USER BENEFITS OF RAILROAD GRADE SEPARATION IN A SMALL COMMUNITY: PRACTICAL TECHNIQUES FOR APPLYING MICROBENCOST

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ABSTRACT

As transportation system elements of this country continue to evolve, issues that may have seemed foregone to a prior generation have crystallized into topics requiring substantive review. Witness, for example, the growth in both freight railroad and vehicular traffic throughout the United States over the past 15 years. The product of their interaction at grade crossings is a mixture of congestion and safety concerns. The challenge for today's transportation professionals is how to monetize these concerns when reviewing project-specific issues. One tool for assessing economic impacts during the project development process is benefit-cost analysis. This paper presents a framework for estimating roadway user benefits and costs associated with railroad grade separation in a small community by applying the software and methodology of MicroBENCOST. In addition, a specific application of this approach in the St. Cloud, Minnesota metropolitan area (population 100,000) has been included.

MicroBENCOST was released by the Texas Transportation Institute in 1993 to conduct benefit-cost analysis for highway improvements. A brief discussion of the software's current release and status has been included. Like most computer software, MicroBENCOST provides the user with a number of default values. This paper identifies defaults and other data that require the use of project-specific inputs. It also discusses practical techniques to focus productive, yet low cost, data collection prior to analysis. Of greatest importance when considering railroad grade crossing issues are railroad operation values such as train distribution, length, and speed. A methodology for collecting and summarizing this data is described in order to assist others with this task.

Once the necessary data has been collected, MicroBENCOST can be used to develop an input file and test a variety of alternatives. To demonstrate application of this framework, a case study involving a potential grade separation is described. Since there was some uncertainty associated with the forecasted data, a sensitivity analysis was conducted. Tips and traps associated with the use of this software are also presented.

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INTRODUCTION

As transportation system elements of this country continue to evolve, issues that may have seemed foregone to a prior generation have crystallized into topics requiring substantive review. Witness, for example, the growth in both freight railroad and vehicular traffic throughout the United States over the past 15 years. The product of their interaction at grade crossings is a mixture of congestion and safety concerns. The challenge for today's transportation professionals is how to monetize these concerns when reviewing project-specific issues. One tool for assessing economic impacts during the project development process is benefit-cost analysis. This paper presents a framework for estimating roadway user benefits and costs associated with railroad grade separation in a small community by applying the software and methodology of MicroBENCOST. In addition, a specific application of this approach in the St. Cloud, Minnesota metropolitan area (population 100,000) has been included.

RECENT PRACTICE

Other than MicroBENCOST, few methods have been available over the past 15 years to quantify user benefits and costs associated with converting a railroad-highway grade crossing to a grade separation. To provide a perspective on recent practice, this section identifies the strengths and weaknesses of these approaches.

Guidebook for Planning to Alleviate Urban Railroad Problems - 1974

This joint FHWA/FRA document outlines analytical processes to support the evaluation of railroad relocation activities. Using a number of nomographs and linked worksheets, construction and highway user benefits and costs are calculated in a manner which could also be applied to grade separation analyses. This method's ease of use led to its wide-spread acceptance during the 1970s and 1980s. But, advances in research and updating Consumer Price and Producer Price Indices from 25 years ago can introduce unintended consequences into the results.

Manual on User Benefit Analysis of Highway and Bus-Transit Improvements - 1977

Although not identified explicitly, this AASHTO document contains the data, figures, and methodology for estimating benefits and costs of grade separation. Construction and maintenance costs, motor vehicle costs, accident costs, and the value of travel time can all be taken into account. Unfortunately, the quantity of hand calculations necessary to accurately apply this methodology has hampered its use for problems of this nature. The caveats noted from the 1974 FHWA/FRA report are applicable to this one as well.

Railroad-Highway Grade Crossing Handbook - 1986

This FHWA document describes an economic framework for evaluating improvements to railroad-highway grade crossings. Similar to the AASHTO document, all anticipated costs and values are referenced. No guidance is provided for actually calculating the benefits and the costs. Thus, it is not possible to apply this document directly.

Evaluating Grade-Separated Rail & Highway Crossing Alternatives - 1987

This NCHRP report provides a framework and procedures for determining whether or not grade separated structures should be replaced. In 1995, AASHTO's Standing Committee on Railways cited this approach as an appropriate way to address grade separation issues. The decision-making framework encompasses three levels of analyses to perform on project alternatives. Using diurnal traffic distribution and detailed train information, all relevant benefits and costs can be determined. Caution must be exercised in using the formulas, since a few of the defaults should be revised using field data.

Roadway Vehicle Delay Costs at Rail-Highway Grade Crossings - 1990

In Transportation Research Record 1262, a methodology is explained for computing the length and cost of delays at railroad-highway grade crossings. Since the intent of the application was to perform a broad assessment of over 1000 crossings, many simplifying assumptions based on data collected early in the study were applied to railroad and roadway traffic characteristics. The computation of user costs is based on a procedure developed by FHWA in 1980. Although this approach should not be used as the basis for decision-making, it is an appropriate screening tool in homogeneous rail corridors.

