TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. WA-RD 459.2	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Review of MicroBENCOST for WSDOT Mobility		5. REPORT DATE July 1998
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Jennifer Barnes		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Washington State Transportation Center (TRAC) University of Washington, Bx 354802 University District Building; 1107 NE 45th Street, Suite 535 Seattle, Washington 98105-4631		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO. Agreement T9903, Task 53
12. SPONSORING AGENCY NAME AND ADDRESS Washington State Department of Transportation Transportation Building, MS 7370 Olympia, Washington 98504-7370		13. TYPE OF REPORT AND PERIOD COVERED Final Research Report
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

The *MicroBENCOST* software was developed by the Texas Transportation Institute (TTI) to calculate user benefits and costs for several types of highway improvement analysis. The purpose of this report was to review the capabilities and the drawbacks of this software and to assess the feasibility of its use for benefit/cost (B/C) analysis in the Washington State Department of Transportation Mobility division (WSDOT Mobility).

This review shows that for the most part, the overall procedures of MicroBENCOST are comparable to many employed by WSDOT Mobility (i.e., similar components are included in benefit and cost calculations, and similar project types can be analyzed). However, the output of the program depends on many default values that differ from WSDOT Mobility's and are designed not to be overwritten. Additionally, the program utilizes some calculations that are much more complex and require more detailed data than those currently used by WSDOT Mobility. Finally, although the general procedures utilized by the software are accepted and widely used throughout industry, they have inherent drawbacks that conflict with the analysis of alternative transportation solutions. Adoption of MicroBENCOST would not advance WSDOT Mobility toward the goal of including more alternative transportation solutions in the process.

Adoption of MicroBENCOST is certainly feasible but would require substantial work by someone who understands both the coding of the program and the sensitivity of its output to any revisions, as well as the WSDOT benefit-cost procedures. The primary advantage of utilizing MicroBENCOST would be that once the default values and procedures had been established, the program could allow better standardization and automation of some benefit/cost calculation methods. However, the change would require a tradeoff decision regarding whether the review, consensus-building, and refinement of both the software and existing Mobility procedures would be justified by some degree of increased standardization. The end result would be a more elaborate way to do a portion of the same benefit/cost calculations, with no added capability for more comprehensive evaluation or for analysis of alternative transportation solutions.

17. KEY WORDS transportation benefit/cost analysis		18. DISTRIBUTION STATEMENT No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616	
19. SECURITY CLASSIF. (of this report) None	20. SECURITY CLASSIF. (of this page) None	21. NO. OF PAGES 34	22. PRICE

Research Report
Agreement T9903, Task 53
Mobility Improvements

REVIEW OF MICROBENCOST FOR WSDOT MOBILITY

by

Jennifer Barnes
Research Assistant
University of Washington
Seattle, Washington 98195

Washington State Transportation Center (TRAC)
University of Washington, Box 354802
University District Building
1107 NE 45th Street, Suite 535
Seattle, Washington 98105-4631

Washington State Department of Transporation
Technical Monitor
Patrick E. Morin
Priority Development and Management Engineer

Prepared for

Washington State Transportation Commission
Department of Transportation
and in cooperation with
U.S. Department of Transportation
Federal Highway Administration

July 1998

DISCLAIMER

TABLE OF CONTENTS

SUMMARY OF CONCLUSION

The *MicroBENCOST* software was developed by the Texas Transportation Institute (TTI) to calculate user benefits and costs for several types of highway improvement analysis. The purposes of this paper are to review the capabilities and the drawbacks of this software and to assess the feasibility of its use for benefit-cost (B/C) analysis in the Washington State Department of Transportation Mobility division (WSDOT Mobility).

This review shows that, for the most part, the overall procedures of MicroBENCOST are comparable to many employed by WSDOT Mobility (i.e., similar components are included in benefit and cost calculations, and similar project types can be analyzed). However, the output of the program depends on many default values that are not designed to be overwritten. Additionally, the program utilizes some calculations that are much more complex and require more detailed data than those currently used by WSDOT Mobility. This applies to both operating cost and delay calculations. To adopt MicroBENCOST, accepted assumptions and calculations within WSDOT Mobility's procedures would have to be redefined, and default values within the program would probably have to be modified to some degree.

A second consideration is how adoption of MicroBENCOST would fit with the broader goals of the Mobility program. Although the general procedures the software utilizes are accepted and widely applied throughout industry, they have inherent drawbacks that conflict with the analysis of alternative transportation solutions. Adoption of MicroBENCOST would not advance WSDOT Mobility toward the goal of including more alternative transportation solutions in the process. In fact, it would more likely hinder WSDOT Mobility's goals because the software is capable of analyzing only traditional capacity-oriented solutions. Other types of projects would still have to be analyzed outside of the program, which might further encourage perceptions that traditional solutions are measured in hard numbers in contrast to a more subjective analysis of alternative solutions.

