CONCLUSIONS

With the advent of probability choice models, cost-benefit analysis can become a more powerful tool for transportation policy evaluation. The major problems with cost-benefit analysis are not so much conceptual as practical. The validity of the computation of changes in consumer surplus is dependent on the accuracy of demand models and the data used in the calculations. As probability choice models become more accurate representations of travel behavior, cost-benefit measures derived from these models become more relevant for policy decisions.

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Cost-Effectiveness Analysis: The Program of the Colorado Department of Highways

Art Ruth

The cost-effectiveness program developed by the Colorado Department of Highways is described. The program includes a computer model and a workbook that explains the computing procedures, input variables, and sources of input information. The computer and the workbook have enabled the department's district personnel to perform complex studies even though many of them have very little background in economic or benefit-cost analysis. The program is one of the first attempts to computerize the Stanford Research Institute methodology for analysis of transportation user benefits. The program quantifies the net present value-of-time, operating, accident, and maintenance benefits of highway project alternatives; compares benefits with required capital costs; and presents results in the form of first- and second-order benefit/cost ratios, net present values, and a verbal statement that indicates the most cost-effective alternative. The computer program also allows sensitivity analysis of selected variables.

Broadly speaking, cost-effectiveness analysis is the comparison of the benefits and the required capital costs of one action with those of another action. Usually, the no-action alternative is the basis on which certain build alternatives are judged to their economic advantage. Among the several measures used to quantify economic advantage, the most common are probably benefit/cost (B/C) ratio and net present value. The ratio is the division of benefits by capital costs, and the net present value is the subtraction of capital costs from benefits. For a certain build alternative to be considered economically justified over the no-action reference alternative, it must have a ratio greater than one or a positive net present value. If the ratio is less than one or there is a negative net present value, the no-action alternative is preferable from an economic standpoint. A ratio of one or a net present value of zero indicates an economic equality between the no-action and build alternatives.

With today's limited financial resources, cost-effectiveness analysis has become a major component in investment decisions in both the public and private sectors. Such analysis will become increasingly important in highway investment decisions because of the expected leveling off of revenues and a continuation of rapid price increases for construction materials and labor.

The Federal Highway Administration (FHWA) has begun to recognize the need to ensure cost effectiveness in highway project selection. This is indicated by the proposed FHWA regulation on urban highway and transit projects (1), which states the following:

> The policy in this regulation seeks to ensure that all federally funded major transportation investments for urbanized areas meet local and national goals and objectives in a cost-effective manner.... Every major urban transportation investment proposed for FHWA or Urban Mass Transportation Administration funding shall be supported by an analysis of relevant alternatives including a cost-effectiveness analysis.

In response to present and future needs for cost-effectiveness analysis, the Colorado Department of Highways has established the HYBENCO program. HYBENCO is an acronym for highway benefit cost. The program is composed of a computer model that performs cost-effectiveness calculations and a workbook manual that (a) defines the basic concepts and procedures involved in cost-effectiveness analysis, (b) describes in detail the calculations made by the computer program, (c) identifies necessary input data required to run the model and how or where data can be obtained and actually supplies some of the necessary input information, and (d) provides the operating instructions for the computer program.

PROGRAM DESCRIPTION

The HYBENCO computer model was based on information and analysis completed by the Stanford Research Institute (SRI) (2). The approach emphasized by SRI was a series of nomographs that allowed the analyst to estimate the road-user costs produced by various alternatives. Comparisons could then be made with capital costs to determine the most cost-effective alternative. Unfortunately, nomographs are inefficient when one is dealing with large projects and/or many alternatives. Individual calculations are time-consuming, and the errors inherent in reading nomographs are compounded to a potentially significant degree. Because of the deficiency of this approach in cases in which many calculations are required, the Colorado Department of Highways relied on an alternate SRI approach—the use of a series of cost tables that identified the specific road-user-cost factors. This approach normally required the analyst to perform a number of individual calculations to estimate total road-user costs, but computerizing these calculations made relying on the cost tables time-efficient, even with large projects, with an acceptable level of error.

