Treatment of Deferred Costs in Economic Analyses

RICHARD W. RENSHAW, *Inter-County Regional Planning Commission, Denver, Colo.*

Engineers have a tremendous responsibility to see that the limited public funds which can be allocated to the planning, designing, and construction of the nation's highways are used to the best advantage. This paper is based on the premise that this allocation of funds cannot properly be made without a thorough evaluation of the economics of the alternatives.

The benefit-to-cost ratio and the rate-of-return methods of ranking alternatives have been suggested as procedures for making such economic evaluations. However, both methods have certain limitations on their use. An analytical analysis and comparison of the two methods shows that the rate-of-return will be a more sensitive method for ranking alternatives which have a high annual cost of maintenance and a short amortization period. On the other hand, the benefit-to-cost ratio will be a sensitive method of ranking alternatives with large capital costs which are to be amortized over longer periods of time. It will also be very sensitive to the choice of an interest rate for this capital.

When it is desired to compare alternatives which have a significant difference in capital costs, maintenance costs, or amortization periods (such as alternatives with different design standards) there is a serious question of the adequacy of merely ranking the alternatives by these methods, because the ranking could be misleading or incorrect.

Since this type of problem may be important in highway planning, this paper suggests that it may prove desirable to make a more thorough economic analysis of these alternatives by graphically comparing the net annual benefits (annual gross benefits minus costs) of the alternatives, and selecting the alternatives on the basis of maximizing net benefits at a satisfactory rate (or range of satisfactory rates) of return on the invested capital.

• THE FIELD of economic analysis for public works projects is relatively new. The water resource field was one of the first to develop and use the techniques of economic analysis with its use of the benefit-to-cost ratio. In the field of highways, an AASHO publication (*2*) did much to start the use of the benefit-to-cost ratio as a tool for the evaluation of highway projects. The use and application of economic analysis in highway planning and design is only beginning.

The benefit-to-cost ratio and the rate-of-return methods have been suggested as procedures for making economic analyses. However, evaluation of these methods shows that they both are limited in their application for ranking alternatives when there is a significant difference in the amount or type of deferred costs in relation to the capital costs of the alternatives.

Eckstein (*4*) has explained the theoretical relationships between these two methods, and has made an interesting comparison of their use in ranking water resource projects. This comparison (Table 1) shows a project ranking first by one method, and seventh by the other method. This type of discrepancy can be explained in terms of differences in any or all of three variables involved in the relationship between the two methods: the rate of interest charged on capital; the amount of deferred costs, such as operating and maintenance costs; and the period of amortization of capital.

TABLE 1
COMPARISON OF TWO INVESTMENT CRITERIA[1]

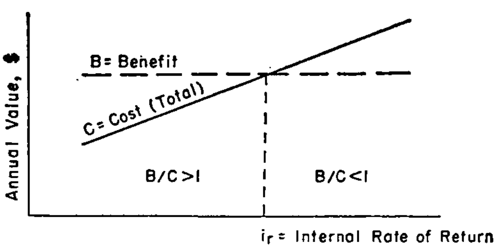
Project					Rank Based on	
Name	Type	O/K[2]	B/C	$r(\%)$	B/C	r
Rice Creek, Fla.	River navigation	0.017	3.58	15.3	1	4
Bellhaven Harbor, N.C.	Harbor	0.034	2.42	12.4	2	5
Brazos River Watershed	Watershed improvement and flood control	0.088	2.42	19.7	2	3
Dauphin Island Bay, Fla.	Harbor improvement	0.111	2.34	22.0	4	2
Collbran Project, Colo.	Multipurpose, especially irrigation and power	0.009	2.34	7.4	4	7
Sakonnet Harbor, R. I.	Harbor improvement	0.012	2.12	7.8	6	6
Green River Watershed, Ky.-Tenn.	River and harbor improvement	0.075	1.71	22.9	7	1
Red River, Ark.	Flood control	0.014	1.23	5.5	8	8
Hackensack River, N. J.	River and harbor improvement	0.016	1.19	5.1	9	9

[1] Source: Table 2 (*4*).
[2] Notation of O/K for the operating-to-capital-cost ratio is equivalent to M/A notation used in this paper.