Adoption of MicroBENCOST is certainly feasible, although it would require substantial work by someone who understood both the coding of the program and the sensitivity of its output to any revisions, as well as the WSDOT benefit-cost procedures. It would also require consensus and involvement from the Technical Advisory Committee (TAC) and the six WSDOT regions. The primary advantage of utilizing MicroBENCOST would be that once the default values and procedures had been established, the program could allow better standardization and automation of some benefit-cost calculation methods, both within and between different programs. However, a decision would be needed regarding whether all of the required review, consensus-building, and refinement of both the software and existing Mobility procedures would be justified by some degree of increased standardization. The end result would be a more elaborate way to do a portion of the same benefit-cost calculations, with no added capability for more comprehensive evaluation or for analysis of alternative transportation solutions.

OVERVIEW OF ANALYSIS CAPABILITIES

The objective of the TTI study that developed MicroBENCOST was to create a comprehensive, user-friendly program that utilized best practical procedures for highway B/C analysis (TTI, 1993). The program combines both user inputs and defaults for values such as traffic volumes, highway characteristics of existing and proposed facilities, and capital costs to analyze the benefits and costs of seven categories of highway improvements. The program ultimately develops several possible economic measures with the calculated benefits and costs that can be used in transportation planning applications.

The seven general categories of projects that MicroBENCOST can analyze are listed below. In parentheses following each improvement category is the component of the Washington State Highway System Plan currently contains that category.

1. Added capacity (I-1 Mobility)
   - *Add lanes*
   - *Change highway type*
   - *HOV lanes*
2. Bypass (I-1 Mobility)
   - *New location facility with existing parallel route*
3. Intersection / interchange (I-1 Mobility)
   - *Replacement of existing intersection or interchange*

- *Usually an upgrade*

4. Pavement rehabilitation (P-1 Roadway)

   - *Compares pavement reconstruction, rehabilitation or maintenance strategies*

5. Bridge (P-2 Structures)

   - *Compares bridge rehabilitation and replacement strategies*

6. Safety (I-1 Mobility and I-2 Safety)

   - *For improvements that affect the accident rate, accident cost, or a combination of the two*

7. Highway-railroad grade crossing (usually in rail improvements)

   - *Upgrades to a higher control, including grade separation*

Note that of the seven general improvement categories, four are highway improvements that are addressed in the WSDOT Mobility component of the Highway System Plan. All of the improvements that can be analyzed by MicroBENCOST are traditional, capacity-oriented solutions. Thus, even if the program can be refined to reflect accepted WSDOT procedures, several "alternative" improvement categories that already exist or are being developed (such as park and ride lots, transportation demand management, transportation system management, or access management) could not be analyzed with this program.

Three additional analysis options are available in MicroBENCOST that can be used in conjunction with any of the seven general categories. These are a workzone analysis option, an incident analysis option, and an emissions analysis option. All three of these features provide analysis more detailed than that desired for project programming, so even if MicroBENCOST were adopted, they would not likely be utilized within WSDOT Mobility analysis for priority programming. The emissions option will calculate carbon monoxide emissions for a facility with given characteristics, but it does not attempt to convert pollution to a dollar value nor include pollution savings in user benefits.

MicroBENCOST compares a "with improvement" alternative with a "without improvement" alternative (which includes an existing route and an optional alternative route). The program performs analysis at the project level, determining immediate area impacts rather than highway system level impacts. Procedurally, this is consistent with the general approach that is used by WSDOT Mobility.

COMPONENTS OF THE PROGRAM

Generally, the program follows the highway analysis procedures outlined in the 1977 AASHTO Manual [1], with some modifications to AASHTO's treatments and some added features. MicroBENCOST contains a Main Program and an Update Program. It also contains six additional default data sets that exist outside these two programs. These components are described in more detail in the following sections.

MAIN PROGRAM

The main program is used to perform economic analysis based on data sets of proposed improvements, and it consists of three data levels. The three levels of data, as well as the variables that are included in each of the levels, are as follows:

1. Problem assumptions and initial costs level

   - discount rate
   - analysis period
   - vehicle parameters and unit operating costs
   - construction costs
   - service life
   - salvage value
   - accident costs
   - discomfort costs

2. Route level

   - traffic volumes
   - traffic distribution
   - vehicle fleet compositions

3. Segment level

   - geometric data
   - traffic operation data
   - intersection / interchange data
   - bridge data
   - pavement condition data
   - maintenance cost data
   - data on accidents
   - data on workzones, incidents, and emissions

UPDATE PROGRAM

The Update Program contains a large number of default data, developed to be used as part of the overall input data required for a problem set. After having opened the Update Program, the user is led from the three data levels to the specific menu where default data are located. These default data include

- discount rate
- analysis period

- vehicle parameters and operating costs
- accident costs
- traffic volumes and distribution
- vehicle compositions
- maintenance costs
- accident rates

The user can input values for most of these items or opt to use the default values of the program.

