# Misunderstandings of Cost-Benefit Analysis as Applied to Highway Transportation Investments

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**Misunderstandings about the concepts, principles, procedures, and applications of cost-benefit analysis seem to be increasing. The role and pricing of traffic accidents in such analyses are often inconsistently and illogically handled. At the same time cost-benefit analysis is being increasingly applied and is attracting newcomers from several disciplines. Suggestions are made for overcoming the current deficiencies of cost-benefit analyses for highway investments, including additional research into the cost pricing of traffic accidents, especially of fatal accidents, and additional education and training in the whole subject of cost-benefit analysis and its application.**

One purpose of this paper is to draw attention to some current misunderstandings about cost-benefit analysis. Readings and conversations on the subject of cost-benefit analysis for highway transportation investment proposals lead the author to conclude that there is an ever-increasing confusion about principles, concepts, procedures, and applications of results in this area. More writers are coming into print but, instead of clarifying the misunderstandings, they tend to perpetuate them. A new writer depends on what he or she has read and been taught. If the reading and the teaching were wrong, then the writer too is wrong—and so on through additional readers and writers.

Perhaps we are losing ground rather than gaining ground in improving our understanding of cost-benefit analysis because laymen and laywomen are now included in the group concerned—lay in the sense that they have no real professional experience in cost-benefit analysis and have not read the works of authoritative writers on this subject. Although they may be competent in the fields of social and business economics, technical engineering, sociology, business, planning, and government, they have read, practiced, and studied but little in cost-benefit analysis of proposed investments in highway transportation facilities.

At the same time it is encouraging that the application of cost-benefit analysis to all modes of transportation is becoming more widespread. Now an improved understanding of the concepts, theories, principles, and objectives of cost-benefit analysis is needed.

The fundamental question in an economic analysis of proposed transportation investments is simply, Will the investment pay off in the sense of realized cost reductions over a chosen future time period? With proper regard to the time cost of money, investments, and annual operations, if the cost reductions are greater than the expenditures necessary to produce the cost reductions, then the proposed investment is economically feasible. In this discussion, future cost reduction may be taken as a measure of the conservation of resources. That is what cost-benefit analysis is all about when it is used as a management tool in allocating monetary budgets and in efforts to get the maximum return on resources committed to investment projects and programs.

The purpose of cost-benefit analysis is to determine whether a proposed investment is economically justified in light of the total economic consequences generated. The objective is not to justify the proposed improvement but to determine whether it is justifiable. In their reports on their analyses, some analysts give the impression that they seek the wrong objective—justification. Such a position is probably more often found in traffic-accident analyses than in other proposals. In these analyses there seems to be an effort to include a large range of cost factors at high dollar amounts each and to play down those consequences resulting from traffic accidents, particularly from fatal accidents, that produce economic gains.

## LEAST UNDERSTOOD PRINCIPLES

The principles of cost-benefit analysis that are least understood include the following.

1. It is the difference between a pair of alternatives that is significant.
2. The analysis should include all consequences, to whomever they may accrue (this is equivalent to making a total system analysis).
3. The basic concept is "with and without" or "to do or not to do."
4. The analysis should be based on net costs and net consequences.
5. A cost-benefit analysis is not the decision on what to do but a tool for the decision-maker to use in arriving at a decision.
6. There is a difference in meaning among the terms price, cost, and value.
7. The objective of cost-benefit analysis is to weigh the differences in the conservation of resources between different proposals, or alternatives, for accomplishing an objective to improve highway transportation.
8. In all methods of analysis, but particularly in analyses using benefit/cost (B/C) ratio and net present value, the answer is not a rigidly calculated figure that is precise and unchangeable, a figure that all analysts would arrive at, as is believed by many readers and analysts.
9. The statement of many writers that the net present value method of analysis is the only method that will give the correct result is untrue. All methods will give the identical selection of the alternative of greatest economy when the procedures of analysis are correctly chosen and properly used.

