumably be equating his private costs and benefits. Pricing in accordance with economic cost will minimize the aggregate accrual to others of economic surplus.

One might add that the element of publicly established penalty or subsidy, particularly for automotive transportation, is frequently difficult to identify. License fees and gasoline taxes may or may not equate, jurisdiction by jurisdiction, with the street and highway facilities provided. Public central-city parking (especially street parking) may be priced far below the opportunity cost justified by the particular location. And the public at large may be bearing a cost in air pollution, noise, and aesthetic discomfort toward which the automotive-vehicle user pays nothing.

COSTS AND BENEFITS TO OPERATORS

The considerations here are rather different as between privately operated facilities and those operated by a public authority. The public at large can have only marginal interest, if any, in providing a surplus of benefit to a private operator, and it cannot long impose on him a surplus of cost without having either to forego or to take over the facility.

When the public operates a facility, it can take into consideration costs and benefits external to the facility itself. If one thinks of the operator of a public facility as the community's taxpayers, it is plain that the kind of facility which results in higher tax collections, or lower costs for some other public service, may provide a balance of benefits over costs even if the facility as such does not pay for itself.

There is, however, a common element in all systems, whose separate examination leads to more knowledgeable policy decisions. There is a core—whether one has in mind, say, a transit system or a system of highways—which consists on the one hand of certain expenses and on the other hand of certain directly-allocable user charges. Public or private, such an entity may be separately examined as an economic unit, and its deficit or surplus position determined.

We discussed some of the aspects of costing capital expenditures and maintenance and improvement of facilities. The fundamental criterion for capital items was the interest, or opportunity, cost of capital employed, and we pointed out that this manner of costing logically may be applied as well to annual, as to initial, costs, provided they are big enough to make any material difference. The latter is consistent with normal private accounting practice, which capitalizes alterations and additions, while expensing repairs and maintenance, though the distinction is frequently quite arbitrary. In connection with capital employed, the private operator is likely to be concerned only with the opportunity cost of his own equity capital, and to regard interest on borrowed funds as an expense; but for a public operator, and for general economic analysis, it is the average cost of all capital employed which is pertinent.

We have pointedly omitted reference to capital consumption or depreciation which, for transportation facilities particularly is probably far surpassed by obsolescence. Both of these are taken as a cost in private accounting practice, and are allowed to varying degrees by income tax authorities and by the public utility commissions which enforce a fair rate of return. One must remember, however, that any such depreciation and obsolescence allowance must also be deducted from the current capital base.

Given our indefinitely-continuing sunk cost concept, allowance on top of that for obsolescence or depreciation would be double-counting. If we are to choose the other kind of costing, we must make a deduction year by year for the diminution of capital employed. To deal only with sunk costs and ignore the capital consumption seems preferable, however, and more in line with economic reality. No cash passes hands by reason of the annual capital write-off, and neither the public nor the private operator has any less investment to cover. The amount of write-off has no relationship to the actual annual cost of continuing the investment and the money invested is not recovered just because the write-off is 100 percent. Thus, the indefinitely accruing, but time-discounted, money-cost seems the better measure, with obsolescence being reflected instead in the forward estimates of revenues derived from patronage.

There are, of course, other costs besides capital costs, including all of the fuel, labor, and operating expenses that are familiar in utility accounting. There are also current revenues to be taken into account, and it is quite legitimate to deduct from prospective capital employed any cash surplus that is projected to be available either to private or to public operators for withdrawal from the business.

Highway Costs and Benefits

The allocable costs and benefits of a highway enterprise are ordinarily most difficult to estimate. Except for toll roads, the public authorities which operate streets and highways make their collections from the users indirectly, through gasoline taxes, license fees, and fines, rather than on and for the occasion of a specific use. Moreover, in the United States at least, drivers may be utilizing the roadways of jurisdictions A, B, and C in far different proportions from those in which they are paying taxes to the same jurisdictions. Also in the United States a large part of gasoline tax collections goes to the Federal Government, which then re-transfers them according to various formulas to the states; hence, it is not at all clear what, for any given community, constitutes an allocable user charge. Undoubtedly there are similar situations in other countries.

