SENSITIVITY ANALYSIS OF RATE OF RETURN

Fred Miller, Program Analysis and Economic Services Section,
Oregon Department of Transportation

The Oregon Department of Transportation recently completed a study of the rate of return method of evaluating highway projects. Sensitivity analysis, the most interesting feature of the research, derives from the flexibility of the computer program that was developed to facilitate the calculations. Most sensitivity analyses have tested the effects of varying the assumptions underlying road-user studies such as project life, discount rate, or terminal value. The Oregon program can analyze the sensitivity of variables such as speed, average daily traffic, and maintenance costs calculated for each project. Using the program, rates of return were computed for 66 projects and then recomputed with a number of specified changes in each of the major variables. Average errors and confidence intervals were calculated for every variable. Changes in some items such as right-of-way and construction costs, average daily traffic, value of time, and, especially, speed greatly affected rate of return. Increases or decreases in other factors such as vehicle operating cost and maintenance and operation cost had negligible effects. This study clearly shows that estimates of some factors need to be improved and that care should be exercised in using the results of highway economy studies. Until better estimates exist, the use of a range of values for a rate of return is more defensible than is specifying a particular number.

•RECENTLY, the Oregon Department of Transportation completed a study of the rate of return method of evaluating highway projects. The resulting report includes a discussion of the assumptions and values used in the calculations, a manual to guide analysts in gathering and organizing data, and a computer program that can be used to calculate both a rate of return and a benefit-cost ratio for highway projects. The research was intended to improve and standardize the methods applied in road-user analyses and to make decision makers aware of the strengths and limitations of highway economy studies.

Sensitivity analyses, the most interesting feature of the report, relate to the flexibility of the computer program. Most road-user calculations assume an increase in traffic throughout the life of a facility and apply a reduction in road-user costs to this flow of traffic. The Oregon program, however, allows the variables in the calculations to be changed in any year. If special circumstances exist that are expected to result in more traffic, fewer trucks, reduced speeds, lower maintenance costs, or other changes, then these can be considered explicitly in the computations. This characteristic is especially valuable when traffic increases toward the end of a project's life result in greater congestion, reduced speed, and lower road-user benefits.

With this program flexibility, one can test the sensitivity of the important assumptions and variables in rate of return calculations. To date, most sensitivity analyses have tested the effect of varying the assumptions underlying road-user studies. The assumptions include the life of a project, discount rate, and salvage value. Usually, these are tested by using a formula, not by studying computations of benefits and costs for actual projects. The Oregon computer program has the capability to analyze such items as speed, average daily traffic, and maintenance costs calculated for each project. The testing of these factors was facilitated by the need to evaluate a number of proposed projects to be considered for construction with funds from the sale of bonds. These prospective investments provided the opportunity to observe the effects of changes in variables in actual situations. Although the tests were conducted with rate of return computations, the results also apply to other kinds of road-user analyses.

SENSITIVITY ANALYSIS

The accuracy of the rate of return calculations is dependent on the accuracy of the input variables. It is recognized that values for all variables are estimated or measured with some degree of error. For each major variable, an analysis was undertaken to determine the sensitivity of the rate of return to errors of specified magnitudes. That is, if it is known that estimates of average daily traffic are generally accurate within a 10 percent range, then the effect of this magnitude of error can be calculated. A confidence interval for such a calculation indicates how the error can be expected to affect the rate of return. A 95 percent confidence interval, for example, would include the true rate of return 95 percent of the time. From these statistics, we can be relatively sure that imperfections or inaccuracies will affect the rate of return within prescribed limits. A short confidence interval for the rate of return when a particular variable is changed means that the rate of return is not sensitive to that input variable; an error in the variable would not be expected to affect the rate of return a great deal.

In this study, 95 prospective highway projects were reviewed. Of these projects, those that had a rate of return in a normal range were selected for sensitivity analysis; 66 projects having a rate of return between 0 and 25 percent were chosen. The exclusion of 29 projects with rates of return below 0 and above 25 percent should have made confidence intervals smaller than if all projects were analyzed.

The sensitivity analysis was conducted by changing a particular variable by a certain amount for all 66 projects. For example, the first change was to increase right-of-way and construction cost by 20 percent. Then, a new rate of return was calculated for each project with the specified change. The algebraic difference of the new rate of return minus the original rate of return was calculated for every project. These differences were used to compute confidence intervals. The average changes and confidence intervals for the rate of return calculation for the 66 projects are given in Table 1.

The data in Table 1 indicate that rate of return calculations are relatively sensitive to errors in estimates of right of way and construction costs, average daily traffic, value of time, and, especially, speed. Because, in estimating right-of-way and construction costs and average daily traffic, an error of 10 percent is considered acceptable, it is clear that rates of return must be interpreted carefully. An error of 10 percent for these variables suggests that, rather than stating a rate of return as 8 percent, for example, it should be expressed as a range of, for example, 7 to 9 percent. Judging from the confidence intervals, one can conclude that the limits in some cases should be broad. Because the value of time represents an assumption that can be applied only generally, even greater reason exists not to specify a particular rate of return.