Some analysts interpret their cost-benefit results as being of a high degree of precision because the B/C ratio and percentage rate of return are calculated to three and four decimals. Further, they try to establish dollar measures for factors that can be neither quantified nor market priced. They seem to have a goal of including in their factors a dollar term for every variable so that they can calculate one overall result—B/C ratio or rate of return—that includes everything (e.g., such factors as comfort, convenience, air pollution, aesthetics, scenery, relocation of persons and businesses, human pain and suffering, and so on). Is not the preferred procedure the one that puts into the calculated numerical B/C ratio or the rate of return only those inputs that can be quanti-

fied and market priced and leaves all other factors in a descriptive form that the decision maker may weigh and consider for each specific proposal and alternative?

In this age of computers there is a tendency to put the whole procedure into the computer. Such a practice has merit, of course, when the computer is a calculating machine. But many people seem to believe that any product of the computer is superior to what could be done by hand, is beyond error, and must be universally accepted.

Many analysts desire a specific, step-by-step procedure that is applicable to all possible situations and that requires simply plugging in the required input data. They appear not to wish to exercise the judgment required to produce the correct and properly selected input data nor a knowledge of the theory, concepts, and principles of analysis but to be willing to accept any published dollar measure of travel time, traffic accidents, fatalities, and discount rates. This trend toward following a strict step-by-step procedure determined by someone else is reminiscent of a statement in the preface of a book by Henck (1):

> It may be remarked that it was not part of the author's design to furnish a collection of mere "rules," professing to require only an ability to read for their successful application. Rules can seldom be safely applied without a thorough understanding of the principles on which they rest....

In cost-benefit analysis, it is necessary to know not only the rules and principles on which the analysis is founded but also the specific factors used as input data. In the presentation of the results of a cost-benefit analysis for investments in highway transportation, it is essential that the decision-maker (or other reader of the results) have a complete statement of the input factors and assumptions. For instance, unless the discount rate used in calculating a B/C ratio or net present value is known, the final answer is meaningless. Analysis period, traffic growth rate, and annual cash flows are also important.

Discussions in the literature often relate to differences in analyses when applied to (a) single projects having mutually exclusive alternatives, (b) multi-independent projects (priority ranking), and (c) programs composed of a series of several projects covering a span of years. To begin with, of course, the base alternative is to do nothing as compared to doing something. But once a decision to do something is made, any number of mutually exclusive alternatives may be analyzed. If it has been determined that doing something will provide more transportation economy than continuing the existing situation, each independent project in the group of multi-independent projects must be compared with each other independent project by the principle of differences. This procedure is a form of reiterative analysis and can become complex, especially if each independent project has more than one proposed design alternative.

The analysis of a program of investments over a period of years, such as a bridge improvement or replacement program or a program to reduce traffic accidents, may use the same procedures and concepts that are applied to mutually exclusive alternatives and selections of multi-independent priority. All that needs to be done is to make certain that the principles of analysis are followed, especially the principle of analyzing the differences in each pair of alternatives and including all consequences that accrue from each alternative. In addition, all cash flows must be properly discounted to a common date.

Some of the confusion in writing and discussing cost-benefit analysis comes from the popular use of the word benefit. The confusion can be somewhat relieved by thinking in terms of cost reduction between a pair of alternatives. The calculations of an analysis deal with cash flows in dollars—highway construction and maintenance cost in dollars, motor vehicle running cost in dollars, and travel time in dollars. In each of these factors, if cost is emphasized and is represented by cash-flow expenditures somewhere along the time scale, the analysis will always remain on solid ground. It is when benefits and values are introduced that difficulties arise.

It should be emphasized that what is being dealt with is cash-flow expenditures for two alternatives (a pair); any lesser discounted differences in the cash flow of the proposed new investment and its operation of the facility, as compared to the base alternative, would represent a cost reduction—a conservation of resources.

## METHODS OF ANALYSIS

There is still controversy in the literature concerning the choice of methods of analysis for analyzing the economy of proposed highway investments. The procedures commonly cited are known as (a) equivalent uniform annual cost (EUAC), (b) present worth of costs (PWOC), (c) rate of return, (d) benefit/cost ratio, and (e) net present value (NPV). When calculations are made properly, based on the principles of analysis, these five procedures will all identify the same alternative as the one having the greatest transportation economy, whether the analysis is applied to mutually exclusive projects, a collection of independent projects, or to an improvement program.