Figure 1 shows a flow chart of the steps by which the HYBENCO program performs cost-effectiveness analysis. As seen, reductions in road-user and maintenance costs from the no-action alternative are the benefits of the build alternatives. Annual benefits for selected years are converted into a present-value "lump sum" by using a specified analysis period and discount rate. The HYBENCO program allows the analyst to input several discount rates for sensitivity analysis. Present-value road-user benefits of the build alternatives are compared with their respective net capital costs. Net capital costs are calculated by subtracting the investment costs of the no-action alternative from the capital costs of each build project option. The capital costs included in the program are right-of-way, relocation, and construction costs.

The HYBENCO model produces three output forms that allow the analyst to determine which alternative is most cost effective: (a) B/C ratios, (b) net present values, and (c) a written indication of which alternative is most cost effective. The model makes comparisons between the build alternatives and the no-action option and also makes comparisons among the build alternatives. Figure 2 shows an example of the computer output.

As mentioned, the benefit calculations made by the HYBENCO model are limited to reductions in road-user and maintenance costs. The road-user costs included in the computer model are time, operating, and accident costs. Four separate types of time costs can be calculated by the model, including time costs for traveling under smooth-flow conditions and additional time costs produced by speed changes and those accumulated while stopping or idling.

Operating costs are separated into four subcost categories: operating costs generated under smooth, level, and straight road conditions; operating costs for positive and negative grades; additional operating costs produced by curves; and operating costs that stem from idling, stopping, and changing speeds. The program also calculates subcategories of accident costs. These costs are for fatality, injury, and property-damage accidents.

The HYBENCO computer can calculate time, operating, and accident costs for the following five vehicle classes (1 kN = 224.8 lbf):

Class	Type
1	Automobiles, pickup trucks, and light delivery trucks
2	Single-unit, 53-kN trucks
3	Combination or 3-S2 diesel trucks
4	Automobiles with trailers
5	Composite, representing vehicles in classes 1-3

Figure 3 shows the input variables required to run the HYBENCO computer program. Line 1 indicates whether a batch-mode or teletype method of input will be used. Lines 2 through 5 include information on discount rates and default values for idling, time, and accident cost factors. Line 5 also indicates the period of analysis (horizon time) so that present-worth calculations can be made. Idling and time cost factors are inputted by vehicle type, whereas accident cost factors are inputted by fatality, injury, and property-damage accident types. All data in lines 1 through 5 are input once and remain the same for all alternatives.

Line 6 is intended for information on roadway segments. Capital and maintenance costs can be entered by segment, or the entire amount for each alternative can be entered into the first roadway segment. "Year one ADT" is defined as the average daily traffic (ADT) for the first year the project alternative is in operation. "Year X ADT" is defined as the average daily traffic for the future design year. "Year X number" is the number of years between year one and year X.

Line 7 is limited to vehicle information, including (a) average running speeds during the year X period; (b) the number of stops and idling times attributable to signals, stop signs, and railroad crossings; (c) speed-change cycles; and (d) operational cost factors. Additional times for speed changes and stops are also in-

Figure 1. Process of cost-effectiveness analysis in HYBENCO program.

