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A Critique of Some Recent Economic Studies Comparing Alternate Highway Locations

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Some 85 recent studies that made economic comparisons of alternate highway locations in 35 different states have been examined. The paper discusses and evaluates the methods of analysis employed in these studies. Certain general principles are outlined that, if recognized in such studies, will considerably improve the quality of the studies.

Some criticisms applicable to certain studies, although not to all of them, are illustrated and discussed at length as follows:

1. Sometimes there is a failure to define clearly the alternatives that ought to be compared. This failure occasionally leads to highly inflated values of stated benefit-cost ratios.
2. The interest rates used in these studies frequently are too low, all things considered.
3. Prospective benefits to highway users often are greatly overstated because of the failure to apply a time-discount factor to benefits in the more distant future.
4. The conclusions of economic studies of alternate highway locations are extremely sensitive to the length of the assumed study period (that is, to the number of years for which the study is made) and to the assumed rate of growth of highway traffic. Apparently, analysts who make such studies are not fully aware of this sensitivity.
5. Some studies are made as if the only consequences of a choice between locations are consequences to highway users. But in many instances prospective other consequences to the public are more important than the highway-user consequences. The problem of making the prospective non-user consequences commensurable with user consequences is an inherently difficult one; this seems to be a fruitful field for research.

• SOME 85 recent studies that originated in 35 states and made economic comparisons of alternate highway locations have been examined. The paper discusses and evaluates certain aspects of the methods of analysis employed in these studies. Certain general principles are outlined that, if recognized in future

studies of this type, will considerably improve the quality of the studies.

In a sense this paper is a sequel to three other papers presented to the Highway Research Board during the past two years. Among other matters, the first paper (*1*) presented the case for the use of the techniques of engineering economy in highway programming, location, and design. The second paper (*2*) stated a number of basic concepts of engineering economy and showed the applicability of these concepts to decision making regarding highways. The third paper (*3*) summarized the case for the use of higher minimum attractive rates of return (interest rates) in highway economy studies than the low rates (0 percent to 3½ percent) now in common use for such studies; it was suggested that, all things considered, a reasonable interest rate for use in such studies ought to be about 7 percent. In order that this paper be complete in itself, certain ideas developed at greater length in the three earlier papers are restated concisely at various points in the present paper.

GENERALIZATIONS

Certain general statements regarding the examined economy studies are as follows:

1. Many man hours of conscientious professional effort have gone into the data gathering for these studies, particularly in the estimation of the required investment for alternate routes and in the forecasting of traffic for these routes.
2. In most of the studies, the benefit-cost ratio is used as the criterion for decision making. The "benefits" are largely or entirely estimated savings to highway users. The "costs" are largely capital costs and maintenance costs of highways.
3. Nearly all the studies involve forecasts of considerable growth of traffic during the assumed study period (often 20 to 30 yr). Thus prospective "benefits" in the more distant future are generally much greater than in the near future.
4. Nearly half of the studies disregard the time value of money, in effect using an interest rate of 0 percent. Most of the other studies use interest rates of 1.5, 2, 2.5, 3, or 3.5 percent. A few of the studies use higher rates, such as 6 and 8 percent.
5. Many of the studies lean heavily on the 1951 AASHO report on "benefit analysis" (*4*), both as to the general procedures illustrated and the actual unit costs of motor vehicle operation given in that report.
6. Relatively few of the studies place any monetary valuation on the prospect of reduction in highway accidents.
7. Because of differences in assumed interest rates, assumed study periods, and other differences in the application of the techniques of engineering economy, computed benefit-cost ratios are not comparable as between different highway agencies.

