Problems, Misconceptions, and Errors in Benefit-Cost Analyses of Transit Systems

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This paper is addressed to the process of evaluating transit systems alternatives in metropolitan areas. The conclusions are derived from the author's experience in conducting such studies and from a review of a number of recent reports. Some 15 separate issues are discussed, and conclusions are drawn as to appropriate research methods for each subject. First, the alternative of not conducting a benefit-cost analysis is discussed, and reasons are described why other methods,(e.g., professional judgment, cost of service, and financial feasibility) may lead to incorrect decisions. Conclusions are then drawn concerning the use of rating systems versus dollar-based evaluations, discounting, the choice of an interest rate, financing considerations, inflation, reflection of all public costs, the use of benefit-cost analysis only as justification for a single recommended system, the structuring of alternatives, analyzing benefits only to existing travelers, modal split and traveler benefit inconsistencies, measurement of motor vehicle running costs, factoring from daily savings to yearly savings, economic valuation of noneconomic factors, treatment of uncertainty, and interpretation of benefit-cost ratios.

•OFFICIALS in an increasing number of cities have recognized in recent years that continued construction of freeways in heavily populated areas does not provide the kinds of transportation improvements needed. They are now considering investments in new mass transit systems to assist in solving their congestion problems. Transit investments also offer improvements in transportation to those persons who cannot drive, do not own or have access to an automobile, or simply do not choose to drive. Studies of transit system alternatives in these cities include a number of tasks—transportation planning, system engineering, construction engineering, architecture, financial planning, and others.

Benefit-cost analysis is becoming increasingly recognized as an additional task that should be included in studying transit systems. It can provide local officials and the public with improved knowledge both about the desirability of alternative systems and about the equity of potential financing schemes. Benefit-cost studies are appearing more frequently in the technical literature and as chapters to consultants' reports on the feasibility of specific urban transit systems.

The use of benefit-cost analysis in highway planning first appeared in the literature of the 1920s. Since then, various procedures and practices have been soundly attacked and continually improved. Some years ago, Grant and Oglesby (1) did a great service to the development of objective decision-making in highway planning by reviewing and criticizing certain studies of the economic feasibility of highway investment projects. In this review, they pointed out errors that had been observed in the definition of alternatives, in selection of an interest rate and a study period, and in the need for considering nonuser consequences.

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The present paper discusses similar considerations for transit systems. The procedures and practices used for evaluating them are also subject to criticism and improvement. In the next section, various methods—other than benefit-cost analysis—for reaching decisions on transit systems are described and criticized. Subsequent sections discuss the following specific issues in designing and executing benefit-cost analyses: rating systems versus dollar-based evaluations, discounting, choice of interest rate, financing considerations, inflation, reflection of all public costs, benefit-cost analysis as justification for a single recommended system, structuring of alternatives, analyzing benefits only to existing travelers, modal split and traveler benefit inconsistencies, measurement of motor vehicle running costs, factoring from daily savings to yearly savings, economic valuation of noneconomic factors, treatment of uncertainty, and interpretation of benefit-cost ratios.

In this paper, the term "benefit-cost analyses" is used in a general sense. Socioeconomic evaluation or cost-effectiveness analysis are alternatives that might have been chosen. The term implies an evaluation that reflects impacts of alternative transit systems on the public and that attempts to reduce the impacts to dollar values wherever possible and appropriate.

The discussion derives from the experience of the author and his colleagues in conducting transit system evaluations and from a review of a number of recent studies conducted in various cities. All of the problems and errors are taken from published reports. Some even are serious enough to have led to an incorrect conclusion as to whether benefits exceed the costs.

ALTERNATIVE OF NOT CONDUCTING A BENEFIT-COST ANALYSIS

Before discussing some of the problems in conducting benefit-cost analyses, it is appropriate to consider the alternative of not conducting a benefit-cost analysis at all. In the past, studies of mass transit that have not used benefit-cost analysis have resorted to a variety of means to justify their recommendations. Among them are professional judgment, cost of service, and financial feasibility.

In the professional judgment approach, the consultant generally cites a range of facts and factors that he feels are important and then states a judgment or a recommendation without stating any objective basis. When an alternative that is not recommended has some features that are more attractive than those of the recommended alternative, the trade-offs are usually not explicitly defined. Opinions as to the desirability of certain features of rejected alternatives are frequently stated in a manner that discourages debate.

The cost-of-service approach is more quantitative in nature than the professional judgment approach. Cost data are developed that can be reduced to an index number, such as the cost per seat-mile or cost per passenger-mile. Such indexes are valuable in understanding the cost-productivity relationships between alternative systems, but they do not reflect all factors that should be considered in choosing a system.

Consider, for example, a hypothetical set of alternatives having different degrees of coverage of the urban area. One might provide high-quality service to the downtown and inner city portions of the area; the second might provide lower quality service to the downtown portion but also provide service to the medium-density areas; and the third might provide extended service all the way from downtown into the low-density suburbs. It would not be surprising to find that the first and third alternatives had higher average costs per passenger-mile than the second—the first because of high capital costs per mile for right-of-way and construction, and the third because of low patronage from the low-density areas. Thus, on the basis of this indicator, the second alternative might be recommended. However, it is obvious that the second alternative may not be the most desirable. The first might be considered most appealing because of its potential for reducing congestion and air pollution in the most densely populated areas of the city; the third might be considered most appealing because of the backhaul service provided to residents of the inner city o. because of its greater effect in maintaining a successful central downtown.