INDEPENDENT DEFAULT DATA SETS

Six additional default data sets are outside of the Update Program. These are *not* intended to be modified by the analyst who uses the program. The values in the default data sets are used in intermediate calculations and have considerable influence over the final calculated economic measures. These data sets are as follows:

1. coefficients of the estimated equations of vehicle operating costs by grade and by vehicle type
2. coefficients of estimated equations for excess vehicle operating costs by curvature and vehicle type
3. estimated coefficients of equations for excess vehicle operating costs for speed changes by vehicle types
4. coefficients of equations of pavement adjustment factors for vehicle operating cost component by vehicle type
5. coefficients of vehicle operating consumption during idling

6. coefficients of equations relating the number of speed changes to V/C ratios by vehicle type and highway type

TTI's report states that these default sets should not be updated because of their complexity and the sensitivity of the analysis to the coefficients. These values do not necessarily match values currently adopted by WSDOT, nor do some of the procedures that utilize them. Additionally, in many instances the input required to use these data sets is greatly more detailed than is typical at the programming level. These data sets are the main reason that MicroBENCOST cannot be directly implemented for B/C analysis in WSDOT Mobility priority programming. These values would need to be scrutinized, and possibly modified, before the program could be used with confidence. This work would have to be done by someone who not only understood the language of the program and the sensitivity of any modifications to the program output, but who also understood the details of adopted B/C analysis procedures in WSDOT Mobility.

STEPS FOR USING MICROBENCOST

The steps for using the MicroBENCOST program can be broken down into those performed by the user and those performed by the program itself. These steps are as follows:

PERFORMED BY THE USER

1. Identify existing, proposed, and alternative routes.
2. Divide routes into segments on the basis of access control type, number of lanes, traffic volumes, intersections/interchanges/structures (one major per segment), and grade/curvature.
3. Select economic assumptions and change default values as desired.
4. Define the problem to be analyzed (area type, project type, and presence of alternative route or not).
5. Describe the characteristics of existing and proposed facilities (number of segments, physical characteristics for each segment).
6. Input problem assumptions and initial costs data.
7. Input traffic and vehicle fleet data.
8. Input segment data for pollution analysis.
9. Run the *Analyze* program.

PERFORMED BY THE *ANALYZE* PROGRAM

10. Calculate average speed and capacity on existing, alternative, and proposed routes, and on minor routes where applicable.
11. Calculate congestion delay and intersection delay.
12. Calculate consumer surplus for induced traffic.
13. Calculate highway costs and salvage value.

14. Calculate user unit costs

- basic section user costs
- intersection / interchange / railroad crossing / bridge costs
- accident costs
- air pollution estimates

15. Calculate user benefits.

16. Calculate present values of user benefits and costs of the improvement.

COMPONENTS OF BENEFIT AND COST CALCULATIONS

The economic analysis of highway improvements in MicroBENCOST includes many elements for both the benefit and the cost calculations, as listed below.

COST COMPONENTS

The cost calculations in MicroBENCOST include numerous construction cost components. The program also considers discomfort costs due to congestion and to pavement roughness, and it estimates non-monetary emissions values. These cost elements are as follows:

1. *Construction costs*
   - right-of-way purchase
   - preliminary engineering
   - major structures
   - grading and drainage
   - sub-base and base
   - surface
   - others that might apply
2. *Other costs*
   - discomfort factors from congestion as an adjustment factor to the value of time
   - discomfort costs from rough pavement as additional time costs
   - carbon monoxide emission is calculated and included in analysis summary, but it is not put in terms of dollars and added to user benefits

Although the construction cost categories are consistent with those included in the WSDOT Mobility procedure, the discomfort costs are not. The discomfort costs would either have to be adopted into standard procedures, or ways to exclude them would have to be determined.

BENEFIT COMPONENTS

Consistent with routine benefit-cost analysis, the calculated benefits of a transportation improvement project in MicroBENCOST actually represent the difference in costs to travelers between the existing and improved facility. Benefits are estimated on the basis of savings in delay (which often constitutes the major share of overall highway benefits), as well as reductions in operating costs, accidents, and routine maintenance. These four components are listed below, along with the elements that MicroBENCOST considers when analyzing them.