CRITICISMS

This paper is largely an exposition of certain criticisms that are applicable to many of the studies, although not to all, as follows:

1. Sometimes there is a failure to define clearly the alternatives that ought to be compared. This failure occasionally leads to highly inflated values of stated benefit-cost ratios.
2. Most of the interest rates used in these studies are too low, all things considered.
3. Prospective benefits to highway users are often greatly overstated because of the failure to apply a time-discount factor to the benefits in the more distant future.
4. The conclusions of economic studies of alternate highway locations are extremely sensitive to the length of the assumed study period (that is, to the number of years for which the study is made) and to the assumed rate of growth of highway traffic. Apparently, analysts who make such studies are not fully aware of this sensitivity.
5. Extramarket benefits (such as increased comfort and convenience to operators of pleasure vehicles) are often merged with benefits that have a market

value (such as reduction in vehicle operating costs). Therefore, the basis for decision making among alternate locations is not so clear as it would be if the prospective extramarket consequences of decisions were separately identified.

6. Where the benefit-cost ratio is used as the primary criterion for decision making, it is not sufficient to compare total benefits with total costs; separable increments of cost need to be associated with their related increments of benefits. Apparently some analysts are unaware of this aspect of the benefit-cost technique.

7. Some studies are made as if the only consequences of a choice between locations are consequences to highway users. But in many instances, prospective other consequences to the public are more important than the highway-user consequences. The problem of making the prospective non-user consequences commensurable with user consequences is an inherently difficult one; this seems to the authors to be a fruitful field for research.

NEED FOR CONSIDERATION OF ALTERNATIVES

An engineering economy study is a comparison of the merits of alternatives. Sometimes a particular proposal appears to be attractive only because some superior alternate course of action has not been considered.

For example, in one report Proposal X required a major improvement of an existing through highway. Proposal Y called for an entirely new location that would relegate the existing road chiefly to the service of local traffic. A prospective favorable consequence of the new location was to make possible the development of a large and entirely new economic activity in a certain area not now served by an adequate highway. This consequence, included in the economic analysis as a "benefit" for Y but not for X, was a major factor in the analyst's recommendation favorable to Proposal Y. The analyst failed to recognize that the same benefit could be obtained by making a relatively small additional investment to add to Proposal X a low cost secondary road that would serve the new area.

The analyst should also have considered a Proposal Z that combined the improvement of the existing through highway with the secondary road. One reason for the analyst's blind spot in this instance was probably the fact that either Proposal X or Proposal Y could be financed largely from Federal funds, whereas the secondary road needed for a Proposal Z could be financed only from state or local funds.

In this particular instance, a rough examination of the basic data indicates that Proposal Y would be favored by a benefit-cost analysis comparing Proposals Y and Z. However the margin of superiority would be much less than shown in the actual report comparing only Proposals Y and X. Although the actual report appeared conclusive, a revised report comparing Y and Z would have indicated that a careful look was needed at the differences between the two locations that had not been evaluated in money terms.

A possible consequence of this sort of error deserves special mention. Proposals for major changes in route often bring strong reactions from persons who feel their interests will be adversely affected. If a gross error such as this is discovered, the highway agency will suffer a serious loss of prestige and good will.

THE CASE FOR HIGHER INTEREST RATES

When economy studies to evaluate alternate proposed investments in physical plant are made by the method of annual costs, the method of present worths, or the method of the benefit-cost ratio, it is necessary for the analyst to choose an interest rate. (If an analyst disregards the time value of money, he is, in effect, selecting a 0 percent interest rate.) The operational effect of choosing a particular interest rate is to adopt that rate as the minimum attractive rate of return. Either in private enterprise or in public works, the issue in selecting an interest rate for an economy study may be phrased as follows: What is the lowest

possible rate of return, all things considered, that is deemed sufficiently attractive to justify the proposed investments?

In this connection, two relevant questions to consider are the following:

1. What is the cost of money, all things considered?
2. What investment opportunities, if any, are likely to be foregone as a result of a decision favorable to a particular investment in physical plant?

In general, the minimum attractive rate of return should never be less than the cost of money. Often, however, the minimum attractive rate of return should be considerably higher than the cost of money because of considerations related to the investment opportunities foregone. In the language of the professional economist, the concept of "opportunity cost" is applicable to the selection of the interest rate to be used in economy studies.