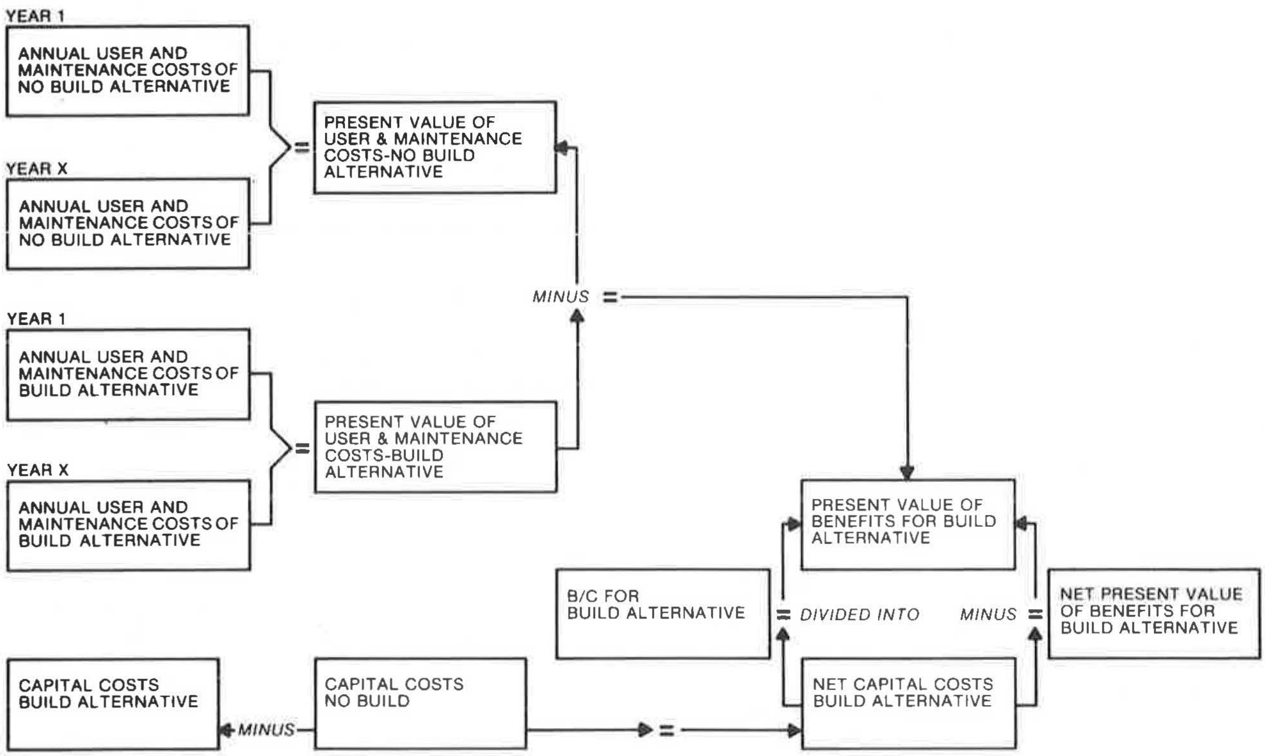


Figure 2. HYBENCO output. PROJECT ID: SH 83 VESTCHARGE RATE: 7 PERCENT 03/27/78 PAGE 8

COMPARISON OF ALTERNATIVES

NET PRESENT VALUES (THOUSANDS)

	USER, MAINTENANCE, AND AUTO TIME COSTS	CAPITAL COSTS	NET BENEFITS	B/C RATIO
1 vs 0	44000	40000	4000	1.100
2 vs 0	36000	30000	6000	1.200
2 vs 1	8000	10000	-2000	0.800

ALTERNATE 1 MOST ECONOMICAL

putted in line 7. Line 7 information is inputted for each vehicle type.