1. *Delay savings*

   - running time delay—produced by reduction in running speed
   - intersection delay—produced by slowing down and stopping at intersections
   - train delay—produced by warning time and waiting for trains to cross at-grade intersections
   - reduced speed experienced by motorists slowing down at railroad crossings
   - ramp delay—results from reduced speeds of vehicles using a ramp
   - delay caused by traveling on rough pavement

2. *Operating cost savings*

   - constantly changing speeds (such as under-congested conditions) result in higher operating costs than driving at smooth traffic flow

- driving at very high speeds increases vehicle operating costs
- grades, curvature, and roughness of road affect operating costs
- five vehicle operating cost components are fuel, oil, tire wear, maintenance and repairs, and depreciation

3. *Accident reduction savings*

- Accident rates of the roadway facility are multiplied by their respective unit costs to arrive at the accident costs.
- Accident savings are calculated from the difference in accident costs between the proposed and existing facilities.

4. *Savings from routine maintenance costs*

- When a roadway improvement reduces the annual routine maintenance required, the cost savings represent a benefit.

Note that although the categories are consistent with those used in WSDOT Mobility, the elements that the program considers are much more detailed, particularly in the calculation of operating cost savings.

CALCULATIONS PERFORMED FOR BENEFIT-COST ANALYSIS

Thirteen major calculations must be understood to evaluate the feasibility of adopting MicroBENCOST for general benefit-cost analysis. The calculations involved for each of these components are summarized on the following pages. In italics, following the description of each calculation component, is a brief assessment of the compatibility of the calculations with current practice in WSDOT Mobility.

1. FORECASTED TRAFFIC VOLUMES CALCULATION (THREE METHODS)

Three methods are available for forecasting traffic volumes

a) The user provides annual volumes for each year of the analysis period.

b) The user provides the base year volume and uniform annual growth rate, and the traffic volumes are calculated for each year of the analysis period with the following equation:

$$\mathbf{ADT_t = ADT_b\,(1 + r)^n}$$

where ADT_t = calculated traffic volume in year t
ADT_b = traffic volume in the base year
r = annual growth rate, in decimal form
n = the number of years between the base year and year t

c) The user inputs the base year volume, an intermediate year and volume, and the forecast year and volume. A curve is fit between the points to calculate volumes for each year of the analysis period with the following equation:

$$\mathbf{ADT_t = ADT_b + d\,(n)^c}$$

where ADT_t = calculated traffic volume in year t

ADT_b = traffic volume in the base year

ADT_f = traffic volume in forecast year

ADT_i = traffic volume in intermediate year

$c = [\ln(ADT_f - ADT_b) - \ln(ADT_i - ADT_b)] / [\ln(n_f) - \ln(n_i)]$

$d = [ADT_f - ADT_b] / (n_f)^c$

n_f = number of years between the base year and the forecast year

n_i = number of years between the base year and the intermediate year

The second method, which utilizes a straight line growth rate, is compatible with WSDOT procedures.

2. NEW LOCATION TRAFFIC ALLOCATION (DIVERTED TRAFFIC)

This procedure allocates traffic between the existing or improved study route and a specified alternative route by using an approximate equilibrium traffic distribution method. Traffic is allocated so as to equalize the marginal trip costs between the routes. There are eight possible allocation methods, and the user also has the opportunity to change any or all of the volumes. Some additional points can be made about the trip costs used for this feature:

- Trip costs can be defined as total user costs or as delay costs only.
- Trip costs are based solely on traffic volumes, so if the volumes are the same under both the improved and no improvement conditions, the allocation will be same under both scenarios. However, if induced traffic is assumed as a result of the improvement, the allocation could be different.
- Trip costs used for allocation are based on traffic volumes from either the year of completion or the forecast year, and volumes for the other years are allocated in proportion to those volumes.

This feature is an optional tool that can be used at the discretion of the user. At the very least it could be ignored. If no alternate route is defined, all estimated traffic volumes are simply assigned to the facility under analysis. However, since this feature provides a sketch analysis technique for estimating traffic allocation between competing routes, it could also be very useful in providing more realistic traffic volumes, particularly in the analysis of a bypass or improvements to a highway that has a well-defined alternative parallel route.

3. TRAFFIC DISTRIBUTIONS

This feature distributes the average daily traffic (ADT) forecasts into hourly traffic volumes (with each hour calculated as a percentage of the ADT). The program has default distributions based on highway type and whether the area is urban or rural. It also includes a directional split factor. The default values can be used, or they can be changed by the user.

The program also has an optional, alternative technique in which a yearly distribution can be input.

This technique should be consistent with WSDOT methods as far as the calculation of hourly distributions.