Under the circumstances, it is more practical simply to attach income, as well as expense, to the existence of the projected facility, rather than regarding the revenues as attributable to specific users.

To do this one must estimate what the particular road or highway increment under consideration is likely to mean in terms of increased vehicle mileage resulting in taxes collectible by the particular jurisdiction, as well as what transfer funds from other jurisdictions may be obtained for and on the basis of the increment's construction. (Or construction grant funds obtained elsewhere may, even more logically, be regarded as a diminution of the capital employed by the community-operator.)

One sort of question that arises is whether the particular increment of facilities pays for itself. The question is especially pertinent to the provision of peak-hour additions to the highway network in comparison with the addition of rail transit to satisfy the same requirement (assuming, for the moment, the feasibility of shifting patronage either way). Since the extra highway facilities would not be needed except for the peak-hour commuters, it is obvious that the entire cost must be charged to this group. Whether this cost is covered by corresponding revenue or whether, as there is some reason to suspect, peak-hour highway commuters are subsidized by other highway users, may be determined from a projection of the additional vehicle-miles which would not be traveled were the extra lanes not available. Since gasoline consumption may be estimated from vehicle-mileage and gasoline tax collections from gasoline consumption, a calculation of the allocable revenues may thus be made.

In assessing highway costs, it is important not to overlook certain peripheral costs that are a necessary adjunct to a highway's utilization. Through-highway capacity is useless, for example, without the local streets which feed into it and take off from it; increased capacity for one may demand an increased capacity for the other. There are also additional costs of policing and traffic control and possibly of general administration. If the community-operator undertakes to provide parking facilities at less than cost, this, too, must be taken into consideration.

Mass transportation systems may also involve some of these peripheral costs (such as policing and administration) which are not met by the operation as such. Moreover, whenever one deals with a bus or street car system, or any other system that makes use of public facilities not directly entering into its accounts, the community as operator of the relevant public facilities finds itself as partner-operator of the particular transportation mode and must enter the differential costs of the relevant public facilities into the operator cost/benefit analysis.

There is still another set of transportation-system costs and benefits to the taxpaying element of a community, that which stems from the impact of systems, or additions to systems, on the community's taxable base.

COSTS AND BENEFITS TO THE COMMUNITY

There is no homogeneity within each of the various groups concerned with transportation system costs and benefits. This is particularly true of the community. In the discussion which follows, when we speak of the impact on the community, we may be glossing over any number of distinctions which are quite critical to actual policy decisions. This is necessary for purposes of general discussion. In any specific situation, the analyst will have to be specific about who is affected, and to what extent, by the kinds of impact set forth.

There are four major ways in which a planned transportation increment may affect the community: (a) in terms of general pattern of community growth; (b) in terms of public revenue and expenditure; (c) in terms of direct income; and (d) in terms of environmental conditions. These aspects are heavily interrelated, but it is convenient to discuss them separately.

Community Growth Pattern

It may be thought that transportation facilitites respond to the demands of community growth, and to a large extent this it true. More importantly, however, they help to determine the pattern of that growth.

A community which provides an extensive system of roads and highways of the type which permit high-speed automobile travel is a community which will grow extensively. One may expect an emphasis on one-family homes, the spread of suburbs, and decentralization of shopping, cultural activities, and much business and industry. The community which discourages automobile travel but provides efficient rapid transit as a substitute is likely to be more closely concentrated, with multiple-family and high-rise residential structures, and a more active central core. The community which provides an adequacy of neither is likely to find its overall growth stunted.

There are numerous variations. For example, both highways and mass transportation facilities may be planned so as to provide clearly detached radial corridors. Development will be extensive, heaviest along the corridors, yet centrally oriented. Provide connecting belts and there will be faster filling in of the space between the radials, plus a greater shift of commercial and business facilities to the suburbs.