The mistake most often encountered in analysis is the failure to compare all alternatives or projects in pairs by differences, so that each alternative is in effect compared directly with each other alternative. A common procedure, though an incorrect one, is to compare each do-something alternative with the base do-nothing alternative and then to choose the alternative that has the highest B/C ratio or the highest rate of return. In the EUAC, PWOC, and NPV procedures the comparison is still by differences: The calculated results are compared visually in order of magnitude. If, in each of the five procedures, the identical input cash flows are used in combination with discount rates, it is only reasonable to expect agreement in results.

Some PhD graduates in economics strongly insist that the rate-of-return procedure could give the wrong answer. It is true that the rate-of-return procedure will give two or more answers in a data set that has a reversal of sign in the accumulation of the minus and plus cash flows. The common method of proving this is to start out with a large plus (income) cash flow and then to follow it with a large negative (construction cost) cash flow. What most writers overlook is the fact that two answers can also be gotten from the NPV procedure simply by using two different discount rates: a rate less than the rate that gives a zero NPV and a rate above the rate producing the zero NPV. This possibility of two or more specific numerical answers is not known without a test of the calculations. However, the situation can easily be recognized by examining the cash-flow series for the reversal of sign.

One objection to the rate-of-return method is that it assumes that the returns (positive inflows) are reinvested at the rate of discount that comes from the solution. If such an assumption is actually the case, whether recognized or not, it is also a correct assumption for the NPV method and B/C ratio. All methods discount the identical cash flows over the time chosen for analysis. If, in the NPV method, a discount rate of 9 percent is used and an NPV of $45 000 is determined, then the total operation

of cash flow must have earned, in some fashion, a return of more than 9 percent. If the same basic information and the rate-of-return method are used, the solution gives a rate of return of 15 percent. Is it not logical then to conclude that the cash flows being analyzed produced a compound earning rate of 15 percent and that any reinvestment factor assumed must also be assumed in the NPV method? If the NPV is calculated at 15 percent, the answer is zero dollars of NPV. This is the same 15 percent that was calculated as the rate of return for the combination of plus and negative cash flows. What is true in one method must also be true in the other.

## COST VERSUS VALUE

Management must be presented with an economic analysis made on the basis of costs (expenditures) for each pair of alternatives considered. These costs must be in terms of market prices—dollars currently paid by the public. These prices, in terms of the total cost required to gain the objectives, are not equivalent to values or the willingness to pay dollars; they are dollars actually paid or forecast to be paid. The decision-maker wants to know the extent to which a new investment will consume resources in the future as compared to the extent to which resources will be consumed if the investment is not made or, between two competing new proposals, which one will consume the least future resources.

The concepts of willingness to pay and value to persons have been injected into cost-benefit analysis of highway transportation investments basically in two areas: travel time and traffic fatalities. Neither willingness to pay nor value is an appropriate measurement to use in cost-benefit analysis for either travel time or fatality, and neither should be used as a surrogate for economic cost.

Willingness to pay a certain price or to suffer a certain cost in no way represents a conservation of resources. Willingness to pay an amount for a reduction in travel time or for the probable prevention of a fatal accident is, in a sense, a measurement of a value. Value, however, is normally in excess of cost, or the willingness-to-pay sum, because people expect and receive greater value from the gain or satisfaction in a transaction than they expend or are willing to expend to receive that gain or satisfaction. If the value were not greater than the cost, people would not pay the cost. Value may be defined or explained in the sense of worth, merit, usefulness, or importance of an object, favor, satisfaction, or experience. Value is what people would be willing to sacrifice to gain possession or ownership of or to experience something. In this sense, value is closely related to what people are willing to pay or to sacrifice to make a gain, to achieve a satisfaction, or to avoid an event or experience.