4. CAPACITY CALCULATION

According to the program documentation, the default roadway capacities in this program are developed from the 1985 Highway Capacity Manual, with ideal flow rates adjusted for conditions such as number of lanes, lane width, shoulder width, and design speed. All of the trucks and buses are converted to passenger car equivalents, and the adjusted capacity is calculated as follows:

$$CAP^* = \frac{CAP}{PE}$$

where CAP* = adjusted capacity
CAP = default capacity
PE = passenger car equivalent of all cars on the roadway, defined as

$$PE = 1 + \sum_i P_i(E_i - 1)$$

where P_i = proportion of traffic volume of vehicle type, i, to traffic volume of all trucks and buses
E_i = passenger car equivalent of vehicle type, i, defined as a + b(grade)
where grade = roadway segment percentage of grade (with grades ≤ 0 set to 0, and grades ≥ 6 set to 6)
and a and b are defined by vehicle type, as described in the following table:

Vehicle Type Number i	Vehicle Type Description	a	b
4	Bus	1.539	0.697
5	2-axle single unit	1.539	0.497
6	3-axle single unit	1.539	0.697
7	2-S2 semi's	1.574	1.068
8	3-S2 semi's	1.613	1.266

Although this method is consistent with the Highway Capacity Manual procedures, the breakdown between vehicle types and grades do not match the breakdown in the 1985 or 1994 HCM. Furthermore, the vehicle classifications do not match those used by WSDOT. Adoption of this program would require further examination of and comparison between the program values *and the HCM values to confirm whether they are equivalent. It does not appear that the program is set up for the user to overwrite the default values for roadway capacity calculations.*

5. SPEED CALCULATION (AVERAGE TRAVEL SPEED)

The 1985 HCM method is used for estimating speeds on sections with the following formula:

$$\text{Average travel speed} = \frac{\text{length of segment}}{\text{average vehicle travel time to traverse the segment}}$$

Speed under "ideal conditions" is adjusted for factors such as number of trucks, grades, and geometric characteristics. The speed can be adjusted directly, or indirectly through adjustments to capacity. All adjustments to speed are made during data entry and data edit.

Calculation of average speed is based on the hourly demand to capacity ratio (d/c). This is consistent with the 1977 AASHTO Manual [1] and modified HIAP[1] studies. Density/speed relationships work better for estimating speed at unstable forced flow (LOS F) conditions, but they can break down at low densities. Figure A1 in the TTI report illustrates an example of the demand/capacity ratio and average speed relationship for freeways.

$$SP = SP_L - [(DC - DC_L) * (SP_L - SP_U) / (DC_U - DC_L)]$$

where, SP = calculated average travel speed
DC = v/c ratio at which the average travel speed is calculated
DC_L = the next lower d/c ratio from the speed-d/c ratio table
SP_L = the speed from the speed-d/c ratio table at DC_L
DC_U = the next higher d/c ratio from the speed-d/c ratio table
SP_U = the speed from the speed-d/c ratio table at DC_U

---

[1] Highway Investment Analysis Package. Documented by Batchelder, et al in TRR 698, 1979

The calculated travel speed is then multiplied by the pavement adjustment factor to determine the speed used in the user cost calculations.

MicroBENCOST utilizes speed-volume relationships different than those utilized in the WSDOT Mobility procedures, which are based on tables in the ITE Transportation Engineering Handbook [2], which are in turn based on the 1965 Highway Capacity Manual[2].

6. DELAY CALCULATIONS

The delay estimated on the existing highway is compared to the delay estimated on the proposed highway, and the difference represents delay savings, which is multiplied by the value of time.

At Intersections/Interchanges

MicroBENCOST uses a modification of a procedure that was developed by TTI for intersection delay analysis. Basic intersection delay calculations were developed from TRANSYT-7F, as follows:

1. Typical intersection geometrics, phasing, and traffic flows were used.
2. Delay was iterated over a range of cycle lengths to determine the minimum for a given traffic volume.
3. This was repeated over a range of volumes.
4. Points were used as default values to describe the relationship between vehicle volume and intersection delay.

---

[2] Transportation Research Board, Highway Capacity Manual, Special Report 209, National Research Council, Washington, DC, first edition, 1965

The default values are intended to represent optimal signal timing for a given traffic volume. Thus, operational changes in signal timings that would be warranted by changing conditions are inherent in these values.

Interchange delay is based on the intersection analysis. Only the portion of the interchange traffic exposed to interrupted flow is used to calculate interchange delay. Speed and distance adjustments for movements on ramps are also added to the interchange delay.

