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Metrication and Enhancement of MicroBENCOST Software Package

This is an NCHRP digest of NCHRP Project 7-12(2), "Metrication and Enhancements of MicroBENCOST Software Package." The project updated a software package originally developed under NCHRP Project 7-12, "Microcomputer Evaluation of Highway User Benefits," distributed by McTrans since 1993. Both research projects were conducted by The Texas Transportation Institute (TTI) and were administered by the Texas A&M Research Foundation. This digest was drafted by TTI personnel under the direction of Dr. Katherine F. Turnbull.

INTRODUCTION

This digest provides details and concepts about a software package consisting of two independent programs on separate disks—an English units version (C:/ MBE) and a metric units version (C:/ MBM)—that update and enhance the original English unit program (C:/ MB). All programs are written in the FORTRAN programming language and use the DOS operating system. The DOS operating system is accessable through the MS-DOS prompt in the Windows Programs listings.

Analyzing the benefits and costs of alternative highway investments and conducting economic assessments of various transportation options is important to transportation professionals, policy makers, and researchers. The financial analysis requirements of the Intermodal Surface Transportation Efficiency Act (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21), as well as rules promulgated by federal and state agencies, support the need for improved techniques for conducting benefit-cost assessments.

The MicroBENCOST software represents one of these techniques. MicroBENCOST provides a planning-level economic analysis tool that can be used to analyze a variety of transportation projects. MicroBENCOST was initially developed under NCHRP Project 7-12, "Microcomputer Evaluation of Highway User Benefits," and has been available since 1993. A follow-up study, NCHRP Project 7-12(2), "Metrication and Enhancement of MicroBENCOST Software Package," was undertaken to improve the initial program and to develop a metric version.

This digest summarizes the enhanced capabilities of the MicroBENCOST software programs, highlights example applications, and suggests areas for future research. The MicroBENCOST software and User's Manual may be obtained from McTrans Center, University of Florida, 512 Weil Hall, PO Box 116585, Gainsville, FL 32611-6585. The program will be listed under Transport Planning Project Management in the McTrans catalogue. McTrans may be reached at (352) 392-0378 or by e-mail at mctrans@ce.ufl.edu.

MicroBENCOST SOFTWARE

General Parameters

MicroBENCOST is a planning-level economic analysis software program. Both the English and metric programs are in FORTRAN programming language. The MicroBENCOST

software provides the ability to analyze the following eight major types of highway projects and three additional options.

- **Added Capacity Highway Projects**. Projects in this category include adding lanes to existing facilities and upgrading roadways.
- **Highway Bypass Projects**. Bypass or reliever roadways, which involve building a new facility around another freeway or geographical area, are included in this category.
- **Highway Intersection and Interchange Projects**. Seven types of projects upgrading existing intersections and interchanges to higher design standards can be analyzed using the MicroBENCOST software. These are two-way stop, four-way stop, and signalized intersections, and simple diamond, 3-level diamond, cloverleaf, and directional interchanges.
- **Highway Rehabilitation and Pavement Improvement Projects**. Roadway projects improving horizontal and vertical alignments, increasing lane widths, adding paved shoulders, rehabilitating pavements, and overlaying pavements are all included in this category.
- **Bridge Projects**. Building new bridges, rehabilitating existing bridges, and other projects that improve the functional or structural characteristics of bridges are all included in this category.
- **Safety Projects**. Roadway projects that focus on improving safety and reducing accidents are included in this category.
- **Highway-Railroad Grade Crossing Projects**. Improvements at highway railroad grade crossings, such as upgrading or adding crossbucks, signals, gates, and grade separations, are included in this group.
- **High-Occupancy Vehicle (HOV) Projects**. Median barrier-separated, concurrent flow, and contraflow HOV lanes on freeways are included in this category.
- **Emission Option**. This option can be used to analyze the vehicle-related carbon monoxide emissions impact of a specific roadway improvement.
- **Work Zone Option**. Up to three work zones can be analyzed on any one route in this option. This component includes closing lanes or otherwise reducing the capacity on a roadway segment for a specified period of time.
- **Incident Option**. Incidents that result in the closing of a lane or lanes can be analyzed in this option. A total of three incidents can be examined for each route.