COMPARISON OF METHODS

A graphical analysis has been made to further understanding of the two methods. Figure 1 plots a hypothetical project, comparing the annual benefits with the corresponding annual costs. The annual cost function includes the capital costs amortized at various discount rates; thus the annual costs rise as the interest costs are raised. Since the benefits are largely annual road-user savings, the benefit function will be almost unaffected by the interest rates.

The functions intercept at the point i_r, which could be defined as the internal rate of return on the investment, since at this rate of interest the benefits have just repaid the costs of the investment. If rates of interest that are determined by economics or other forces outside the project are considered as external interest rates, to differentiate them from the internal rates of return on the investment, then discounting by an external rate equal to the internal rate, i_r, would yield a benefit-to-cost ratio of 1.0 for the project. Discounting at any rate less than this would yield ratios that would be greater than 1.0 because the project benefits would exceed project costs. Discounting by rates greater than i_r would give ratios of less than 1.0 because costs exceed benefits.



Legend:
B = Benefit function
C = Cost function (total)
i_r = Internal rate of return

Figure 1. Benefit-cost relationship.

To elaborate the example and propose an alternative method of accomplishing this project—one which has lower initial capital costs and more deferred costs, but which would handle the same traffic and achieve the same benefits—might give a situation such as is shown in Figure 2. Here C_2 is the alternative with the larger capital costs, and hence has a steeper slope than C_1 which has more deferred costs. Points i_{r1} and i_{r2} indicate the internal rates of return the respective alternatives would yield on their investments. Any external discount rates less than these rates of return would cause benefits to exceed costs and benefit-to-cost ratios to be greater than 1.0 for the respective alternatives. However, because of the difference in the cost structures, the functions intercept at point i_{rd} causing the benefit-to-cost ratios of the projects to be equal. Any external discount rate below this value would cause the costs of C_2 to be less than the costs of C_1, thus giving ratios that would rank C_2 over C_1, in

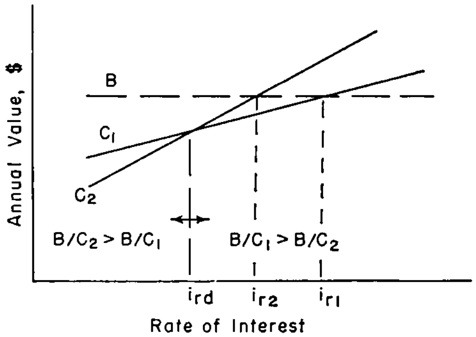


Figure 2. Benefit-cost relationship for alternate capital costs.

contradiction to the ranking of C_1 over C_2 given by the respective rates of return.

Faced with this contradiction of rankings, it cannot immediately be said which project should really rank above the other. The causes of the conflict should be more thoroughly examined and then an attempt should be made to determine how a satisfactory ranking of alternatives could be realized.

This discrepancy of ranking by two methods is obviously due to the difference in the slopes of the functions. The slope of these curves is a function of the relationship between the capital costs and the deferred or operating costs.

The following notation is used: B = total annual benefits; C = total annual costs (including capital recovery); A = fixed capital investment; M = annual operating and maintenance costs (deferred costs); i = interest rate (internal or external); r = internal rate of return; T = time period of amortization; K_{iT} = capital recovery factor (*5*) at interest i over time T; and K_{rT} = capital recovery factor (*5*) at internal rate of return.

The cost function will be equal to the total annual project costs, which would be the total of the annual maintenance costs and the amortized capital costs, or the capital investment multiplied by the capital recovery factor, thus:

$$C = A(K_{iT}) + M \qquad (1)$$

This equation is already in the form of the equation of a straight line, $y = mx + c$. If the capital recovery factor is equal to some constant, K_T, times the variable i, then the slope would be a direct function of the capital cost and the constant K_T. The y intercept would be equal to the annual operating and maintenance costs, M.