The third approach, financial feasibility, focuses on the impact of a new system on the transit operator rather than on the public. It compares the estimated revenues of the proposed system with the estimated costs. Three methods of analyzing financial feasibility can be found in the literature. They are the total cost method, the capital cost method, and the yearly revenue-cost method. The total cost method entails a comparison of total revenues with total costs in a manner not unlike that often used to evaluate the economic feasibility of a business enterprise. In some cases, the method used is simple arithmetic summation of all costs and revenues over the expected life of the system; in others, discounting techniques are used. With this method, the alternative with the greatest excess of total revenues over total costs is favored. In the capital cost method, alternatives are compared in terms of the total capital expenditures and may be rejected if it appears that expenditures cannot be financed through taxation. The third method, comparison of yearly operating revenues with operating costs, has recently been used in a number of cities. Here it is presumed that the capital costs of the system are to be paid by the general public through some form of taxation. Thus, a system is feasible if operating revenues exceed operating costs, and sometimes a system is recommended simply if its excess of operating revenues over operating costs is greater than that of the other alternatives.

The fundamental criticism of the financial feasibility approach is that it takes the wrong point of view. What is important is not how well the operator succeeds (although, obviously, investment by a private operator has to attract at least a minimum attractive return) but how beneficial the proposed system is to the public. Such an approach also masks the problem of establishing an optimal fare structure from the public's point of view. The financial analysis is a necessary part of an overall study because the operator must be financially solvent. The essential point is that it should not be used as the sole criterion on which the most desirable system is chosen.

RATING SYSTEMS VERSUS DOLLAR-BASED EVALUATIONS

In a number of studies of urban transportation, rating systems have been used to compare alternatives. Usually, the construction of a rating system of evaluation entails (a) identification of the factors to be rated, (b) estimation of a numerical value of each factor for each alternative transportation system, (c) generation of a rating or weighting for each numerical unit of the factor, and (d) development of an overall index or rating for each alternative. Errors in evaluation are most frequently generated in the last two steps.

One example of misuse of the rating system occurred in a rapid transit study of bus and rail alternatives for a metropolitan area. In this study, ten alternatives were evaluated on each of six factors. For each factor, the ten alternatives were assigned rankings from one to ten. Then the numerical values of the rankings were added up, giving a ranking summary from which the recommended alternative was chosen. Table 1 gives the results of the ranking, along with cost and patronage data for the ten alternatives.

TABLE 1

EVALUATION SUMMARY OF MAJOR TRANSIT SYSTEM ALTERNATIVES

Alternative	Evaluation Item: Cost Per Passenger Trip		Capital Cost for System		Passengers Attracted, Automobile Travel Reduction		Operational and Physical Feasibility, Rank	Staging Possibilities, Rank	Community and Regional Objectives, Rank	Ranking Summary	Recommended Alternative
	Rank[a]	Cost in Cents	Rank	Cost[b]	Rank	Thousands of Daily Passengers					
A	10	28	10	460	8	330	3	10	8	49	—
B	9	24	6	385	7	335	5	8	5	40	—
C	7	23	8	400	2	350	1	7	3	28	Acceptable
D	5	22	5	375	4	345	2	4	4	24	Best
E	6	23	7	390	3	345	8	3	2	29	—
F	8	24	9	420	1	355	6	9	1	34	Acceptable
G	1	11	1	140	10	285	10	5	10	37	—
H	2	17	2	260	7	305	7	1	9	30	—
I	3	21	3	350	4	340	4	6	7	29	Acceptable
J	4	21	4	360	9	345	9	2	6	30	—

[a]1 = best ranking; 10 = worst ranking.
[b]Cost in millions of dollars, 1966-1967.

This case presents a particularly misleading use of rating systems. Equal rankings on two factors are given equivalent weights in the summary evaluation, yet one factor may be far more important than another. For example, the community might place much greater weight on the attainment of community and regional objectives than on staging possibilities. A weighting scheme that would relate the importance of each criterion to the others would mitigate this error. However, data to permit reliable weighting and combination of diverse criteria are difficult to obtain and, in their absence, the ratings should not be combined in any way (2).

An additional problem is created if whole numbers (1, 2, 3, . . .) are used in the ranking system. Alternatives that differ very little on an absolute basis must differ by at least one rank unit in the ranking system. In Table 1, note that alternatives B through F differ in cost per passenger trip by less than 10 percent, yet the range of rank values is from 5 to 9. This range of four units must be greater than the true differences in value. The same problem appears in the ranking of the capital cost and the passengers-attracted criteria.

Still another problem that can be noted in the example is the way in which factors are implicitly treated as being independent in the assignment of ranks and in the addition of rank values, in spite of the fact that considerable dependence between them exists. The cost per passenger trip is a function of the capital cost and of the number of passengers attracted, among the factors listed. A low ranking on one will lower the ranking on the other.

DISCOUNTING

Discounting techniques are widely applied to reflect the time value of money in studies of the feasibility of public and private investments. These techniques permit the decision-maker to realistically reflect the fact that, because of the time value of money, future dollar expenditures have less utility than present expenditures. This difference in value is accounted for by the fact that the dollars received earlier can be invested and can earn interest before the distant future dollars are received. Even if not invested, the present dollars can be used for purchasing goods or services, and the benefits from these goods and services can be enjoyed sooner.

To adjust the benefits and costs for time differences, it is necessary to discount them—to multiply them by a factor that depends both on the time of their occurrence and on the rate of interest. The rate at which the costs and benefits in the study should be discounted depends on the value of money over time to those who must bear the costs. For public investments, rates of 5 to 10 percent are commonly used. By applying formulas based on the interest rate, the benefits and costs occurring in future years can be converted to their worth at the present time. Using other formulas based on the interest rate and study period, the value at the present time can be converted further to an equivalent uniform annual cost. The equivalent annual cost may be thought of as the annual amount that would have to be spent to repay a loan with interest.

Although many concepts in the fields of economics and engineering economics are subject to variations in opinion, the concept of discounting is universally accepted. Yet, one recent study was presented to the voters of a metropolitan area with undiscounted money data. Figure 1 shows the conclusion of the economic and social benefits section of the report in terms of the cumulative flow of costs and benefits. The text states, "By 1979, the cumulative flow of benefits would begin to exceed the cumulative cost flow . . . . The conclusion to be drawn from this analysis is that anticipated quantifiable benefits from transit exceed anticipated costs." One is led to wonder if, using discounting techniques, the net present worth of the benefits exceeds the net present worth of the costs.