Combinations of projects in these categories can also be examined. For example, adding a lane to an existing freeway and completing a pavement overlay project can be analyzed or a new bypass with new interchanges can be combined into one alternative to be tested.

These types of projects can be analyzed considering different economic analysis parameters, traffic growth factors, traffic volumes, traffic mixes, impact assessments, and vehicle operating costs. A user may select specific values for each analysis from default tables or modify the default values to match local data and conditions.

Software Enhancements

A number of enhancements were made to the original English MicroBENCOST software program as part of this project. As highlighted in this section, these focused primarily on enhancing the ease of use, improving the informational messages, adding new elements, and updating some default data sets.

- **User Interface and Program Operation Enhancements**. The number of key strokes needed to enter data was reduced to make the program easier to use. Minor problems present in the original version with a few subroutines and other calculations were corrected. A feature was also added to trap hardware errors during input/output and print operations. Users can now terminate a session and re-enter a program if there is a hardware problem.
- **Improvements to Informational Messages**. Changes were made in the software to improve some of the information messages and to prompt the user on the ability to modify default values. Modifications were made in some of the data menus to reflect these enhancements.
- **New Elements**. A number of new elements were added to the program. These included a work zone adjustment factor for accident rates and intersection delays, linking the ramp type with ramp speed and distance saved, and changing the default speed limits from functional classification to highway type in order to match the default speed-volume data. A new measure, discounted total agency costs, was developed and added as an output in the summary of benefits. This measure consists of the discounted construction cost plus the discounted increase in maintenance and rehabilitation costs, minus the discounted salvage value.
- **Changes to Update the Program**. The default data sets in the update program were expanded. Traffic operation data (design speed, capacity adjusted for lane width and shoulder width, and speed limit); speed-volume data (demand/capacity ratio and average operating speed); minor route or cross street data (free flow speed, average running speed); intersection and interchange data (miscellaneous items, route volume, delay data, and ramp data); and bridge data (geometric/operational data and diversion of vehicle fleet) were all added.

- **Updating Default Data Sets**. Given that the initial MicroBENCOST program was developed in the early 1990s, part of this project focused on updating some of the default data sets to more accurately reflect current conditions. Five data set tables were updated to account for inflation, and two data tables were revised to match the new Highway Capacity Manual.

Development of Metric MicroBENCOST Program

The development of a metric version of the enhanced MicroBENCOST software represents the second major task accomplished in this project. A number of steps were completed to convert and modify the enhanced MicroBENCOST software into a metric program. These included converting the input and output data, modifying the internal subroutines, and addressing rounding problems.

Input data on 39 variables used in the program were converted from English units to metric units. Four output data elements were also converted to metric. The format for most of these input and output variables had to be modified to accommodate the change to metric.

A number of the subroutines contained in the English MicroBENCOST software were also modified to accommodate the metric units. Conversion subroutines were developed and added to the program for mile/kilometer, gallon/liter, quart/liter, foot/meter, kip/metric ton, and Fahrenheit/Celsius. The potential for rounding problems with these conversions and the metric subroutines was also addressed.

MicroBENCOST OUTPUT AND ANALYSIS TOOLS

The results generated from the MicroBENCOST program include a variety of data that can be used to conduct economic analyses and cost-benefit assessment of alternative transportation projects. Table 1 highlights the specific output values calculated by the program. This information can be used in the following three types of economic analyses—benefit-cost, net present value, and internal rate of return assessments—which are often conducted on transportation projects.

- **Benefit-Cost Ratio**. The benefit-cost ratio compares the benefits generated by a project with the cost incurred over a specific time period. Discount rate formulas are used to put all values in terms of the date of valuation. A benefit-cost ratio greater than one indicates that a project has a positive impact. The benefit-cost ratio represents the most common analysis technique used to evaluate transportation facilities and other types of projects.