At Railroad Grade Crossings

The program combines a simple queuing model with a formula to calculate the delay of a car slowing to cross the railroad tracks to estimate railroad crossing delay. This can be used for railroad crossings and for grade separations. This model might possibly be used for a Mobility project; however, railroad crossing improvements are generally done with money allocated to rail improvements.

At Incidents and Workzones

These optional features would never be used in analysis for priority programming, so they are omitted from this review.

Discomfort Cost Adjustments

MicroBENCOST calculates discomfort costs resulting from three sources: vehicle stopping, congestion, and rough pavement.

Stopping and congestion are adjustment factors to the value of time in the time cost calculation. Discomfort cost congestion factors vary depending on d/c ratio. Rough pavement costs are added to time costs. The unit of measure is cents/vehicle-mile, which varies depending on the Pavement Serviceability Index (PSI).

Defaults for each of these factors are given in Tables A1, A7, and A8 in Appendix A of the MicroBENCOST User's Manual [4].

This is not consistent with WSDOT Mobility procedures, in which intersection delay is calculated through Highway Capacity Manual methods, and discomfort costs are not included at all.

7. VEHICLE OPERATING COSTS

Five components make up vehicle operating costs: fuel consumption, oil consumption, tire wear, vehicle depreciation, maintenance and repair.

Vehicle type and running speed are factors in all component categories. Other factors used for various components are percentage of grade, surface roughness, and road curvature. To obtain vehicle component costs, the consumption of each component category is estimated from roadway characteristics and traveling speeds. This is then multiplied by the unit price of the corresponding cost component. Unit prices and vehicle consumption data were taken from a study by Zaniewski[3] and factored from 1980 to 1990 values.

Total consumption of a vehicle cost component is broken down into the following four categories of vehicle consumption:

1. vehicle traveling at a uniform speed at a specific grade

---

[3] Zaniewski, J.P. et al, *Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Condition Factors*. Final Report, Texas Research and Development Foundation, Austin, June 1982

2. additional amount of a vehicle changing speeds
3. additional amount of a vehicle idling
4. additional amount of a vehicle negotiating a curve

The relationship between each consumption component category under uniform speed and a range of grades is approximated with regression equations. The following user cost categories are explained in more detail in the report:

- Running costs at uniform speed - Tables C1 through C10 in Appendix C of the MicroBENCOST report [3] (based on Zaniewski's data)
- Additional running costs for horizontal curve - Tables C12 through C26 in Appendix C of the MicroBENCOST report [3] (based on Zaniewski's data)
- Pavement roughness adjustment factors - measured in pavement service index (PSI) - Table C42 in Appendix C of the MicroBENCOST report [3] (based on Zaniewski's data)
- Speed change cycling costs - Tables C36 through C41 in Appendix C of the MicroBENCOST report [3] (from NCHRP Report 133)
- Idling costs - Table C35 in Appendix C of the MicroBENCOST report [3] (from Zaniewski's data)

Vehicle operating cost estimation is much more complex and requires substantially more data than are currently used under WSDOT procedures

8. ACCIDENT COSTS

Accidents are categorized as fatal, injury, or property damage only (PDO). Total accident costs are obtained by multiplying the number of accidents for each accident type by the unit accident cost for that type.

Accident Rates

Accident rates are calculated in terms of number of accidents per 100-million vehicle-miles, and the total vehicle-miles traveled.

Accident rate data in the Highway Economic Requirements System (HERS) are used as the default. Default tables are given in Tables A37 through A39 in Appendix A of the MicroBENCOST User's Manual [4].

Unit Accident Costs

MicroBENCOST default accident costs are the Rollins and McFarland accident costs, updated to 1990 dollars with the CPI.

Default accident costs for highway segments, intersections, interchanges, and bridges are given in Table A6 in Appendix A of the User's Manual

The WSDOT values and methods could apparently be directly input into the program for accident reduction calculations.

9. CARBON MONOXIDE EMISSIONS

To estimate carbon monoxide (CO) emissions, a regression equation was developed from 1987 emission data generated by the MOBILE 4 program. The equation is as follows:

$$\text{Log(CO)} = 148.66542 - .8063745\ \text{Log(SP)} - .0122428\ \text{TEMP} - .1937841\ \text{ALT} - .0714954\ \text{YR} + .0147989\ \text{PCCN}$$

where, CO = carbon monoxide emitted, in gram/mile
SP = average speed, in mph
TEMP = ambient temperature, in degrees F, 0 - 60
ALT = altitude, low = 1 and high = 0
YR = year, 1987 to 2005
PCCN = percentage of VMT of cold-start engine of non-catalyst vehicles, 0 to 70

MicroBENCOST uses default values based on uniform speed and broken down by three periods of the year: (1) Dec-Feb (2) Mar-Apr, Oct-Nov (3) May-Sep. Total annual vehicle-miles traveled must be distributed according to the same three periods of the year for CO emissions to be estimated.