Value should not be used in cost-benefit analysis in the place of market cost. Value is more than cost would be if cost were obtainable and therefore, in a dollar sense, value is in excess of cost. In the broad sense, the economic structure of the nation would be severely disrupted if new highway facilities were constructed on the basis of what the general public considered the value of the improvements to be. To finance these investments in new facilities it would be necessary for the public to shift their expenditures from other satisfactions in life to highways because the values they place on highways would not increase their incomes and would not reduce their transportation costs by the difference between true cost reductions and the higher value placed on the highway improvement. The theory is that, if cost reductions are used as the basis of selecting new highway projects for investment, people will not suffer economically because their cost reductions will more than pay for the cost of the construction and operation of the new facility as compared to costs for existing operations.

An example of this concept is the recent increase in the price of gasoline from about $1.32 to $2.46/liter (35 cents to 65 cents/gal). Without considering any inflation in the value of the dollar, this increase in gasoline price has been absorbed by the motoring public with little or no reduction in vehicle use, which proves that the 1975 value of automotive fuel was considerably greater than the market price. If, in a cost-benefit analysis for highways, the concept of value (or willingness to pay) is used for travel time or fatalities, then why not use the value concept for fuel, tires, vehicle maintenance, and all other factors in the calculations? Why not be consistent in selecting the factor to put into the analysis?

Another popular economic concept that merits discussion is that of perceived cost. In many transactions, decisions, and agreements, people do develop—consciously or unconsciously—some impression of the cost they are committed to. Their perceptions are generally inaccurate, hazy, and poorly developed. In motor-vehicle trip making, route selection, speed selection, and driving action, any perception of cost used in technical papers can be nothing better than a vague conception of the true cost. Even if a vehicle driver makes such a perception, his or her numerical answer is worthless in cost-benefit analysis. Persons who have a solid concept of what it costs to operate a motor vehicle under any specific condition are very rare. It is actual economic cost that must be used in cost-benefit analysis, not perceived cost or value dollars. Perceived costs may be appropriately used in traffic diversion studies when there is proof that the driver bases his or her route decision on such factors.

## TRAFFIC FATALITIES

The current emphasis in reducing the annual number of traffic fatalities is on safety programs and spot improvements. This emphasis includes cost-benefit and cost-effectiveness measurements. The result is a renewed search for a dollar cost for traffic fatalities suitable for use in cost-benefit analyses. At this point researchers, analysts, and writers fail to realize that those factors that cannot be market priced are to be taken into consideration by the decision-maker as separate factors. There is no necessity to cost price these factors for inclusion in the calculation of B/C ratio or the rate-of-return solution.

How to handle traffic fatalities in cost-benefit analyses is a subject of great controversy and uncertainty. Much has recently been written on the subject and studies are still under way. However, analysts in this area have so far taken the wrong track, examining all the devices and procedures for placing a value on human life. The following discussion of the factors involved in fatal accidents is based on the assumption that the economic consequences would be market priced and the human and social factors would be identified and described for use as desired by the decision maker.

The analysis of a traffic fatality, like the analysis of direct economic cost factors that are priceable, is no different from the basic analysis concept: The objective is always a comparison of with and without—do-something or do-nothing—alternatives. When a fatality is involved, the measure sought is the economic change in society over the expected time of survival of the fatality. This change is found by comparing the economic costs incurred

over that period with the economic cost to society after the death for the same time period. A comparison should be drawn between the economic impact of a living person on society over the period of normal life expectancy with the economic impact after he or she became a traffic fatality.

The development of a dollar amount for a traffic accident fatality to be used in cost-benefit analysis for proposed highway transportation investments, regardless of their character, should begin by answering the following questions:

1. How should the dollar amount be used?
2. Why is it necessary to use a dollar amount in the calculations?
3. What is the basic objective of the cost-benefit analysis?
4. What are the characteristics of a fatality that could possibly affect such a measurement (age, sex, economic status, employment status, trade, or profession)?
5. What information is available and of possible use?
6. Should the dollar amount be determined for separate geographical locations and different time periods—say, yearly?
7. What are the possible measures for consideration without attention to their suitability or possibility of quantifying and pricing?
8. What is the basic comparison that is to be made on a with and without basis?
9. What are the differences between the with and without situations?

In such an analysis, the concept of value of life is irrelevant, as are also the social and emotional aspects of human life and death. Income, in the sense of support for a surviving family or other dependents, is also irrelevant except as it affects economic factors. What is needed is a dollar amount for a fatality that is consistent with the dollars of cash flow that represent highway construction and maintenance costs and the cost of running motor vehicles on the highway. The same is true of the other factors of traffic accidents that represent physical goods consumed and labor or professional services involved in treating injured persons and in repairing vehicles and roadside and highway structures.