The extreme sensitivity of speed suggests that, if the analyst does not have confidence in his or her computations, then he or she should not calculate a rate of return. The effects of errors of 10 percent or 5 mph (8 km/h) are so great that, if calculations are not more accurate than these levels, they are of dubious value.

It is interesting to note that, even with large differences in variables [such as a difference in speed of 5 mph (8 km/h)], the rank order of the 66 projects did not change appreciably. The correlation coefficient between the original ranking and new ranking after an assumed change in a variable was never less than 0.99.

For several variables, including vehicle operating cost, percentage of trucks, and maintenance and operations cost, sensitivity was slight enough so that errors were not of such great importance. It appears that efforts should be devoted to improving estimates of the other variables rather than these because their effect on rates of return will not be appreciable whether the items are exact or whether they are substantially in error.

Unfortunately, the analyst cannot be certain of the magnitude or direction of error

Table 1. Sensitivity analysis for major rate-of-return variables.

Variable	Amount of Change	Avg Change in Rate of Return (percent)	95 Percent Confidence Interval[a] (percent)
Right-of-way and construction cost	+20 percent	-1.8	±4.8
	-20 percent	2.4	±4.8
	+10 percent	1.0	±2.2
	-10 percent	1.1	±2.2
	+5 percent	-0.5	±1.1
	-5 percent	0.5	±1.1
Average daily traffic	+20 percent	2.0	±4.4
	-20 percent	-2.2	±4.4
	+10 percent	1.0	±2.2
	-10 percent	-1.1	±2.2
	+5 percent	0.5	±1.1
	-5 percent	-0.5	±1.1
Value of time	+50 percent	1.4	±3.2
	-50 percent	-1.5	±3.2
Vehicle operating cost	+20 percent	0.1	±0.5
	-20 percent	-0.1	±0.5
Trucks	+20 percent	0.2	±0.4
	-20 percent	-0.2	±0.4
Proposed maintenance and operations	+20 percent	0.08	±0.2
	-20 percent	0.09	±0.2
	+10 percent	0.04	—
	-10 percent	0.04	—
Base maintenance and operations	+20 percent	0.06	±0.2
	-20 percent	-0.07	±0.2
	+10 percent	0.03	—
	-10 percent	-0.04	—
Base speed	+20 percent	-5.9	±16.9
	-20 percent	7.7	±16.9
	+10 percent	-2.5	±8.0
	-10 percent	3.8	±8.0
	+5 mph	-5.4	±15.5
	-5 mph	6.4	±15.5
	+2 mph	-2.5	±7.0
	-2 mph	2.4	±7.0
Proposed speed	+10 percent	1.7	±8.0
	-10 percent	-3.3	±8.0
	+5 mph	2.4	±8.2
	-5 mph	-3.4	±8.2
	+2 mph	1.1	±5.0
	-2 mph	-1.5	±5.0

Note: 1 mph = 1.6 km/h.

[a]The confidence interval shows the range within which we are confident that the true rate of return will fall 95 percent of the time. For example, if one of the 66 projects has an 8 percent rate of return, but we are only assured that we are within 20 percent of the actual right-of-way and construction cost, then it can only be stated that the true rate of return will fall between 3.2 and 12.8 percent 95 percent of the time.

in the estimates of many variables. If errors in the more sensitive variables tend to be self-canceling, then relatively more confidence can be placed in a rate-of-return solution. It is possible, however, that traffic, speed, and cost, for example, might all be estimated in a way that would cause the rate of return to be either overestimated or underestimated. This is a further reason to interpret a rate of return as representing a range rather than a single value.

CONCLUSIONS

It has been argued elsewhere that economic analysis often is not understood, frequently is misused, and should be used more with improved methods. Although this paper most likely will not cause a rush to apply road-user analyses more often, it should contribute to their more intelligent application.

It is clear from this study that estimates of some variables need to be improved and that care should be exercised in using the results of highway economy studies. It appears that a rate of return or benefit-cost ratio is best used as 1 indication of a project's merit. A deficiency or sufficiency index, accident rating, and surface condition rating and an environmental assessment also should be used. A rate of return will be relatively more important for some investments than for others. As estimates are improved, the kinds of projects to which road-user analyses can be applied successfully will increase. At best, however, it seems that the use of a range of rates of return would be more defensible than would using a particular number.

In the future, if the rate of return program is going to be as useful as possible, more work will have to be done on (a) improving the estimates of the values for variables that substantially influence the rate of return; (b) generalizing the approach for applying the program, for example, to safety projects and maintenance programs; and (c) combining rate of return results with those of a deficiency index and with accident information for interpreting project evaluation techniques for decision makers.

Notwithstanding the problems described in this paper, a highway agency should be capable of producing a rate of return evaluation for its investments. The method described in this paper represents a significant contribution to project selection methodology.