CHOICE OF INTEREST RATE

As indicated earlier, most experts recommend the use of an interest rate between 5 and 10 percent for public investments. In addition to the error of not using discounting techniques at all, which is equivalent to using a 0 percent interest rate, is the error

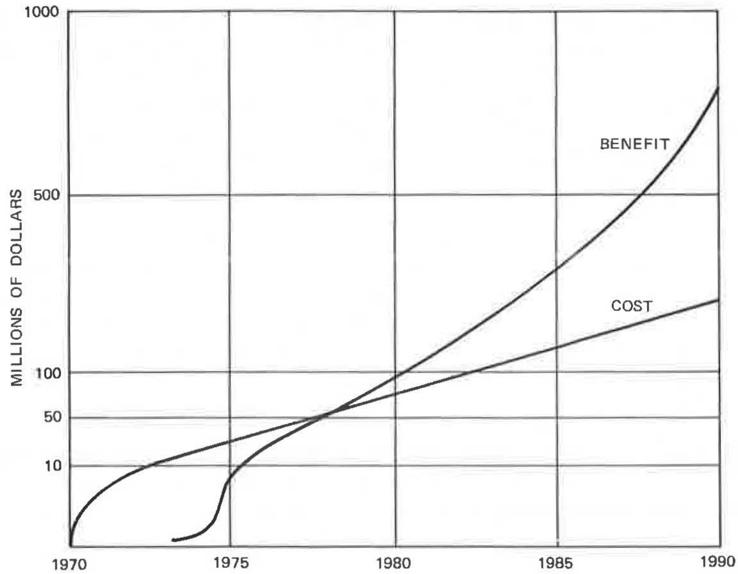

Figure 1. Cumulative cost/benefit flow.

of using an incorrect rationale for determining an interest rate and the resulting application of an inappropriate interest rate.

A number of bases have been offered in the literature for the choice of an interest rate for government investments, including the social discount rate, the opportunity cost of capital, the government bond interest rate, and the marginal rate of return. Opportunity cost appears to have the widest professional acceptance at present (3, 4). Inasmuch as the fundamental source of funds for government investments is the general public, the opportunity cost rationale asserts that an interest rate be chosen that represents the opportunity cost of money taken in the form of taxes from the hands of the general public. Opportunity cost is therefore based on foregone opportunities for private investment.

The most popular mistake in choosing an interest rate made in some recent transit studies is to base the rate on the cost of public borrowing. The argument in one report was stated as follows:

> Although trends in the last few years have indicated a 5 to 5.5 percent average present worth discount factor, this is assumed to be a short term phenomenon, and 4 percent, as used by most public agencies, is considered more appropriate to represent typical interest rates in public borrowing. In this analysis, therefore, the total revenues occurring during the 50-year life span of the project have been discounted at 4 percent compounded annually.

(Even though this quote uses the term "revenues", elsewhere in the report it is disclosed that the 4 percent figure was applied to benefits.)

Another transit benefit-cost study exhibits the same thinking:

> Local Member Grants, comprising the balance of net project costs, were annualized over a period of 37 years—equivalent to 4%, 25-year bonds issued during the construction period . . . both benefits and costs were multiplied by a discount factor equivalent to 4% compounded to reconcile the effects of timing on annual flows.

In most transit studies, a number of different interest rates may be found. It is imperative that they not be confused. In these two examples, it is clear that the difference between public borrowing interest rates and the opportunity cost interest rate has been confused. The fact that a public agency may be able to borrow money at an interest rate of, say, 4 percent has no bearing on the choice of an interest rate for discounting purposes. The borrowing rate is used to compute the costs entailed in repaying a loan for capital expenditures, and must therefore indicate the magnitudes of money that must be collected year-by-year by the transit operator to repay the borrowed funds. In contrast, the opportunity cost interest rate is used to compute the present value or the equivalent annual value of a series of benefit and cost flows. This computation is used to indicate the differences between benefits and costs that are incurred at different times.

Although a difference of 1 or 2 percent in the interest rate may sound minor, results of an economy study can be sensitive to such variations. For example, using a rate of 4 percent instead of 6 percent for discounting uniform annual benefits over a 30-year study period will cause an increase of approximately $^1/_4$ in the present value of the benefits.

FINANCING CONSIDERATIONS

Recent studies of benefits and costs of public transportation systems have differed on the question of whether to include the effects of financing in the analysis. In these cases, the question of financing arose as a consideration in project planning because the construction cost of the project was to have been financed through bond issues and repaid by the general public through increases in sales or property taxes.

One argument for not including financial considerations in a benefit-cost study is the well-accepted principle that separate decisions should be studied separately. Following this rule, the cost and effectiveness of alternative systems should be assessed first, and then the project that is most desirable should be studied from the standpoint of the most feasible financing alternatives.

The fact of the matter is, however, that the financing decision in most cities is not entirely separable from the system decision. Even though the city's engineering and financial consultants and elected officials may have considered these issues separately, the final decision is left to the public. The voting public is offered a package and is asked to accept or reject that package, which includes both the proposed system and the proposed method of financing. In such cases the decisions are not, in the final analysis, separable.

There is another argument to support the inclusion of financing considerations in the benefit-cost study. It is increasingly recognized that a simple sum of benefits and costs over the entire community does not fully illuminate all facets of the decision. Elected officials and the public are concerned also with the manner in which the benefits and costs would be distributed among the various groups in the community. A public transit project will affect travelers, businessmen, property owners, unemployed persons, and taxpayers differently. The benefit-cost study should display these differential effects. Thus, the amounts and timing of repayments of the borrowed capital should be displayed in the context of the persons who will be burdened by the repayment requirements. The recommended scheme should be developed to display the impacts of all of the benefits and costs on each of a number of groups in the community.