There is unquestionably a need to put a price on fatalities in economic dollars and not social dollars and to include these dollars in the analysis along with highway and motor-vehicle dollars. The principle of including all consequences that may accrue (a form of system analysis) requires that the dollar amount for a fatality must be the net of all costs to the economic system based on the comparison between the economic costs had the person lived and the costs following the death. This means that the costs of food, housing, clothing, education, health, and other similar costs of maintaining a person in society until death should be included in the calculations on a time-discounted basis. Another factor requiring consistency in the total procedure is the handling of temporary disability and permanent disability with reference to a fatality.

A procedure or concept should be developed that will make the dollar for vehicle fuel equivalent to the dollar applied to a fatality; this means an economic base related to consumption of resources.

There have been few attempts to study the gains accruing to society from a traffic fatality. When a death occurs in a traffic stream, the main consideration is the timing of that death with respect to when that death might reasonably have occurred otherwise, i.e., normal life expectancy based on the causes and conditions of all deaths with respect to age and occupation or daily activity. The only economic difference between a temporary disability caused by bodily injury and a fatality is one of time duration. In both cases a logical procedure and one following the principles of analysis is to compute the time discounts of all cash flows over the time periods applicable and then calculate the net present worth of these discounts plus and minus cash flows. An illustration is the case in which the death of a worker in a traffic accident requires the training of a replacement employee. That training expense would be required eventually without the traffic accident. The employed victim could resign, get sick and die, or be promoted to another position. So the net cost in economic analysis is the discounted cost of training between the date of the fatality and the expected future date when training would be necessary. The same logic applies to funeral cost and other items.

If the future earnings of a fatality are to be expressed as a cost to society, why then should not the future earnings accruing to the fatality's replacement be considered a gain to society? Does not the principle of considering all consequences apply to such actions or events? If an accidental death comes at a younger age for the deceased than it would have come had the accident not taken place, then the analysis of fatalities should be directed to what the economic system gains and loses by the earlier death as compared to gains and losses resulting from a later death.

What worthwhile economic contribution is now made to society that will not continue to be made after the death of the principal contributor? This is the critical question. If the contribution is not continued and is important to society, then there is an economic loss; if some other person continues the contribution, then there is no loss—no change in the economic balance. The loss of the services of a citizen who devoted his or her energies to civic activities without direct pay is expressed as a loss to society. But this ignores the fact that, if society wants to continue the dead person's activity, some living person takes it over. In addition, if older persons did not die, younger persons coming up would find no employment and no role in community functions.

Certain writers have objected to the use of probable future income of the fatality as a measure of his or her economic worth to society on the ground that a high-salaried executive is given a much higher value than a day laborer. But in this type of economic analysis the objective is not to determine a dollar sum for a specific individual. What is wrong about using different dollar sums for the fatality according to age, sex, economic status, and education? What is sought is the total economic impact, calculated by including any subdivisions that will be helpful in arriving at the grand total. No attempt should be made to apply the results to an individual as a social entity.

Suppose that a man is killed in a traffic accident and within a few days his job vacancy is filled by a replacement. The replacement comes in the form of an employee promoted or transferred from within the organization, transferred from another organization, or hired from the old or young on the unemployed rolls. In a few days it is business as usual as far as the economic consequences of the accident are concerned. Suppose that a motor vehicle is wrecked in a traffic accident. Within a few days the owner has procured another vehicle: a used automobile purchased from a dealer, a friend, or a stranger, or a new automobile. In a few days, the owner has returned to his or her normal motor-vehicle use. These two types of events are similar, even though one refers to a human fatality and the other to a machine fatality. For cost-benefit analysis based on the economic

factors related to conservation of resources, the procedure should be the same in both cases. Basically, the procedure is to decide what the economic consequences of the accident are and their timing. It must be remembered that in our economic system what is a loss to one person may be a gain to another. The total system (all consequences) must be considered and the economic changes (gains or losses to society) and their relative time periods determined.