  Two approaches are used with benefit-cost ratios, depending on the placement of increased maintenance costs and salvage value as adjustments to user benefits in the numerator, or adjustments to construction costs in the denominator. A gross benefit-cost ratio calculates savings in user costs between an existing facility and improved alternatives, with the cost component including construction costs minus salvage costs plus the increase in maintenance. A netted benefit-cost ratio includes user benefits and salvage value, minus the increase in maintenance and rehabilitation expenditures, and costs include only those associated with construction. An incremental benefit-cost ratio may also be used in some studies. In this approach, the benefit increments are compared to cost increments, rather than comparing the total benefits and costs, for alternative projects.
- **Net Present Value**. Net present value represents the benefits of a project minus the costs over a specific time period. A net present value greater than zero indicates the benefits from a project are greater than the costs.
- **Internal Rate of Return**. The internal rate of return is equal to the discount rate that makes the net present value of a project equal to zero. A potential limitation of using the rate of return as an evaluation measure is that multiple rates of return may be possible. This result could happen if the flow of net benefit changes more than once over the analysis period. This situation does not appear to happen with most projects, however. An internal rate of return greater than the discount rate indicates a viable project.

MicroBENCOST APPLICATIONS

Nine case studies and example problems are included in the MicroBENCOST Users Manual. These are provided to help familiarize first time users with the components of the software and use of the program. MicroBENCOST has also been used on other research projects in Texas and throughout the country. Two examples are provided here: one from the Users Manual and one from an ongoing assessment of HOV facilities in Texas.

An added capacity project comparing an existing 4-lane undivided highway with a new freeway in Fort Worth, Texas is the first example in the Users Manual. Table 2 highlights the general characteristics and input data for the existing facility and the proposed freeway. The results from the MicroBENCOST software are presented in Table 3 (both English and metric outputs are presented). Overall, the new freeway had a netted benefit-cost ratio of 5.1.

In the second example, the MicroBENCOST software was applied in the ongoing monitoring and evaluation of HOV lanes in Houston and Dallas. The following locally available data was used in this analysis.

- Aggregate construction costs
  —initial construction
  —HOV lane extensions and access ramps
  —improvements, such as barrier modifications

TABLE 1 Examples of MicroBENCOST results

Total Discounted User Benefits (millions of dollars)
Discounted Construction Cost (millions of dollars)
Discounted Salvage Value (millions of dollars)
Discounted Increase in Maintenance and Rehabilitation Costs (millions of dollars)
Discounted Total Agency Costs (millions of dollars)
Fuel Consumption Savings (millions of gallons/liters)
Fuel Savings, Adjusted for Induced Traffic (millions of gallons/liters)
Carbon Monoxide Emission Reduction (million of kilograms)
Carbon Monoxide Reduction, Adjusted for Induced Traffic (millions of kilograms)
Net Present Value (millions of dollars)
Gross Benefit-Cost Ratio
Netted Benefit-Cost Ratio
Internal Rate of Return (percentage)

TABLE 2 Added capacity example—Fort Worth, Texas

Data Item	Existing Route	Proposed Route
Year	1992	1992
Area Type	Urban	Urban
Construction Costs ($)	N/A	145,890,072
Discount Rate (%)	5	5
Analysis Period	20	20
Year of Completion	1993	1993
Type of Traffic Growth Rate	Constant	Constant
Functional Class	Principal Arterial	Freeway
Number of Route Segments	8	8
Method of Inputting or Editing Traffic Data	Annual Growth Rate	Annual Growth Rate
Type of Traffic Distribution	Hours of Day	Hours of Day.
Base Year of Traffic Data	1992	1992
Base Year AADT	26560	35050
Average Annual Traffic Growth Rate (%)	2.40	3.00

TABLE 3 User benefits, costs, and economic measures of Forth Worth Case Study

	English	Metric
Total Discounted User Benefits (millions of dollars)	$670	$670
Discounted Construction Cost (millions of dollars)	$139	$139
Discounted Salvage Value (millions of dollars)	$45	$45
Discounted Increase in Maintenance and Rehabilitation Costs (millions of dollars)	$4	$4
Discounted Total Agency Costs (millions of dollars)	$98	$98
Fuel Consumption Savings (millions of gallons/liters)	54.5	206.5
Fuel Savings, Adj. for Induced Traffic (millions of gallons/liters)	63.3	239.7
Carbon Monoxide Emission Reduction (millions of kilograms)	8.8	8.8
Carbon Monoxide Reduction, Adj. for Induced Traffic (millions of kilograms)	10.2	10.2
Net Present Value (millions of dollars)	$572	$572
Gross Benefit-Cost Ratio	6.8	6.8
Netted Benefit-Cost Ratio	5.1	5.1
Internal Rate of Return (percent)	38.7	38.7