Because emissions estimates are calculated as stand-alone values and are not converted to monetary values, this component has no bearing on benefit-cost calculation.

10. HIGHWAY COSTS AND SALVAGE VALUES

Two possible components in the salvage value of a highway project at the end of an analysis period are (1) the value that the service that the highway is expected to provide from the end of the analysis period, and (2) the value of salvageable land and materials at the end of its useful life, net of any costs incurred selling or salvaging these items. MicroBENCOST assumes the second component to be zero. The first component is calculated in terms of the percentage of the initial highway costs. The program calculates salvage value by annualizing these percentages uniformly over the period between the service life and the analysis period. These future values are converted into present worth. The mathematics of salvage value calculation are given in detail in the TTI report.

In contrast to MicroBENCOST, current Mobility procedures consider the value of salvageable materials but do not consider the value of the service that extends beyond the end of the analysis periods. However, if adoption of the MicroBENCOST method were not desired, default salvage values could be overwritten by the user, so they would not have to be included. Additionally, it should be possible to simply externally calculate the salvage values consistent with *existing Mobility procedures and manually subtract them from the cost input. However, by this method, the salvage values would not be distinguished from the actual project cost. Since the input project cost would be lower than the true project cost, this could be confusing.*

11. SERVICE LIVES

Projects under analysis can be defined in terms of their

1. analysis life - the period under analysis for an engineering economy study, quite often 20 years.

2. service life - the duration of actual total usage of the facility. It is the time span from installation of a facility to its retirement from service, which can potentially be 50 to 100 years.

3. economic life - the span of time over which a facility is economically profitable, or until the service provided can be provided by another facility at lower costs.

The MicroBENCOST report points out that it is not uncommon for highway analysis studies to assume zero salvage values at the end of an analysis period, even though a major part of the investment may be expected to be useful far beyond that time period. As was previously discussed, MicroBENCOST does calculate a salvage value, which is based on the time span between the end of the analysis period and the end of the facility's service life. Table A5 in Appendix A of the User's Manual lists the default values for several different project types.

The user may or may not agree with the default service life values, but they can be overwritten. The service life values are only needed if the MicroBENCOST salvage calculations are used.

12. VALUE OF TIME

The researchers who developed MicroBENCOST recognized that time savings is usually the most substantial category of benefits for major highway improvements and that the estimation of the value of time can be an extremely complex process. Many complex and theoretically defensible methods can be used to assign worth to time savings, each of which will likely provide different values. Therefore, MicroBENCOST utilizes a common simplified method of valuing time, which is simply to take 80 percent of the average wage rate for all adults drivers and passengers in the area under study. For the value of time for trucks, the MicroBENCOST default values are based on AASHTO recommendations and values developed by Buffington and McFarland[4] updated to 1990. The default values of time are included in Tables A2 and A3 in Appendix A of the MicroBENCOST User's Manual [4].

This method is consistent with the value of time used by WSDOT Mobility, although the calculations used to determine travel times are not. The user can input the WSDOT values of time for automobiles and trucks.

13. CONSUMER SURPLUS CALCULATION

MicroBENCOST identifies three types of traffic for the purpose of calculating benefits and consumer surplus. These are

1. continuing traffic—traffic that continues to use the same route after the improvement
2. diverted traffic—traffic that diverts from another facility to the improved facility, because of the decreased travel costs that result from the improvement

---

[4] Buffington, J.L., and McFarland, W.F., *Benefit-cost Analysis: Updated Unit Costs and Procedures*, Research Report No. 202-2, Texas Transportation Institute, Texas A&M University, Texas, 1975.

3. induced traffic—traffic induced to use the improved route that would not have made the trip otherwise

The program performs different calculations for these types of traffic, depending on whether analysis is being performed for a single route or for multiple routes. In either case, for continuing traffic the benefits consist of the full calculated cost savings between the trip before and after the improvement. The benefits for induced traffic are also the same for both cases. They are calculated as one half the savings per trip for traffic on the new route. For single route analysis, benefits for diverted traffic also equal one half of the savings per trip for continuing traffic. For multiple route analysis, the benefits for diverted traffic equal the cost per trip on the old route minus the cost per trip on the new, improved route.

If diverted and induced traffic are not considered in analysis, this method is consistent with WSDOT Mobility procedures because the calculated benefits for continuing traffic are simply the cost savings per trip due to the improvement.