ADVANTAGES AND DISADVANTAGES OF HYBENCO

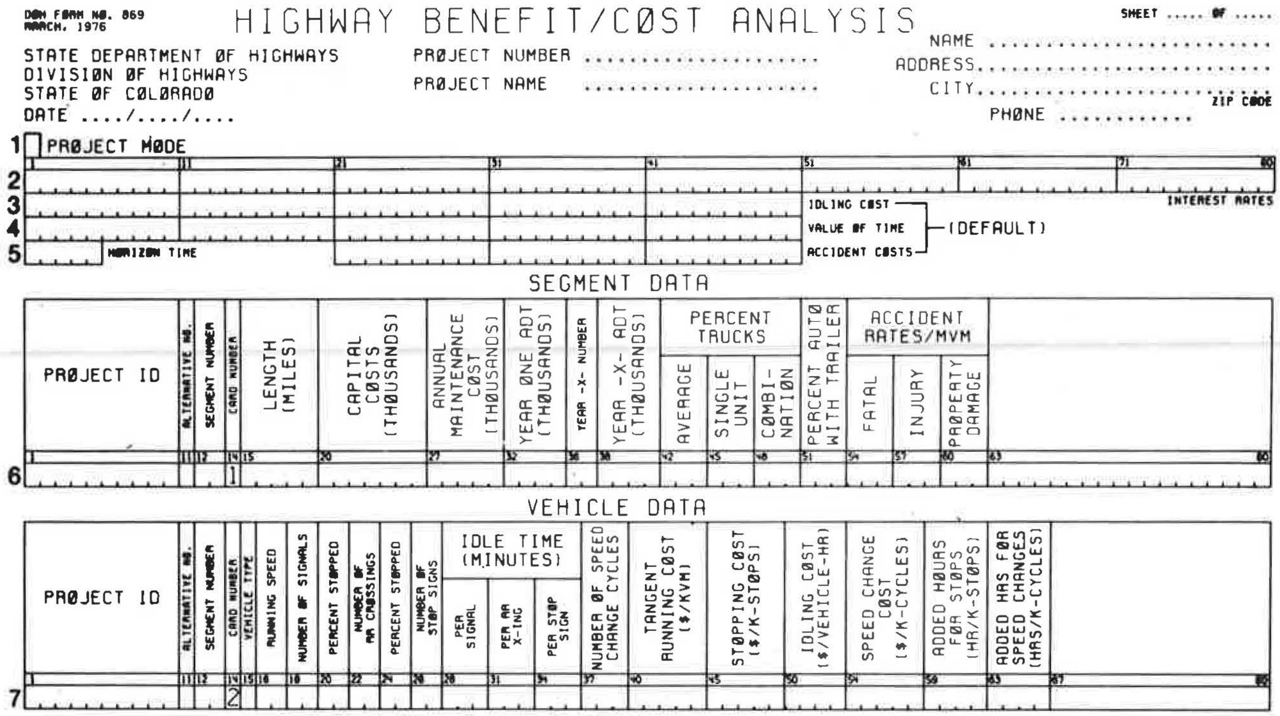
The HYBENCO computer program can perform a relatively precise road-user analysis with reasonable input demands. The program is flexible enough to allow the exclusion of some input variables that are expected to be frequently insignificant, such as idling and stopping costs. Particular vehicle classes can also be excluded. The HYBENCO program has been successfully transferred to Colorado Department of Highways district offices, where cost-effectiveness analysis is performed by persons who have little knowledge of economics or computers.

Another advantage is that the program can be used for a wide range of projects, from interchange to railroad-separation alternatives. The HYBENCO computer program also identifies the most cost-effective alternative in a verbal form that is easily understood by those who are not familiar with cost-effectiveness measures.

Finally, the computer model can be run by remote terminal as well as by batch. The availability of access by remote terminal allows the department's district offices around the state to directly input data and receive results without going through the central office.

The principal disadvantage of the HYBENCO computer program is that it requires the analyst to draw cost factors from tables contained in the manual. The program also requires the user to estimate additional time for idling and for stops. A further disadvantage is that the model is limited to a road-user analysis. Other economic, social, and environmental costs and benefits are not included in the cost-effectiveness analysis. However, the appropriateness of including these considerations in a single numerical measure is questioned. Not all economic, environmental, and social costs and benefits can be quantified. Thus, decisions cannot be based on any single measure. Unfortunately, cost-effectiveness measures are frequently assumed to be all-inclusive when they lump various types of impacts into a single number. When specific impacts are analyzed separately, whether in quantitative form or not, the danger of misinterpreting the results is lessened.