Nearly all the economic analyses of alternate highway locations deal with sections of the interstate highway system. Therefore, most of the money for this highway construction will be provided by the Federal government. Recently, the Federal government paid a 5 percent interest rate on bonds maturing in 4 yr and 11 months. The interest ceiling of 4¼ percent on debt maturing in more than 5 yr presently makes it impossible for the Federal government to do any long-term borrowing. Even if the cost of money were to be viewed as the controlling element in selecting an interest rate for highway economy studies, nearly all the studies are using rates that are unrealistically low. The foregoing statement applies to the states using 3 or 3½ percent as well as to the many states using 0 percent.

However, it seems that the controlling element in selecting an interest rate for highway economy studies nearly always ought to be the various investment opportunities foregone. This rate of return normally will be considerably higher than the cost of money to the governmental agency financing the highways. Two types of investment opportunities require consideration: the highway investments foregone and the investments foregone by the taxpayers who provide the funds for investment in highways.

In each state there are many highway proposals every year that are competing for the limited funds available for highway investment. If prospective rates of return were to be computed for each proposal and for the separable elements of each proposal, all proposals might be listed in order of rate of return. Such an array would usually show that available funds would be exhausted by projects yielding relatively high rates of return. It is believed that, with the growth of population and motor vehicle traffic, this condition is likely to continue for many years. If so, the justification of certain projects and project elements on the basis of a prospective rate of return of from 0 percent to 3½ percent will cause the elimination of other projects and project elements that would yield much higher rates of return.

There are also the investment opportunities foregone by many of the taxpayers who provide the funds for investment in highways. For the many individual taxpayers who have to borrow money for one purpose or another, a risk-free investment is to borrow less money or to reduce the amount of an outstanding loan. The yield from such an investment will rarely be less than 5 percent and will frequently be a great deal more. For business enterprises that pay taxes, the minimum rate of return that makes a proposed investment in industrial assets seem attractive is rarely less than 7 percent and is often much higher. If the time ever comes when all the funds available for highway investment cannot be invested at a yield of more than 3½ percent, it will then be in the public interest to reduce highway user taxes.

ERRORS IN PRINCIPLE

In most of the studies it is estimated that there will be a substantial growth of traffic during the 20- to 30-yr study period. An estimate that traffic will triple within the study period is not unusual.

In general, estimated benefits each year are proportional to the estimated traffic for the particular year.

A general principle that should be recognized in the analysis of the merits of proposed investments is that favorable consequences in the distant future are less attractive than favorable consequences in the near future. For example, considering a proposed investment of $1,000 that is expected to yield $1,220 one year hence, it is obvious that the prospective rate of return is 22 percent. In contrast, consideration of a proposed investment of $1,000 that is expected to yield $1,220 twenty years hence shows by elementary compound interest mathematics that the prospective rate of return is only 1 percent.

A few of the economy studies of alternate highway location make the error of reporting as the benefit-cost ratio the ratio of the annual benefits at the end of the study period to the equivalent annual costs throughout the period. Most of the other studies make the error of giving benefits in the distant future equal weight with benefits in the near future.

A simple numerical example may be used to illustrate the effect on the stated benefit-cost ratio of different interest rates and different methods of treatment of distant future benefits. The following assumptions are made:

1. Location B requires $3,000,000 more investment than Location A.
2. The estimated life of this extra investment is 25 years with zero terminal salvage value.
3. The two locations have no differences in estimated maintenance costs.
4. The estimated additional benefits from Location B are $100,000 in the first year.
5. These benefits are expected to increase by $8,333 a year to $300,000 in the 25th year.

Therefore, it may be shown by elementary compound interest mathematics that these benefits are just sufficient to recover the investment with a return of slightly more than 3½ percent.