—support facilities, such as park-and-ride lots and bus transfer centers

- Traffic data
  —initial AADT for a base year of 1995
  —average annual traffic growth over a 20-year analysis period
  —composition of truck fleet on the mainlanes
  —distribution of ADT by hour for a 24-hour period
- Geometric data for mainlanes and HOV lanes
- Routine maintenance, operation, and enforcement costs
- Accident rate data
- HOV lane operational data
  —type of HOV lane
  —vehicle classifications and occupancies
  —hours of operation
  —percent of persons using HOV lane, inbound and outbound

The results of this analysis indicated that seven current freeway HOV facilities in Houston and Dallas produce benefits outweighing the costs over a 20-year life cycle. The benefit-cost ratio ranged from 6 to 48. The higher ratio reflects the lower construction costs associated with a concurrent flow lane, while the lower ratios reflect the higher costs related to barrier-separated facilities.

FUTURE RESEARCH ACTIVITIES

A number of enhancements were made to the original MicroBENCOST software as part of this project and the metric program was developed. These represent advancements over the original software and allow for greater use of MicroBENCOST in Canada and other parts of the world. Additional improvements to enhance the ease of use, to expand the capabilities of the program, and to update default data were identified during the course of this project. The suggested areas for further research fall within two general categories of additional enhancements to the MicroBENCOST software and an ongoing benefit-cost analysis research program.

Further Enhancements to the MicroBENCOST Software

The FORTRAN programming language and the DOS operating system represented the state of the practice when the initial MicroBENCOST program was developed in the early 1990s. Windows has now become the operating style of choice for most users. As a result, the development of a Windows MicroBENCOST software program would serve a wider market and enhance the ease of use.

Providing ongoing technical assistance and support services to MicroBENCOST users would also benefit numerous agencies and groups. Although the software is not overly difficult to use, a basic understanding of computer programs, benefit-cost analysis concepts, and MicroBENCOST features is needed. Maintaining the program code, providing quick help to users by telephone and e-mail, and responding to more detailed questions could all be part of an ongoing support function.

As noted previously, MicroBENCOST provides the ability to analyze eight major types of highway projects and three additional options. Further transportation projects and options were identified by researchers, panel members, and users during this project. These included adding the ability to analyze different percent-passing opportunities for separate travel directions; value pricing and high-occupancy toll (HOT) projects; transit alternatives; and Intelligent Transportation Systems (ITS) improvements. The ability to conduct risk analyses and expanding the environmental variables were also suggested.

The development of the initial MicroBENCOST program and the enhancements completed in this project were limited in some instances by the lack of good data on many of the needed input values. Adding improved default data from other research studies as it becomes available would enhance the quality of the results provided by the MicroBENCOST software. Improved default data on accident rates associated with different types of projects, intersection and interchange delay estimates, work zone and incident delay values, and environmental factors would all improve the capabilities of MicroBENCOST.

Ongoing Benefit-Cost Assessment Research Program

As noted, one of the problems with benefit-cost assessments is the lack of available data on many of the needed input values. To overcome these limitations, most models or analysis techniques, including MicroBENCOST, use default values. In many cases, the available data are very limited or outdated. In other instances, no default values are available. To address these needs, a comprehensive ongoing benefit-cost assessment research program is suggested.

Possible elements to be considered in such an ongoing research program include the establishment and operation of a benefit-cost assessment clearinghouse, developing or updating default values, and adding the capability to analyze new and emerging transportation alternatives. The clearinghouse could build on the user support services described previously. The clearinghouse could offer expanded capabilities, however, including a central database on benefit assessments that have been conducted, available benefit-cost analysis tools and techniques, and other information.

Additional research studies may also be appropriate to develop new or updated default data on accident rates, delay estimates, and other factors associated with different transportation projects. Examining and obtaining the data needed to analyze additional alternatives, and developing the appropriate software programs represents future research activities. Value pricing, HOT lanes, congestion pricing, transit, and ITS represent a few transportation projects that could be further examined, along with enhancing the ability to conduct risk assessments and environmental analysis.

These **Digests** are issued in order to increase awareness of research results emanating from projects in the CRP. Persons wanting to pursue the project subject matter in greater depth should contact the Cooperative Research Programs Staff, Transportation Research Board, 2101 Constitution Ave., NW, Washington, DC 20418.

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