Figure 3. Input variables for HYBENCO program.


DØH FØRM NØ. 869
MARCH, 1976

HIGHWAY BENEFIT/CØST ANALYSIS

SHEET ..... ØF .....

STATE DEPARTMENT ØF HIGHWAYS
DIVISIØN ØF HIGHWAYS
STATE ØF CØLØRADØ
DATE ..../..../....

PRØJECT NUMBER ....
PRØJECT NAME ....

NAME ....
ADDRESS....................
CITY.................... ZIP CØDE
PHØNE ....

1 PRØJECT MØDE
2
3
4
5 HØRIZØN TIME

IDLING CØST, VALUE ØF TIME, ACCIDENT CØSTS (DEFAULT)
INTEREST RATES

SEGMENT DATA

PRØJECT ID | ALTERNATIVE NØ. | SEGMENT NUMBER | CARD NUMBER | LENGTH (MILES) | CAPITAL CØSTS (THØUSANDS) | ANNUAL MAINTENANCE CØST (THØUSANDS) | YEAR ØNE ADT (THØUSANDS) | YEAR -X- NUMBER | YEAR -X- ADT (THØUSANDS) | PERCENT TRUCKS: AVERAGE, SINGLE UNIT, CØMBI-NATIØN | PERCENT AUTØ WITH TRAILER | ACCIDENT RATES/MVM: FATAL, INJURY, PRØPERTY DAMAGE

6

VEHICLE DATA

PRØJECT ID | ALTERNATIVE NØ. | SEGMENT NUMBER | CARD NUMBER | VEHICLE TYPE | RUNNING SPEED | NUMBER ØF SIGNALS | PERCENT STØPPED | NUMBER ØF RR CRØSSINGS | PERCENT STØPPED | NUMBER ØF STØP SIGNS | IDLE TIME (MINUTES): PER SIGNAL, PER RR X-ING, PER STØP SIGN | NUMBER ØF SPEED CHANGE CYCLES | TANGENT RUNNING CØST ($/KVM) | STØPPING CØST ($/K-STØPS) | IDLING CØST ($/VEHICLE-HR) | SPEED CHANGE CØST ($/K-CYCLES) | ADDED HØURS FØR STØPS (HR/K-STØPS) | ADDED HRS FØR SPEED CHANGES (HRS/K-CYCLES)

7

REFINEMENT OF THE PROGRAM

The Colorado Department of Highways plans to include the factor cost tables in the HYBENCO computer program. In addition, calculations of additional time for stopping and idling will be performed by the HYBENCO model. The final revision in the model will eliminate vehicle speed input. Instead, the HYBENCO program will calculate necessary speeds, given information on vehicle type, degree of curvature, grade, and ratio of volume to capacity. These changes will substantially simplify the present program.

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Benefit-Cost Analysis Based on the 1977 AASHTO Procedures

Douglas S. McLeod and Richard E. Adair

The benefit-cost analysis performed for FL-426A, a new highway facility in Florida, is described. The analysis was completed in general accordance with the American Association of State Highway and Transportation Officials (AASHTO) publication, A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements. The project, the analysis procedures, deviations from the AASHTO methodology, the analysis results, and suggested improvements to the AASHTO procedures are examined. A network approach was used for the benefit-cost analysis of this new facility, which has partial access control. A summary of the analysis appeared in the project's 1978 final negative declaration, an environmental impact document. Thus, it was one of the first benefit-cost analyses modeled after AASHTO procedures to appear in an environmental impact document approved by the Federal Highway Administration. It is concluded that, although the AASHTO procedures need to be computerized and their results are subject to wide variability among users, they are useful in determining the economic desirability of major highway improvements.

This paper presents a case study of a benefit-cost analysis for a 6.9-km (4.3-mile) segment of FL-426A. The study is generally based on the American Association of State Highway and Transportation Officials (AASHTO)