From the definition of the rate of return as the rate at which the benefits equal the costs of the capital investment:

$$B - M = A(K_{rT}) \qquad (2a)$$

or

$$B = A(K_{rT}) + M \qquad (2b)$$

Then

$$\frac{B}{C} = \frac{A(K_{rT}) + M}{A(K_{iT}) + M} \qquad (3)$$

from which

$$K_{rT} = \frac{B}{C}(K_{iT}) + \frac{M}{A}\left(\frac{B}{C} - 1\right). \qquad (4)$$

The rankings by the two methods are influenced by both the M/A ratio and the capital recovery factor, K_{iT}, which is a function of both the interest rate and the period of amortization. From this relationship, an increase in the B/C ratio would not necessarily cause a proportional increase in the rate of return, but this relationship would depend upon these other factors.

Figure 3 shows this relationship for various values of M/A and amortization periods which might be found for highway projects. This shows that the rate-of-return is more sensitive to projects with short amortization periods or large maintenance and operating costs. The benefit-to-cost ratio will give a sensitive ranking of alternatives with longer peri-

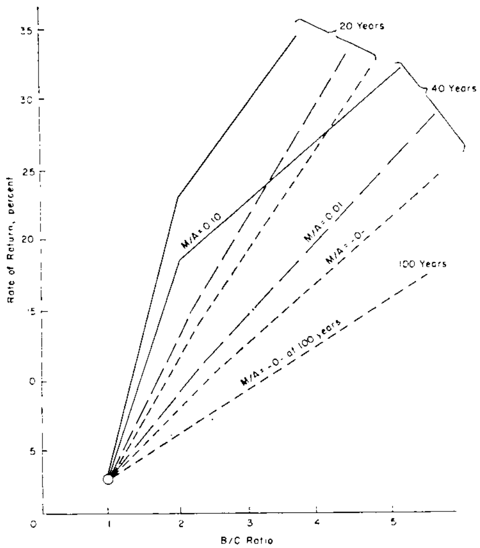


Figure 3. Benefit-cost ratio vs rate-of-return for 20-year and 40-year amortization.

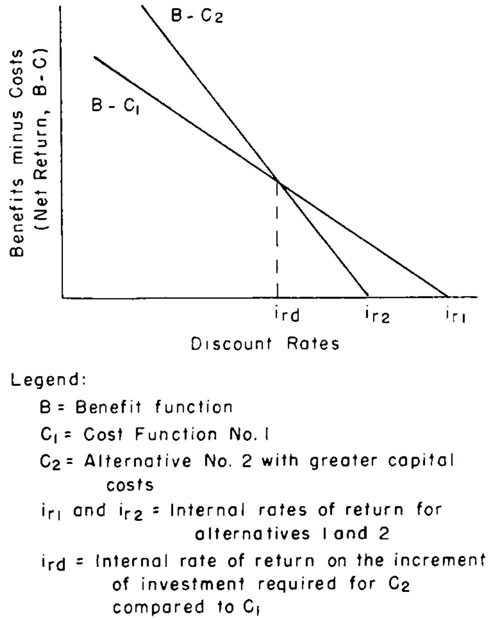


Figure 4. Net return-discount rate relationship.

ods of amortization and low annual maintenance costs.

TECHNIQUES FOR ANALYSIS OF DEFERRED COSTS

Since the rate-of-return is more sensitive to alternatives involving deferred costs, it would seem that it rather than the benefit-to-cost ratio should be the basis for analysis of such alternatives. If all the alternatives being considered had equivalent amounts of deferred costs, it would be satisfactory to rank them by their respective rates of return. However, this is not usually the case. It is usually desired to compare an alternative with considerable amounts of deferred costs with one which requires more initial capital costs. With this being the case, the problem becomes more of a problem of analyzing the economics of the incremental investment required for one alternative in contrast to the other.

Using the example in Figure 2 and taking the difference between the benefits and the costs of the respective alternatives ($B - C_1$ and $B - C_2$), would give curves like those plotted in Figure 4. Here the points i_{r_1} and i_{r_2} are the same internal rates of return for the two alternatives and are located where the benefits minus costs are equal to zero. The two curves intercept at the point i_{rd}. Here the benefit-to-cost ratios are the same, and this point also represents the point at which the incremental net benefits of alternative C_2 over C_1 have equaled the costs of the increment of initial investment of C_2 over C_1. Thus, i_{rd} would be equal to the rate of return on this increment of investment. Discounting by an external rate of interest equal to i_{rd} would cause the benefit-to-cost ratio of the incremental investment to be 1.0. Discount rates below i_{rd} would cause the marginal benefits to exceed the marginal, or incremental costs, and the benefit-to-cost ratio for the additional investment to be greater than 1.0. Thus, for discount rates below i_{rd} the total benefits minus costs for alternative C_2 will be greater than for C_1.