This author, therefore, would advocate estimating benefits in reference to the service life or study period of the project, and comparing these benefits with the debt repayment costs over the same period. Such a procedure permits the study to display the distributional effects. In it, the capital costs would be converted to the bond repayment amounts over the life of the bond issues. These amounts would include both repayment of the principal and the associated interest costs, and would be computed at the bond interest rate. This flow of costs should be compared with the flow of benefits over the study period, and a subtraction of one from the other would indicate the net value of those criteria considered costable. These values can then be considered in reference to the criteria that are not costable.

If the benefits and costs, including financing costs, are considered to be constant over the study period, the net difference between annual costable benefits and annual loan repayment costs can be directly evaluated. The difference will be a single figure. However, a more accurate representation of the situation may recognize that growth in population and increases in travel will change the amounts of the benefits over time. For example, benefits might increase over a portion of the study period up to a point at which the system's capacity is reached. When flows of benefits (or costs) are predicted to change over time, the problem of assessment is complicated; it is not possible to judge the costable aspects of the system from a single year's data. Here, as indicated earlier, benefits and costs should be discounted, and a single present value of the net benefits or equivalent annual net benefit should be computed. Such a procedure will produce a single index of the costable criteria that will be useful for decision-making.

The procedure may appear to be an exercise in sleight-of-hand, however, when the interest rate on bond repayment is different from the interest rate based on opportunity cost used in the discounting process. If, as is usually the case, the interest rate for bond repayment is lower than the rate used for discounting, the project cost will appear cheaper, in terms of the present worth of repayment amounts, than the actual capital cost. For example, assume a 4 percent interest rate on bond repayment, a 6 percent opportunity cost discount rate, and a 40-year study period and bond repayment period. A project whose capital cost is $1 billion will then have an annual loan repayment cost of $50.5 million, but the present value of those loan repayments is only $760 million, or 24 percent less than the actual capital cost.

The $240 million difference between the actual present cost and the present value of the loan repayments appears to be a benefit that has materialized out of nowhere. Yet, such is the case for all local projects that are financed by municipal bonds, because of income tax regulations. The current IRS procedures leave interest income on municipal bonds tax-free. This procedure has permitted local governments to finance capital improvements at low interest rates and taxpayers to gain tax-free income. The local government and its citizenry gains, and the bond buyer gains. The "loser" is the federal government.

INFLATION

Most studies of transit systems recognize that inflation may have a significant effect on transit projects. Estimates are made in most studies of the effect of inflation on construction costs, to ensure that the amount of money obtained will be sufficient to pay for costs as they are incurred in the construction period. However, other costs are also affected by inflation.

Recent benefit-cost studies have taken different positions regarding how the overall effects of inflation should be reflected in the analysis. One study incorporates actual inflationary trends: "Dollars have been inflated on the basis of 4.5 percent annually for construction-related items, 6.0 percent annually for wage-related items, and 2.5 percent annually for money-related items."

In another study, construction costs were inflated at an expected value of increase of 7 percent, and benefits were inflated at 2 percent per year. This study reflected the fact that the project costs incurred by the community would be fixed bond repayments, not capital costs, and that these costs would be paid in inflated dollars. It also reflected the fact that benefits would also be received in inflated dollars:

> ... The value of the benefits to be received has been estimated in terms of present-day dollars. The amount required to pay the interest and principal due each year on bonds is fixed by the bond terms, but may decline in value by today's standards because of decreased purchasing power of the dollars used to make these payments. We have therefore increased the benefits at a constant annual rate to measure the value of the benefits and the amount of money paid for bond service in any year in equivalent dollars.
>
> There has been a general trend toward lower purchasing power of the dollar. The cost of living, measured by the consumer price index produced by the U.S. Bureau of Labor Statistics, has increased in every year but one since 1949. The rate of price increases varies widely from product to product and from year to year due to public policy, reflected by governmental spending, and as a result of the dynamics of the economy. It is generally agreed that the overall value of the dollar is decreasing at a rate between 1.5 and 2.0 percent per year for the United States, and estimates for (the study area) tend toward the higher figure. We have therefore used 2 percent as the rate of increase in the value of increase in benefits.

A third study concludes that it is inappropriate to include inflationary effects:

> All benefit and cost flows examined in this report are measured in 1968 constant dollars. The effects of inflation have been factored out in both flows for several reasons. First, inflating dollar benefits or costs does not actually represent a "net" increase in their real value—it simply reflects an absolute increase in monetary value. In addition, the effects of inflation over so large a time segment containing numerous benefit and cost components are extremely volatile and difficult to estimate. Finally, we do not believe that benefits and costs, flowing over different time segments, can be validly compared if they are inflated. For these reasons, we have inflated neither benefits or costs.

The problem of deciding how to handle the question of inflation in a benefit-cost study is one of the more difficult problems that must be resolved. One of the best studies made is by Lee and Grant (5). In their work, the authors make two important distinctions (a) between general inflation and differential price changes and (b) between the local viewpoint and the national viewpoint. Both distinctions are crucial to deciding how to handle the question of inflation.

They conclude, as do others in the literature they review, that general inflation effects should not be included in transit studies but that "in principle, expected differential price changes should be included in an economy study." However, they recommend that, for highway economy studies, ". . . there are good reasons for using current prices to evaluate costs and benefits."

Their conclusions regarding the local versus the national viewpoint are made with respect to general inflation. They state that, in the local case, ". . . the repayment of the debt can be made with inflated dollars which means that the real cost to the area is less than it would have been had inflation not occurred. A loss occurs to the creditors who failed to anticipate inflation, but this is generally of little concern to the local area." But in the national case, because losses to creditors and gains to debtors are both of concern, they recommend that general inflationary trends not be considered in the economy study.

In this author's view, the evaluation of transit systems is different from the evaluation of highway projects in a number of important ways. First, transit systems are frequently financed in part by the sale of bonds, whereas highways are built with current tax revenues. Second, the decision on whether to go ahead is usually made with a financing plan as an integral consideration of the total decision, and it is a local decision. Third, there is need to study a range of system alternatives that may be affected differently by price changes, e.g., a capital-intensive system versus a labor-intensive system. Fourth, the magnitude of the project frequently is such that several years may pass between the time that the decision is made and the system is finally operating (San Francisco's BART system will require 9 to 10 years). Changes in prices over this period must explicitly be considered in planning the project.