A mass transportation facility provided early in the development of a particular area may generate its own traffic in terms of close-by high-density residential construction; one provided later may have forfeited its clientele to low-density development, regardless of whether or not adequate road facilities have also been built.

Quite apart from economics, there are both positive and negative values which may be attached to different kinds of community organization. These values will vary from community to community. Where one community values dispersed living, another will be more interested in easy access to metropolitan-quality theaters and sports arenas. One will prefer growth and differentiation; another exclusivity and uniformity. More importantly, different elements in a community may have different views as to the most desirable urban configuration. It will be up to the analyst in each case to determine to what extent the furtherance or hindrance of any of these values attaches as a benefit or a cost to a particular transportation proposal.

Public Revenue and Expenditures

It is not uncommon, in analyzing the impact of a proposed transportation improvement, to estimate the increases in land values along its path and count the improvement as an addition to the community's taxable real estate base. On this basis, kinds of transportation additions which result in more concentrated development (such as subways) tend to be attributed larger benefits than additions of equivalent capacity which lead to less concentrated development. The practice is dubious, for any influence which simply places the location of development in one area rather than another, or concentrates rather than disperses it, is likely to produce somewhat higher land values in one area only at the expense of somewhat lower values elsewhere. For one system to be attributed more of a contribution to the tax base than another, it has to be shown either that it results in a volume of urban occupancy or activity which is greater in total, or that value of land and structure use per person or per unit of activity is greater in one kind of location/density arrangement than another.

At this point one must also note that what is a benefit to the community in revenue terms may not be a benefit to it in other terms. It is possible, of course, that if a given kind of development results in higher land value per unit of activity or per resident than another, this is exactly balanced by a locational saving. But it is also possible that competitive bidding for some land areas may run up their values to the point of displacing former users who are then forced into less advantageous combinations of cost and location. This is a typical consequence of urban renewal or of the opening up of metropolitan transportation to formerly detached rural settlements. It is also possible, where the effect is to encourage more extensive use of outlying land, that the community may gain increased tax base only at the cost of losing to present development land which is highly valuable for future recreational and other public needs.

Another aspect of competitive transportation systems which affects tax revenue is the relative land consumption of the facilities themselves. Nearly all transportation facilities predominanty or wholly involve public rights-of-way rather than taxable land and thus bring in little or no real estate revenue. By economizing on the use of land, buses compared with private automobiles, and rail transit compared with automotive, should leave that much more land (especially in valuable downtown areas) available for taxation. Except, however, where the total land available to an urban community is limited (by the presence of competing jurisdictions on the boundaries or otherwise), one cannot be certain, as in the case of along-the-route impact, that displaced activities may not occupy equally valuable (though more extensive) parcels of land elsewhere. As a rough guide, however, one can assume that the kinds of transportation development that raise the proportion of land occupied by highways and streets to the total of all occupied land in the municipality do detract from the revenue-expenditure balance in comparison with kinds of developments which keep the proportion lower.

Community Income

One of the ways in which transportation systems act differentially on urban finances is in their differential impact on community income. Here, too, however, what serves to increase tax collections is not necessarily of real income advantage to the community's residents.

The clearest case of advantage is the kind of differential transportation development that attracts to the community more income-producing activity per capita. Growth as such may mean more income in the aggregate and higher tax collections, but unless it is on a par with what already exists it may mean even faster increases in community expenditures.

In monetary terms, increased transportation facilities themselves create more income (and more tax revenue), but in real terms exactly the opposite may be the effect. If the average urban dweller is to ride a half-hour for 50 cents where before he traveled 15 minutes for 25 cents (or walked, at no monetary cost) can it be said that he is any the wealthier for it? He may be, if he has gained some net locational advantage, but more likely is the fact that sheer extensivity of growth has created for the average person a greater real cost. Similarly, comparing two proposed transportation systems, the one designed for longer travel distances at higher cost and the other for shorter distances at lower cost, it does not follow that the higher dollar income producer is the more beneficial.