When a human fatality is to be input to a cost-benefit analysis, calculations must be restricted to solidly based, market-determined costs. The nonquantifiable, nonpriceable social and emotional aspects of human life must be left as abstract elements to be given such weight as the decision-maker believes is proper. If efforts can be directed toward the economic goal and away from the social goal, a workable solution can be found that should be comparatively easy to apply and one that will keep all the dollar inputs in cost-benefit analyses on the same basis instead of mixing cost dollars with value dollars.

As mentioned above, we need to hunt more diligently for a true cost basis of measuring the economic effects of death on the highway. Attempts to place a value on human life have been unsatisfactory. One concept that could be explored is that of considering the human being in the various early stages of life—infancy, childhood, youth—as a net economic burden to society in the sense that, in these stages, maintenance cost (i.e., food, shelter, clothing, health, education) is greater than contribution to economic production. Up to the time of gainful employment or gainful activity, a person's cash flow is outgoing (negative sign). When productivity starts, approximately between the ages of 14 and 22, he or she begins to produce cash flow (positive sign) as opposed to economic consumption. It would be reasonable to compound the negative sums up to the age of economic productivity and then write them off over the future period of productivity, based on life-expectancy tables. This concept is similar to that applied to depreciable plant. The investment cost when a facility is installed and ready for use is written off as depreciation expense over the years of usefulness. In cost-benefit analyses, a fatality could be handled in a similar manner.

This may be perceived as treating man as a machine. That is exactly the concept that should be used. Placing a value on man as a human being in society makes no sense when such value is to become dollars in an economic analysis along with the dollars for highways and for motor vehicles. We must use the same kind of dollars for all factors.

Another concept that should be considered in the search for new concepts and bases for getting highway traffic fatalities into cost-benefit calculations on an economic basis is longevity. Schwing (2) in his paper presents rough figures on the number of years of increase in human life expectancy that would result from 100 percent achievement of fatality reduction from certain causes of death. He considers diseases and classes of accidents, including highway traffic accidents segregated by method of accident reduction. His increased longevity varies from 0 to about 10 years. No mention is made, however, of how to convert increase in longevity to dollars. Schwing mentions that the concept of longevity is more appropriate than the concept of mortality, and this author agrees with his conclusion.

Another possible consideration is one related to time. The main economic difference between a temporary, disabling injury and a fatality is one of time duration. Placing a dollar amount per hour on a vehicle or its occupants as the cost of travel time is generally accepted practice; the same concept and the same unit dollar cost could be applied to a fatality. All that this application would require is calculating the present worth of the expected hours of work over the life expectancy of the fatality and then applying the same price per hour as that applied to travel time. This concept needs to be applied under the principle of total consequences and, from the computed dollar amount, the present worth of the cost of sustaining the fatality over the normal life expectancy should be deducted from the dollar cost of time calculation.

## CONCLUSIONS

The available literature on itemized costs associated with traffic fatalities consists of compilations made by individual investigators, who were in turn guided by what they found in the literature. In attempting to put a dollar amount on a fatal traffic accident, not one of these investigators starts with an analysis of the real objective of the effort, the basic logic to be followed, or the concepts and the basic criteria commonly associated with cost-benefit analysis. They also omit a discussion of the internal factors of the total system to be investigated.

The whole approach to pricing fatal accidents should be reexamined by doing the following in the order listed.

1. Set forth the concepts, principles, and theories involved both in the gathering of information and in the use of this information in calculating the cost-benefit answer.
2. Determine the total system to be analyzed and, within this system, identify and isolate each factor of input and consequence.
3. Thoroughly study the factors of input and consequence to determine their role, if any, in the analysis.
4. Determine the basis of quantifying and pricing each factor.
5. Set forth the procedures to be followed in the pricing of each factor.
6. Complete the actual quantification and pricing of the factors in the form and concept to be used in the final calculations and tabulations.

The main item in this procedure that has been followed in past efforts is the pricing of the factors—the last step. Many past studies began and ended with this step, having paid little or no attention to the first five steps. New research on the pricing of traffic fatalities must begin at the beginning, with step 1.

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