These factors argue for including differential price trends in the benefit-cost analysis: benefits are affected by inflation, whereas debt repayment is not—once the repayment schedule is fixed. If the community gains by the fact that creditors have not anticipated inflation, the gain is real. Systems that are more capital-intensive stand to gain because of inflation relative to those that have a high labor content. Finally, it is difficult to obtain additional funds if inflation has not been properly allowed for.

The decisions on the choice of differential price change factors, on the potentially feasible financing interest rate, and on the interest rate to be used for discounting should be made in careful relation to one another. Consideration should be given to the degree to which the effect of inflation should be reflected as a separate factor, or included in the interest rate used for discounting (6).

REFLECTION OF ALL PUBLIC COSTS

In many rapid transit projects, the process of raising and managing funds for construction and operation requires careful study. Frequently, the responsible agency will engage a financial consultant to develop plans for the financing aspects of the project development. The consultant will be concerned with the type of bonds to be floated, their amounts and timing, the tax funds to be collected, and their amounts and timing.

These data, together with the capital and operating cost payment schedules and the revenue schedules from transit operations, are assembled into a total financial estimate of the agency's operations. The problem is made more complex when the new project's financing is to be combined with the financial results of an existing transit operation.

Failure to understand the financial planning can lead to errors in a benefit-cost analysis. In one recent study, the benefit-cost analyst took as the project costs the flow of money required to pay off the bonded indebtedness and failed to appreciate the fact that, during the early years of the project, more money would be collected in taxes than would be required to service the bonds. The financial consultant planned to use the surplus to pay directly some of the construction costs and thereby reduce the required borrowing.

This example points out two guidelines: first, that the benefit-cost analyst must clearly understand all aspects of the financial plan if he is to incorporate the distributional effects of financing in his study and, second, that the use of separate contractors for financial analysis and benefit-cost analysis may result in communications failures.

In another recent study, the total benefits from rapid transit were compared with only the local share of the anticipated capital costs, because two-thirds federal funding was anticipated. The transit system was estimated to produce benefits that would exceed the local costs, and thereby produce a local net benefit. On this basis the consultant recommended that the public approve the impending bond issue. But if the federal share had been included, it would have been clear that costs exceeded benefits.

BENEFIT-COST ANALYSIS AS JUSTIFICATION FOR A SINGLE RECOMMENDED SYSTEM

The magnitude of proposed transit investments outclasses most urban area capital projects. Recently in Los Angeles, a rapid transit system having an estimated capital cost of about $2.5 billion was proposed to the voters. This is one of the largest single capital investments ever considered by an urban area, and transit proposals in many other cities are proportionately as costly for the population of the area served.

The sheer size of such projects calls for careful appraisal of alternatives, because errors in decisions can have large effects in terms of unrealized or overstated benefits. All too often, benefit-cost analysis is called for only after the final design and route configuration have been chosen. The public is presented with a "to build or not to build" choice. It is thus not surprising that considerable opposition is raised by those who believe that the chosen system is not the most desirable. Instances can be cited in which proponents of other kinds of systems or of other route configurations have caused considerable unrest in the community by independently offering their concept of what is best. Even if the decisions that have been made by the transit agency and its consultants have been correct, calling in the benefit-cost analyst only to appraise the go, no-go decision carries the risk of losing public support.

More important, however, is the possibility that the final system is not the best choice. There is no assurance that decisions among alternative systems based on technical considerations or certain analytical practices described earlier will be the same that would have been reached by a well-structured benefit-cost analysis.

The obvious procedure is to conduct analyses of the benefits and costs of all meaningful alternatives and to present the results of those analyses to the public through its representatives. Also, the phrase "all meaningful alternatives" should be broadly construed, both because expansion of existing systems may be feasible in some urban areas and because radically new transit systems may be only a few years away. The following points are made to illustrate these possibilities in more detail:

1. One important source of opposition to transit programs is the sector of the public who are proponents of automobile travel and highway construction. These groups argue for the unquestioned benefits of flexibility and independence of travel of private transportation, but usually without quantitative data. The responsible transit agency should recognize this point of view, even the possibility that it may be correct. One way of considering this possibility is to structure a highway program of the same capital cost magnitude and to analyze the benefits and costs, including undesirable side effects, of

such a program within a framework consistent with that used to analyze transit alternatives.

2. Recent studies sponsored by the federal government indicate that entirely new systems of public transportation may provide considerably improved service at reasonable costs. Such systems are not available at present but could be developed for future implementation if a vigorous program of research and development were undertaken. Local transit studies should therefore explicitly compare the benefits and costs of waiting for a new system with those of immediately constructing a currently available system.

Beyond the issue of considering all valid transportation alternatives, more questions should probably be raised in rapid transit studies regarding complementary investments in city and environmental planning along transit rights-of-way, alternative ways of achieving certain subobjectives of public transportation (such as improved service between low-income neighborhoods and potential employment locations), and trade-offs between transportation investments and other means of achieving basic city goals. To cite only one example of such a trade-off, it is usually the aim of cities to reduce or reverse the emigration of middle- and high-income families to the suburbs, yet rapid transit may accelerate the exodus by making it easier and cheaper to commute long distances. Detailed comments on alternative mixes of public expenditures to better achieve such broad community aims and values are beyond the scope of this paper, but it should be clear from this single example that the interdependencies and feedback effects in cities, as in any complex system, must be recognized.

STRUCTURING OF ALTERNATIVES

Developing the appropriate structure of alternatives is a fundamental requirement in all benefit-cost studies, and errors in this step can result in errors in the benefits reported. One recent study of rapid transit in a large metropolitan area made a gross error of this type. In this report the valid point was made that the community could build a rapid transit system or more freeways and surface streets. However, benefits were estimated in relation to the existing freeway and street system, and these benefits were erroneously added to "cost saving" items, including additional miles of freeways and surface streets not required.