TABLE 1

Method	Ratio (0%)	Ratio (3½%)	Ratio (7%)
1. Final year's benefit to equivalent annual cost	2.50	1.65	1.17
2. Average annual benefit to equivalent annual cost	1.67	1.10	0.78
3. Equivalent annual benefit to equivalent annual cost	1.67	1.02	0.67

Table 1 gives solutions to the example at three different interest rates and using the three different methods of computing benefit-cost ratio that were found in the reports. At a given interest rate, the denominator in the benefit-cost fraction is the same in all three methods, namely, the annual cost of capital recovery of a $3,000,000 investment in 25 years. This is $120,000 at 0 percent, $182,000 at 3½ percent, and $257,000 at 7 percent.

The numerator in the benefit-cost fraction in Method 1 is $300,000, the estimated benefit in the 25th year. The fallacy in Method 1 should be obvious. The benefit-cost ratios obtained by this method tend to be highly inflated.

The numerator in the benefit-cost fraction in Method 2 is $200,000, the sum of the estimated total benefits in the 25 years, $5,000,000, divided by the number of years. In the example, the $200,000 figure is also the estimated benefit for the mid-year of the study period. Method 2 gives prospective benefits 25 years away the same weight as prospective benefits in the immediate future. In effect, this method uses a 0 percent interest rate in computing the numerator of the benefit-cost fraction regardless of the rate that is used in the denominator. (Methods 2 and 3 give the same ratio, 1.67, at 0 percent interest.) In the usual case in which it is assumed that benefits will increase from year to year, the result of using Method 2 is to inflate the benefit-cost ratio. The magnitude of the error caused by this method depends on the estimated growth of benefits, on the length of the study period, and on the interest rate.

Method 3, which requires the use of compound interest mathematics, is the

only method that is correct in principle. In general, the calculation of a uniform annual figure equivalent to a nonuniform series of future money amounts requires the calculation of the present worth of each money amount. These present worths are added together and the equivalent uniform annual figure is obtained by multiplying the sum of the present worths by the appropriate capital recovery factor.

In this particular example, the estimated benefits increase each year by a uniform annual figure of $8,333. In cases of this type, it is possible to simplify the compound interest calculations by the use of a table of so-called gradient factors (*5*).

SENSITIVITY OF DECISIONS TO ASSUMPTIONS

The end product of an economy study comparing proposed investments in physical assets is a decision or recommendation for a decision. In an economy study there normally will be some primary criterion for decision making (such as the prospective benefit-cost ratio or prospective rate of return on investment). In the actual decision among the proposed alternatives, it is desirable for the decision maker to be aware of the extent to which moderate changes in the basic estimates influence the criterion for decision making.

With the interest rates at or near 0 percent used in many economy studies for highways and with the benefit-cost ratio used as the major criterion for decision making, the decisions among alternate highway locations are extremely sensitive to the assumed length of the study period and to the assumed rate of growth of traffic. However, the main effort in data gathering for highway economy studies cannot be directed at either of these matters. The decision whether a study period will be 20, 25, or 30 years is an arbitrary one. And the growth of traffic, particularly in the more distant future, is not something that can be estimated with great precision. The higher the interest rate used in the economy study, the less sensitive will the decision be to these arbitrary and uncertain matters.

For example, the previous example evaluated the merits of a proposed extra investment of $3,000,000 to adopt Location B rather than Location A. It will be recalled that extra benefits from Location B were expected to start at $100,000 a year and to increase by $8,333 a year. The effect of length of study period and interest rate may be brought out by the following comparison of benefit-cost ratios. (For simplicity, it is assumed that the life of the investment is equal to the length of the study period and that the terminal salvage value is zero.)

	Ratio		
Study Period	(0%)	(3½%)	(7%)
20 years	1.19	0.81	0.57
25 years	1.67	1.02	0.67
30 years	2.21	1.23	0.75

The extent to which the foregoing benefit-cost ratios are influenced by prospective growth of benefits may be illustrated by computing the benefit-cost ratios for the same study periods and interest rates on the assumption that benefits will continue for the entire study period at the initial value of $100,000 a year.