Selecting a discount rate, or a range of discount rates, which would represent a satisfactory cost of the capital, the diagram shows which project would maxi-

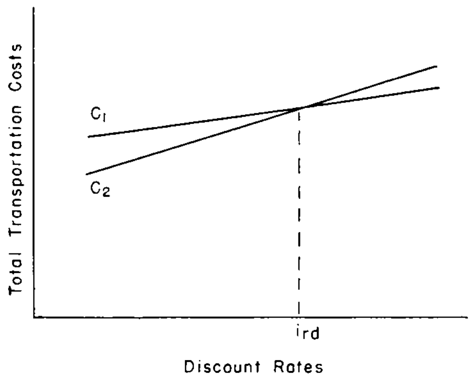


Figure 5. Method of comparing total transportation costs of highway alternatives.

mize returns on the investment at a satisfactory rate of return on the capital.

Hewes and Oglesby (*6*) have indicated a method for comparing the total annual transportation costs of highway alternatives. Figure 5 shows this method as it might appear in graphical form. Here the total annual transportation costs would include capital recovery costs, maintenance costs, and total road-user costs. Benefits would consist of savings in any of these costs. After making the necessary calculations or plotting the curves, selection of alternatives could be made on the basis of minimizing the total transportation costs at a satisfactory rate of return on the capital.

This procedure has some definite application and is necessary if it is not possible to determine benefits as a separate item—as would be the case if there were no basic condition upon which road-user savings could be measured. However, the procedure is limited to the comparison of alternatives handling the same situation. For example, it could not be used to compare alternative bypass routes involving different volumes of traffic, as the total transportation costs for larger volumes of traffic would naturally be higher than for small volumes, even though there were much larger road-user savings.

An example of the application of this graphical analysis procedure to this type of problem is shown in Figure 6. The problem involved alternative designs for an interchange, two high-type designs, I and III, and two moderate cost alternatives, II and IV. The deferred costs in this example are in the form of road-user operating costs for the interchange.

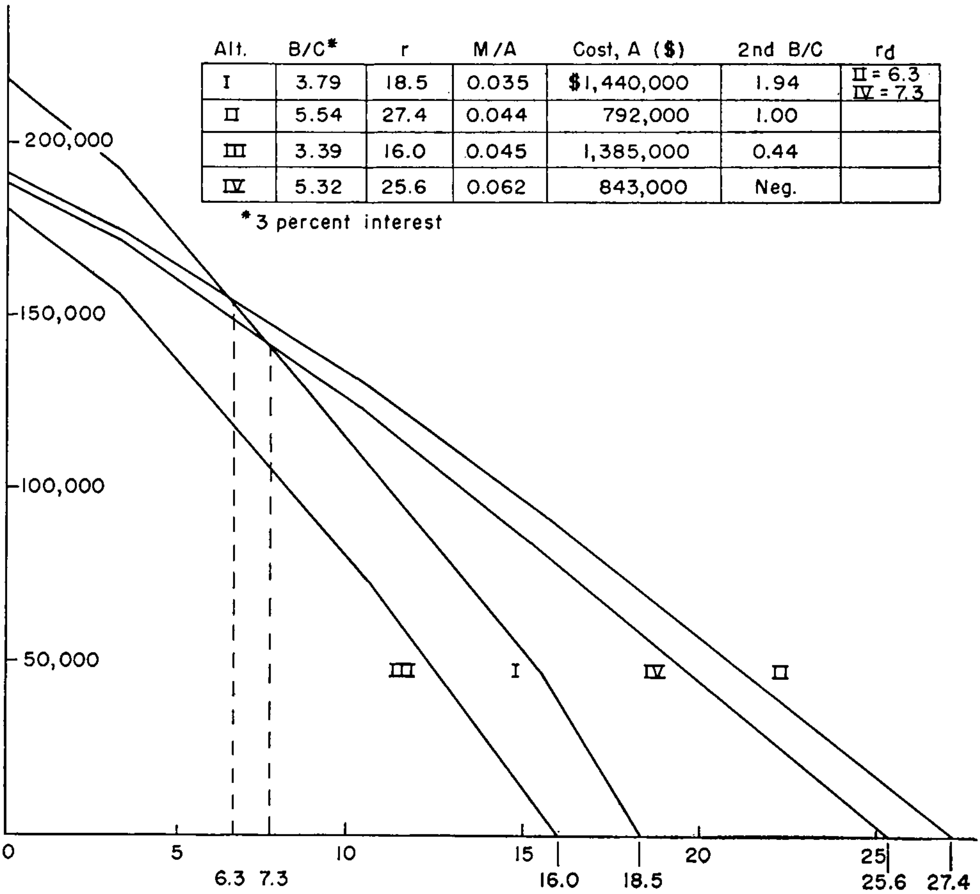
A ranking of these alternatives by both the benefit-to-cost ratios and the rates-of-return would rank the moderate cost alternatives above either of the high-type designs. The graph shows, however, that for any rate of interest below 6.3 percent, alternative I will maximize the net benefits. If 6.3 percent interest represents a satisfactory return on the additional cost of alternative I over II, it might be chosen in preference to the others based upon the criteria of maximizing the return on the investment of highway funds.