A correct structuring of alternatives would have recognized three separate alternatives:

1. Do nothing (d.n. in the following discussion);
2. Build a rapid transit system (r.t.); or
3. Build more freeways and streets (f.s.).

With such a structure, the benefits of rapid transit should be measured in relation to the do-nothing alternative. The travel benefits are the difference in travel costs between the two alternatives:

$$\text{Travel Benefit}_{\text{r.t.}} = \text{Travel Cost}_{\text{d.n.}} - \text{Travel Cost}_{\text{r.t.}}$$

The travel benefit should be compared with the cost of building the rapid transit system in order to assess feasibility. The net travel benefit is

$$\text{Net Benefit}_{\text{r.t.}} = \text{Travel Benefit}_{\text{r.t.}} - \text{System Cost}_{\text{r.t.}}$$

Similarly, the benefits of more freeways and streets should be measured in relation to the do-nothing alternative. The travel benefits are the differences in travel costs between the two alternatives:

$$\text{Travel Benefit}_{\text{f.s.}} = \text{Travel Cost}_{\text{d.n.}} - \text{Travel Cost}_{\text{f.s.}}$$

This travel benefit should be compared with the cost of building the freeway and street system improvements in order to assess feasibility. The net benefit then is

$$\text{Net Benefit}_{\text{f.s.}} = \text{Travel Benefit}_{\text{f.s.}} - \text{Investment Cost}_{\text{f.s.}}$$

Finally, the feasibility of the rapid transit alternative as compared with the freeway and surface street alternative is

$$\begin{aligned}\text{Overall Benefit}_{\text{r.t.}} &= \text{Net Benefit}_{\text{r.t.}} - \text{Net Benefit}_{\text{f.s.}} \\ &= \text{Travel Benefit}_{\text{r.t.}} - \text{System Cost}_{\text{r.t.}} \\ &\quad - \text{Travel Benefit}_{\text{f.s.}} + \text{Investment Cost}_{\text{f.s.}}\end{aligned}$$

If the overall benefit is positive, the rapid transit system is preferred to the alternative of freeway and street improvement. Yet, in the study report referred to above, benefits were computed as

$$\begin{aligned}\text{Overall Benefit}_{\text{r.t.}} &= \text{Travel Benefit}_{\text{r.t.}} - \text{System Cost}_{\text{r.t.}} \\ &\quad + \text{Investment Cost}_{\text{f.s.}}\end{aligned}$$

This same study made a similar error of including operations and maintenance costs of the freeway and street system as a savings resulting from rapid transit. The total amount of items erroneously included reaches $749 million. The overall net benefit claimed was $822 million; it should have been $73 million.

ANALYZING BENEFITS ONLY TO EXISTING TRAVELERS

For a number of reasons, transit authorities have sometimes restricted a benefit analysis to only the traveler (or user) benefits and thereby have not recognized or pursued studies of other benefits that may accrue to the area. Some of the technical literature has supported this view on the grounds that all effects beyond the direct effects on travelers are simply transfers of benefits from one sector of the community to another. This argument asserts that adding more general community benefits to traveler benefits results in a fundamental error of double counting.

However, even though errors of double counting should be meticulously avoided in all phases of a benefit-cost analysis, such a procedure should not be applied so as to eliminate consideration of community effects. Even if traveler benefits are transferred to other members of the community, analysis of such transfers can be included by tracing the transfers as far as possible but not adding them to total benefits. Other community effects may be identified that are not transfers and should definitely be included in the study.

Imperfections in the current state of the art of benefit-cost analysis in transit studies result in increased possibilities that benefits to other than present travelers may not be recognized. For example, most studies measure travel demand in terms of a trip table—a table showing the number of trips between each pair of travel zones—that is held fixed for all alternatives to be analyzed. Under these conditions, the analysis does not recognize that a new system may cause some travelers to choose different origins or destinations and may result in some persons taking trips that they would otherwise not have taken. Persons who make different trips or who travel more must certainly benefit from such actions or they would not choose to do so. Yet a traveler benefit analysis conducted under the assumption of a fixed trip table would not identify those benefits.

Even with more advanced analysis techniques, such a procedure of redistributing trips for each system alternative (with a trip distribution model) or using a travel demand model that reflects the characteristics of the transportation system and thereby estimates varying amounts of demand under conditions of varying accessibility may not identify and measure such benefits. The advanced technique may not, for example, adequately reflect the fact that increased accessibility may reduce unemployment and thereby produce a sizable community benefit.

A view that the benefits of transportation systems are not adequately measured solely by the reduction in transportation costs should be fundamental to the study. Travel usually takes place not for travel itself, but to obtain some beneficial effect at another location. Thus, the net value of a trip is equal to the following difference:

$$\begin{bmatrix}\text{Value of being at} \\ \text{place "X" (place value)}\end{bmatrix} - \begin{bmatrix}\text{Cost of getting to "X"} \\ \text{(transportation cost)}\end{bmatrix}$$

This view may someday be made operational through a computational procedure, but until further research makes that possible, it will help at least to identify any benefits that are not measured in the analysis. Furthermore, it will help to trace the benefits of travel to their ultimate recipients, who may not always be the travelers.

It is recommended that transit benefit-cost studies (as well as highway benefit-cost studies) consider a range of possible effects, such as the following:

1. Transit user effects;
2. Highway user effects, including savings in (a) travel time, (b) operating costs, (c) ownership costs, (d) accident costs, and (e) parking costs;
3. Unemployment effects;
4. Educational opportunity effects;
5. Business productivity effects;
6. Government productivity effects;
7. Real estate effects;
8. Life-style effects;
9. Environmental pollution effects;
10. Tax effects;
11. Disruption effects, including those that are (a) temporary during construction and (b) permanent in neighborhood division;
12. Construction labor effects;
13. Highway construction effects;
14. Aesthetic effects;
15. Property losses and relocation effects;
16. Regional and neighborhood growth effects;
17. Crime effects;
18. Civil defense effects;
19. Achievement of desired urban form;
20. Detailed nodal studies and projections;
21. Implementation evaluation;
22. Financing effects; and
23. Tourism effects.