	Ratio		
Study Period	(0%)	(3½%)	(7%)
20 years	0.67	0.47	0.35
25 years	0.83	0.55	0.39
30 years	1.00	0.61	0.41

It is obvious that estimates about future happenings become less reliable as the length of the forecast period increases. One favorable consequence of using a realistic interest rate in an economy study is to place less weight on uncertain estimates of the more distant future.

EXTRAMARKET BENEFITS

In economy studies for highways, there are certain consequences of proposed investments for which the market provides no valuation, even though the conse-

quences may be forecast in other units than money units. Thus it may be estimated that a proposed highway improvement will increase the "comfort and convenience" for a particular number of miles of vehicle operation per year and that time saving by pleasure vehicles will be a certain number of vehicle minutes per year. Such extramarket consequences are important in many studies, and analysts often assign an arbitrary money valuation to them in order to count them in the benefit-cost ratio. Many of the reports do in fact include these extramarket benefits, usually valuing them at the unit figures suggested in the 1951 AASHO report (*4*).

A controversial and unresolved question in highway economy is whether it is better to assign money values to such extramarket consequences, and thus include them in the formal economic analysis, or to consider them only as irreducible data that are given weight in the final decision making. However, because of the essentially arbitrary nature of the money values assigned to such extramarket benefits, they should always be separately identified whenever they are included in the formal economic analysis. In some of the studies, these extramarket benefits constitute a large fraction of the total benefits attributed to a proposed highway improvement.

Generally, these studies make no separate identification of these extramarket benefits. It seems that where a computed benefit-cost ratio is, for example, 0.65 with extramarket benefits left out and 2.10 with them included, this fact should be pointed out by the analyst in presenting his economic analysis. In this way, the analysis becomes a better guide to decision making which is its purpose.

A PITFALL IN THE BENEFIT-COST RATIO

In both the 1950 and 1958 editions of the well-known "Green Book" (*6*), which deals with the economic analysis of Federal water projects, certain difficulties in interpreting the benefit-cost ratio are discussed. It is pointed out that where the benefit-cost ratio is used as the criterion for decision making, the objective should be to maximize the excess of benefits over costs. This objective will not necessarily be accomplished in studies of alternate highway locations by selecting the location that has the highest benefit-cost ratio as compared to a present condition. Neither is it appropriate to increase costs to a point where the total benefit-cost ratio just exceeds unity. In comparing a number of separable alternatives, it is essential to compare increments of benefits with increments of costs.

Not all of the analysts seemed to be aware of the foregoing aspect of the interpretation of benefit-cost ratios.

NON-USER CONSEQUENCES IN DECISIONS

In the frequent instances where the location of an express highway is a matter of local controversy, prospective nonuser consequences are likely to be the source of the strong differences of opinion. Some of the reports contain excellent discussions of such consequences. Other reports disregard them completely, even though a reader of the reports, unfamiliar with local conditions, might guess that nonuser consequences are actually important.

In most cases where nonuser consequences of highway location are discussed, the consideration is only on a qualitative basis. Although some such consequences are clearly extramarket, it is evident that money valuations could be placed on other such consequences if it were possible to forecast these matters in a satisfactory way. It seems that the forecasting of nonuser consequences is an important field for future highway research.

CONCLUSION

In examining the many comparisons of alternate highway locations, these reports have been viewed primarily as exercises in engineering economy. Comments have related chiefly to the methodology of this field. The quality of highway decision making might be considerably improved

if analysts responsible for studies in highway location, programming, and design should acquire a clear and more sophisticated understanding of the principles and techniques of engineering economy. Or stated less diplomatically, too many of the reports proved to be a fine job of data gathering that were partially, and in one case largely, negated by poor or improper economy study techniques.

In other writings (*1, 2, 3*), the authors have stressed the view that the rate-of-return technique is superior to the benefit-cost-ratio technique as the major criterion for highway decision making. However, because nearly all the reports examined for this paper used benefit-cost ratios, this paper has been written in terms of analyses based on such ratios.

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