It is also possible to arrive at this ranking of alternatives by considering either a second benefit-to-cost ratio or the rate-of-return on the incremental costs. However, the graphical presentation of the alternatives gives more precise information concerning the relationships of the alternatives and provides a firmer basis for a policy decision between any of the alternatives.

The necessary calculations for a rate-of-return solution yield a great deal of information about the real relationships between the efficiencies of alternatives and the invested capital, and when this information is presented graphically it provides a clear picture of the alternatives which might result in some real benefits to the public in the development of its highways.

REFERENCES

1. ABELARD, A. R., "Benefit-Cost Ratio Method of Computing Priorities of Construction." Highway Conference, Univ. of Colorado, Papers, 22: pp. 46-49 (1949).
2. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, "Road User



Alt.	B/C*	r	M/A	Cost, A ($)	2nd B/C	rd
I	3.79	18.5	0.035	$1,440,000	1.94	II = 6.3 IV = 7.3
II	5.54	27.4	0.044	792,000	1.00	
III	3.39	16.0	0.045	1,385,000	0.44	
IV	5.32	25.6	0.062	843,000	Neg.	

*3 percent interest

Figure 6. Intersection alternative study.

Benefit Analyses for Highway Improvements." (1952).

3. Campbell, M. E., "Highway Research and User Benefit Analysis." Paper presented at Kentucky Highway Conf. (Feb. 1959).
4. Eckstein, O., "Water Resource Development." Harvard Univ. Press (1958).
5. Grant, E. L., "Principles of Engineering Economy." 3rd Ed., Ronald Press (1950).
6. Hewes, L. I., and Oglesby, C. H., "Highway Engineering." Wiley & Sons (1954).
7. Oglesby, C. H., and Grant, E. L., "Economic Analysis—The Fundamental Approach to Decisions in Highway Planning and Design." *HRB Proc.*, 37:45-57 (1958).
8. Krutilla, J. V., and Eckstein, O., "Multiple Purpose River Development" (1958).
9. McKean, R. I., "Efficiency in Government Through Systems Analysis." Wiley & Sons (1958).
10. "Proposed Practices for Economic Analysis of River Basin Projects." Report to Federal Inter-Agency River Basin Committee ("Green Book") (May 1950).

11. RENSHAW, E. F., "The Controversy over Alternative Procedures for Ranking Water Resources Projects." Natural Resources Paper No. 13, Univ. of Chicago (1956).
12. RENSHAW, R. W., "An Analysis of Highway Benefit-Cost Analyses." Master's Thesis, Northwestern Univ., Evanston, Ill.
13. ZETTEL, R. M., "Highway Benefit and Cost Analysis as an Aid to Investment Decisions." ITTE Reprint No. 49 (1956).