MODAL SPLIT AND TRAVELER BENEFIT INCONSISTENCIES

In certain instances, the procedures used to estimate patronage of transit systems and those used to estimate traveler benefits lead to inconsistent results. Such an instance is shown in Figure 2, where an existing highway would compete with a proposed transit system for trips between zones A and B. From zone centroid to zone centroid, the travel times by highway and transit are 30 and 36 minutes respectively.

Without transit, all travelers would use the highway route, and each would travel 30 minutes from A to B. With transit, using a typical modal split procedure, a diversion from highway to transit would be computed in relation to travel times. Such a model might forecast the transit percentage of the total on the order of 20 percent. With

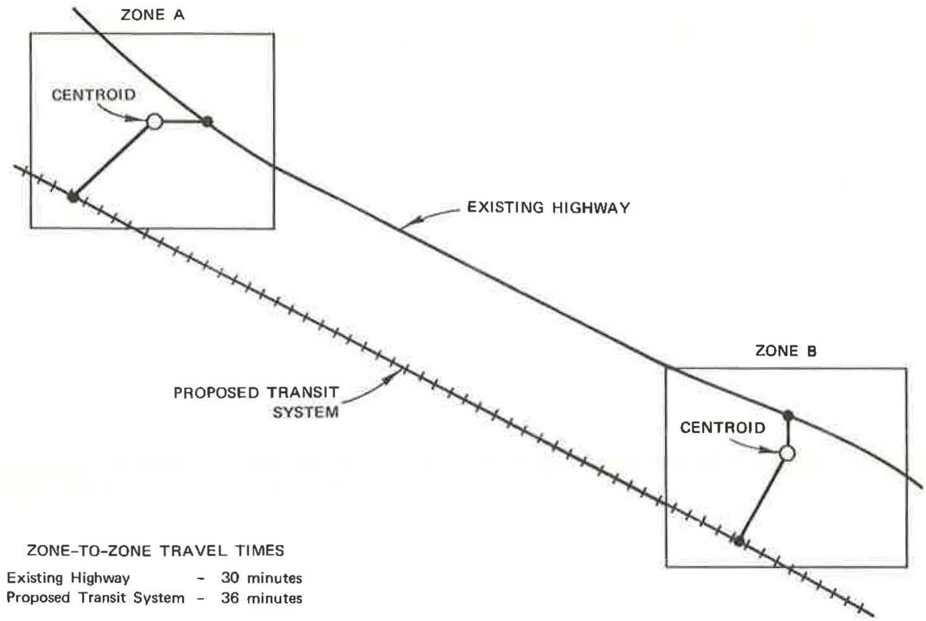

Figure 2. A hypothetical highway-transit modal split.

transit, then, 20 percent of the travelers would take 36 minutes to travel by transit, and the benefit-cost analyst would compute a 6-minute disbenefit.

In actuality, the travelers who would be most inclined to use transit would be those whose origins and destinations are close to the transit stations in the lower left corners of the zones. These travelers would actually experience a benefit because of easier access to transit than those in other parts of the zones. This benefit should be recognized.

In areas where the geographically larger suburban zones are expected to experience most of the population growth over the period of the projects, the calculation of a disbenefit in travel time can lead to substantial errors. The errors can be even greater when it is expected that the proposed transit system will have an effect on the geographical distribution of the forecast growth of population and economic development of a zone. When the zone centroid is held fixed in location over a number of plan alternatives, and when pronounced land use differences can be expected, the problem becomes more serious. In practice this problem can be alleviated somewhat by judicious design of zone boundaries and selection of access times. Otherwise, manual adjustments of the data may be required.

Even with judicious design of the zonal system, however, another inconsistency must be guarded against if modal split equations are developed separately from benefit-estimating equations. The two should be developed together, because the value system of the individuals making a choice between private automobile and transit can be measured to provide a basis for modal split and to gain insight into value parameters that should be used in estimating benefits. For example, a consistent means can be devised for relating the way in which individuals trade off time and money in choosing modes and for measuring the value of travel time savings.

MEASUREMENT OF MOTOR VEHICLE RUNNING COSTS

In conducting benefit-cost studies of both transit and highway improvements, many investigators have not been able to take into account the fact that motor vehicle running costs vary significantly with operating conditions. These costs vary as a function of speed and acceleration and deceleration; thus, as new facilities result in less congestion, higher speeds, and less stop-and-go driving, costs will change.

Data on the cost variations caused by these factors have been available for some time (7) and more data are in process of being developed (8). Although observed data on speed change cycles are limited, there is no reason why approximations should not be incorporated into the estimates of motor vehicle running costs. Such a procedure is believed to be far sounder than using a single value per vehicle-mile (such as the national average published by the U. S. Bureau of Public Roads) that masks all differences in road types, congestion, and speeds. In a recent series of 117 highway economy studies (chiefly for new freeways), inclusion of these considerations resulted in almost all projects being economically attractive solely on the basis of savings in motor vehicle running costs, and inclusion of time savings added even more to their attractiveness.

As an additional point, in recent transit studies the study teams have sometimes not incorporated the fact that, when travelers are diverted from automobile to transit, congestion on existing highways is relieved and both time savings and reductions in motor vehicle running costs are likely. In one recent rapid transit study, such reductions in running costs amounted to 7 percent of the total travel benefits.

FACTORING FROM DAILY SAVINGS TO YEARLY SAVINGS

Although it would seem obvious that daily savings for work trips should be factored to annual amounts based on the number of work trips per year, such a procedure has not been followed in some studies. In one report, daily commuter trip cost and time savings were multiplied by 365 to arrive at yearly savings. In another report, the method of factoring cannot be understood; apparently, 95.4 days per year were used to factor time savings, 437.5 days per year for operating cost savings, and 691.7 days per year for parking cost savings.