Other things being equal, it may be said that the transportation alternative which minimizes average travel time is the superior contributor to community real income. Other things may easily not be equal, if one alternative also inhibits more than another the pursuit of some other personal income value. Nonetheless, the productivity of the average person's day is clearly higher if he need spend less of that day in routine travel, and the aggregate productivity is a multiple of the average. Similarly, other things being equal, the system which provides the greater degree of per capita comfort and health is also the most productive system for the community as a whole. Thus, there is an identity between certain user benefits and the general community good, and to this extent, it may be in the community interest not to exact a corresponding user charge.

Another important aspect in which there is an identity between user and community benefit is that of relative freedom from accidents. Judging by insurance costs, systems differ markedly in this respect: typical United States costs per thousand passenger miles are $8.00 for private automobile travel, $1.70 for buses, and less than $0.80 for subways. These costs already suppose an impressively large countervailing expenditure in the form of safety campaigns, policing, road hazard elimination, special driver training, etc. To the extent that there is still an accident incidence, the community is doubly hit, both in the necessity for hospital and other accident-relief expenditures and in the lost productivity of the individuals involved, not to mention the incidental property losses.

Environmental Aspects

Finally, there is a whole series of environmental costs and benefits which directly affect not the individual transportation user, but broader segments of the community. They involve such relatively tangible factors as health and welfare and such quite intangible factors as aesthetics and other forms of psychic income or expense.

Different transportation means are quite different in their contribution to environmental health hazards. The most notable contributor, in urban areas, is the automotive vehicle, and one must take account, in any cost/benefit analysis, of the relative pollutant effect per passenger carried of an automobile as against a bus, of a gasoline engine as against a diesel. The particular regulatory antidotes which are possible will affect the cost/benefit appraisal in any given situation, as will the relative density of vehicular movement and varying climatic conditions.

Different transportation means are also different in their contribution to noise levels, exclusion of sunlight, pedestrian hazards, and other factors bearing upon health of city dwellers and workers.

Air pollution, noise, vibration, etc., can also be hazards to property and result in economic loss directly. Some authorities contend that property damages caused by air pollution in the United States average $65 per capita annually, of which about 80 percent, or $52 per capita, is attributable to automotive exhaust. These damages take the form of accelerated corrosion, and damage by dirt or dust to buildings, furniture, machinery, tools, and other items.

In some ways, aesthetics is the most difficult of all items to evaluate; yet in any given community it is possible to get a feel for what the community values and will come to value. Different transportation alternatives have varying effects on the presence or absence of open spaces, trees, wooded areas, depending on their land requirements and the section of the city through which they go; different communities place different values on these amenities. Street car tracks, surface railroad, open cuts, and elevated lines all present differing degrees of negative value to different groups. Some communities are ready to accept modernistic monorail structures, where an old-fashioned elevated line would be taboo. Some communities take huge automobile parking lots for granted, while other regard them as eyesores. Some communities cherish quiet urban byways or pedestrian walkways, while others "couldn't care less."

Perhaps the most important question in applying these values is to determine who is to be the arbiter. Certainly not majority opinion alone, for a successful community must also satisfy important minorities; on the other hand, not the experts and planners alone, for they may be out of tune with the great bulk of the public, and in matters of aesthetics there is no absolute right; and not the opinion of today alone, for interests and styles change.

About the only real guide the transportation planner can follow is (bearing in mind economics) to make those choices which will offend the fewest and please the most. He will also be most careful with the kinds of choices that leave the longest-term imprint and are the hardest to reverse, for in respect of these particularly, he must be certain that what is a benefit today will continue to be a benefit in the years to come.

REFERENCE

1. Lang, A. Scheffler, and Soberman, Richard M. Urban Rail Transit—Its Economics and Technology. MIT Press, p. 83, 1964.