CONCLUSIONS

MicroBENCOST procedures and current WSDOT Mobility procedures are compatible in the following ways:

- Project types are similar for traditional capacity-oriented solutions.
- Benefits are defined by reduction in travel delay, reduction in operating and maintenance costs, and accident savings.
- Construction costs include the same components.
- Traffic forecasting methods are consistent.
- Procedures for estimating accident costs are consistent.
- The methodology of assigning a value of time to delay savings is the same, even though the values used to estimate time savings are not.
- The final calculation of benefit-cost ratio is the same (it is one of three options in MicroBENCOST), although the methods and values used to calculate the benefits and costs are not.

The two procedures are dissimilar in the following ways:

- MicroBENCOST is not capable of analyzing non-traditional transportation solutions, so even if it were adapted to WSDOT Mobility procedures, these other types of projects would still have to be analyzed outside of the program.
- MicroBENCOST allows induced and diverted traffic due to the improvement to be calculated, in addition to continuing traffic.
- Roadway capacities appear to be calculated differently.
- The vehicle classifications in MicroBENCOST are different than those used by WSDOT.
- The speed-volume relationships used to estimate travel times are different.
- Procedures for estimating intersection delay are different.

- Coefficients and calculations that are used to calculate vehicle operating costs are much more elaborate in MicroBENCOST than in WSDOT Mobility procedures.

- MicroBENCOST considers the discomfort costs of congestion and rough pavement, while WSDOT Mobility procedures do not.

- The theories for calculating salvage values are different.

On the surface, the overall procedures of MicroBENCOST are comparable to many employed by WSDOT Mobility. However, the output of the program depends on many default values that are not designed to be overwritten. Additionally, the program utilizes some calculations for both operating cost and delay that are much more elaborate and require more detailed data than those currently used by WSDOT Mobility.

Another consideration is how adoption of MicroBENCOST would fit with the broader goals of WSDOT Mobility. Although the general procedures utilized by the program are accepted and widely used throughout industry, they have inherent drawbacks that conflict with the analysis of alternative transportation solutions. Adoption of MicroBENCOST would not advance WSDOT Mobility toward the goal of including more alternative transportation solutions in the process. In fact, it would more likely hinder Mobility's goals, since the software is only capable of analyzing traditional capacity-oriented solutions. Other types of projects would still have to be analyzed outside of the program, which could possibly encourage perceptions that traditional solutions are measured in hard numbers in contrast to a more subjective analysis of alternative solutions.

The TTI report identifies several areas in which further research is recommended, indicating that like WSDOT, the researchers used the best data they could find based on existing data and statistics, but still recognize their data as a "best guess." The areas identified for further research are

- new vehicle operating cost consumption data
- new accident rates
- new values of time
- improved estimates of intersection and interchange delay
- improved capacity and delay data on workzones and incidents
- improved estimates on the number and magnitude of speed-change cycles.

To adopt MicroBENCOST, accepted assumptions and calculations within WSDOT Mobility's procedures would have to be redefined, and default values within the program would probably have to be modified to some degree.

Adoption of MicroBENCOST is certainly feasible, although it would require substantial work by someone who understood both the coding of the program and the sensitivity of its output to any revisions, as well as the WSDOT benefit-cost procedures. It would also require consensus and involvement from the Technical Advisory Committee (TAC) and the six WSDOT regions. The primary advantage of utilizing MicroBENCOST would be that once the default values and procedures had been established, the program could allow better standardization and automation of some benefit-cost calculation methods, both within and between different programs. However, a decision would be needed regarding whether all of the required review, consensus-building, and refinement of both the software and existing Mobility procedures would be justified by a yet-to-be-determined degree of increased standardization. The end result would be a more elaborate way to do a portion of the same benefit-cost calculations, with no added capability for more comprehensive evaluation or for analysis of alternative transportation solutions.

REFERENCES

1. American Association of State Highway Officials (AASHTO), A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements, Washington, DC, 1977.

2. Institute of Transportation Engineers (ITE), Transportation and Traffic Engineering Handbook, second edition, Prentice-Hall, Inc. Englewood Cliffs, NJ, 1982.

3. Texas Transportation Institute (TTI), Microcomputer Evaluation of Highway User Benefits: Final Report, prepared for National Cooperative Highway Research Program project 7-12, Texas A&M University, College Station, TX, October 1993.

4. Texas Transportation Institute (TTI), MicroBENCOST User's Manual, prepared for National Cooperative Highway Research Program project 7-12, Texas A&M University, College Station, TX, October 1993.

5. Transportation Research Board (TRB), Highway Capacity Manual, Special Report 209, National Research Council, Washington, DC, second edition, 1985.

6. Transportation Research Board (TRB), Highway Capacity Manual, Special Report 209, National Research Council, Washington, DC, third edition, 1994.