For purposes of developing complete patronage, revenue, and benefit data, it is necessary to consider all times of day. Because the amount of travel and the degree of congestion change during the day, it is appropriate to consider dividing the day into a number of segments or otherwise to make recognition of such variations (6).

ECONOMIC VALUATION OF NONECONOMIC FACTORS

Most benefit-cost analyses in recent years have recognized that many effects of highway and rapid transit investments fall into the qualitative class, or into the quantifiable but not costable class. However, the bent of most benefit-cost analysts is to try to reduce as many effects as possible to dollar terms. In some cases, overzealous analysts have taken "stabs" at dollar values without a firm basis and even, in the worst cases, without stating any rationale for their estimated value.

In one study, improvements in urban life-style were discussed at some length. Under this category, subjects such as the effects on the nondriver, the increased range of choice, the preservation of open space, and the potential for rapid transit use as a standby mode of transportation were discussed. Then, a value for life-style benefits of $25 million per year—equal to $2.75 per capita per year—was assigned without any quantitative basis.

In another study, an analysis was conducted of the gains and losses to the tax base. Gains resulting from increased development intensities were estimated on a station-by-station basis, and losses were computed directly from right-of-way requirements. The net gain in tax revenues was estimated at $426.6 million. Although no mention is made of the fact, it is certain that some of the increased development around stations would otherwise have located elsewhere in the region. No basis was given for an arbitrary conclusion that ". . . Twenty-five percent (or $106.6 million) of these tax revenues is assumed to be a net increase to the Region and directly attributed to the impact of rapid transit." This total was not insignificant; it amounted to 13 percent of the total claimed net benefit.

Although it is difficult to argue that, in these two examples, a zero dollar value can be claimed for the items, the arbitrary assumptions themselves can certainly be challenged. More often than not, however, they go without challenge; the professional judgment of the analyst stands. Nevertheless, in the interests of providing an unbiased view, the analyst should disclose as much as possible of the facts that led to a choice, and clearly state that the value assignment is based on his judgment.

TREATMENT OF UNCERTAINTY

Although this author strongly recommends the inclusion of a formal evaluation procedure as a necessary part of an overall transit feasibility study, it should be clearly pointed out to local officials and the general public that the nature of benefit-cost analyses is much different from that of engineering analyses. Benefit-cost studies depend on forecasts of the future, on computer analyses that are only rough simulators of actual travel conditions, and on value measurement procedures that are approximate at best. Under these conditions, potential uncertainties should be analyzed as an integral part of the overall study, and the results of the analysis should be communicated in the written report.

One approach is to make estimates of important variables not only on a most-likely basis, but also on a 10 percent-90 percent basis (values for which there is only a 10 percent probability that the actual value will be greater or less than the estimated value). Then the three variations should be followed through the analysis to determine whether the conclusion would be changed. Another simple approach is to determine what value each important variable would have to take in order for the conclusion to be changed, which is a form of sensitivity analysis. Unfortunately, few benefit-cost studies in the literature have gone to the trouble of conducting an analysis of the effects of uncertainty.

INTERPRETATION OF BENEFIT-COST RATIOS

Some benefit-cost studies have made great play in citing the ratio of benefits to costs as an indicator of the degree of goodness of a project. Statements such as ". . . will achieve a benefit-cost ratio of well over 3:1 by 2020 . . ." and ". . . returns $1.31 for every dollar invested . . ." imply that the higher the ratio, the better the project. Although such an implication is generally true, it should be recognized that the only correct use of the benefit-cost ratio in choosing between two mutually exclusive alternatives is to determine whether or not the ratio exceeds unity.

By choosing different methods of computing the ratio of benefits to costs, it is possible to derive significantly different values of the ratio. Consider a hypothetical project with four items of cost as follows:

Item	Present Value
Transit investment cost	$1.0 billion
Transit maintenance and operation cost	$0.4 billion
Items of increased private cost	$0.5 billion
Items of decreased private cost	$3.0 billion

Under one method of computation, the ratio is 2.1:

$$\frac{\text{Cost Changes Due to the Investment}}{\text{Investment Cost}} = \frac{2.1}{1.0} = 2.10$$

Under another method, the ratio declines to 1.78:

$$\frac{\text{Private Costs}}{\text{Public Costs}} = \frac{2.5}{1.4} = 1.78$$

And under a third method, the ratio is 1.58:

$$\frac{\text{Items of Decreased Cost}}{\text{Items of Increased Cost}} = \frac{3.0}{1.9} = 1.58$$

What is clear is that the public, not informed of the meaning of the benefit-cost ratio, may consider a project that will return "over $2.00 for each $1.00 invested" to be more desirable than a project that will save them only a bit more than $1.50 for every dollar. What is important is that the project should be considered favorably in terms of dollar-valued benefits and costs and that the net excess of benefits and costs is $1.1 billion.

Another crucial point with regard to the benefit-cost ratio is the need to use incremental ratios when comparing multiple alternatives. Although this point is documented exceedingly well in the literature, it is still overlooked in some studies.

CONCLUSION

The conduct of benefit-cost studies of transit systems requires not only a fundamental and clear recognition of the various points of view that can be taken and a careful structuring of alternatives, but also careful attention to detail. The recommended framework for such evaluations is to recognize that an improvement in transportation will affect different members of the community differently; thus, the differential effects should be measured separately to the extent possible. The framework should include all appropriate effects, both those that are beneficial and those that cause disbenefits, in both traveler effects and community effects. It should carefully avoid errors of double-counting. It should place dollar values on those effects that can be reasonably reduced to such a basis, measure in a quantitative manner those effects that cannot be valued in dollar terms, and analyze in a qualitative manner those remaining effects that cannot be measured quantitatively.

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