RAILDEC: Public Rail Investment Decision Support Software - 1996

The Federal Railroad Administration (FRA) developed this software for intermodal investment decision support for rail and rail-related investments, including grade separations. RAILDEC incorporated a risk analysis framework to account for uncertainty in model inputs. In addition, the underlying methodology is consistent with the current benefit-cost methodologies employed by USDOT agencies. This project level model contains an extensive default database that can be replaced with more project specific or localized data. Although this approach may be too complex to be used as a screening tool in rail corridors, it is an appropriate basis for decision-making in project level analysis.

Development of Evaluation Tools for Road-Rail Crossing Consideration for Grade Separation - 1997

In Transportation Research Record 1605, simplified tools for evaluating the economic losses caused by at-grade crossings are presented. If the product of daily vehicle traffic and the number of hours per day when the crossing is closed for road traffic is over 13,000, then the crossing is a candidate for grade separation. Since the intent of the application was to perform a broad assessment of over 200 crossings in Israel, a sample was used to develop a multiple linear regression formula for approximating vehicle delay costs (in Israeli currency). Since the potential user is unable to revise the value of travel time (which is not disclosed), its usefulness for sketch planning in the U.S. is limited.

GETTING TO KNOW MicroBENCOST

MicroBENCOST was developed by the Texas Transportation Institute (TTI) in 1993 for the National Cooperative Highway Research Program (NCHRP) to conduct benefit-cost analysis for highway improvements. This section provides an introduction to the overall methodology and how it is applied to railroad grade crossings.

Basics

MicroBENCOST is a computer program for conducting highway user benefit-cost analysis on a personal computer. The objective of benefit-cost analysis is to put all of the direct effects of a transportation improvement into dollar terms so the effects can be compared using a common measure. Benefit-cost analysis looks at the benefits generated by a project and compares them to the cost incurred over a certain analysis period. A project is considered economically feasible if the benefits are greater than the costs. MicroBENCOST calculates user benefits and costs of an improvement and outputs several economic measures that can be used by decision makers in their planning decisions. It can also allocate corridor traffic and calculate forecasted traffic volumes. The focus of the analysis is directed at the project level and its immediate area impacts rather than at the highway system level.

There are seven project types that MicroBENCOST can analyze: (1) added-capacity; (2) bypass; (3) intersection/interchange; (4) pavement rehabilitation; (5) bridge; (6) safety; and (7) highway-railroad grade crossing. The program compares the motorist (user) costs in the existing situation to the user costs if the improvement is completed. User costs include measures that are easily monetized: the time cost of delay, vehicle operating costs and accident costs. Three economic measures are generated to judge the desirability of a project: the benefit-cost ratio, the net present value, and the internal rate of return. MicroBENCOST also provides the change in fuel consumption and carbon monoxide emissions generated by the improvement. Environmental effects such as these are not easily monetized and are therefore not included in the quantitative economic measures.

Railroad Grade Crossing Module

A project in the highway-railroad grade crossing category is an upgrade to a higher control. There are seven items related to railroad grade crossing that the user can enter and edit.

(1) The type of train warning device: crossbuck, flashing lights, and automatic gates.
(2) The number of trains at the crossing per day.
(3) The percent reduction in speed of a vehicle crossing the tracks when the crossing is open and traffic can cross without interruption.
(4) The time, in seconds, to lower and raise gates while the crossing is occupied.
(5) The average train speed, in mph, when occupying the crossing.
(6) The average train length, in feet, of the trains occupying the crossing.
(7) The train distribution, i.e. the percent of trains during each of the 24 hours.

Table of Contents

The delay at railroad grade crossings is comprised of three components. A simple queuing model is used to calculate the delay of the train occupying the crossing and the delay of opening and closing the warning gates. In addition, a formula is used to calculate the delay of slowing down to cross the railroad tracks. The User's Manual provides guidance on speed reduction, based on the roughness and grade of the crossing.

Current Status

In July 1998, the updated manual for the next version of MicroBENCOST was submitted to the NCHRP. A demonstration of the new software to the NCHRP review committee is scheduled for the fall. According to TTI, the railroad grade crossing module is improved in the new version providing more choices to the user.

MicroBENCOST DATA NEEDS

A MicroBENCOST problem data set consists of certain data input by the user and certain data provided by default. As the user enters project specific data, the program automatically pulls in default data. This section describes several of the project specific data needs of MicroBENCOST as well as practical techniques to focus productive, yet low cost, data collection prior to analysis.

Project Specific Data

At the beginning of any improvement project, there is one fundamental question to be answered: What is in place and what should replace it? To use MicroBENCOST, an answer to this question (but not necessarily the final one) must be in place. The following subsections describe how the answer is woven into the application of the software.

Initial Assumptions

The first items required by MicroBENCOST are the initial assumptions about the project. The user must input the following project specific items: current year; area type, either urban or rural; project type, choosing one of seven stated earlier; presence or absence of an alternate route switch; discount rate; analysis period in number of years; and year when the improvement will be completed.

Construction Costs

MicroBENCOST has default values by area type and project type to distribute construction costs across the following six different components: preliminary engineering; right-of-way; major structures; grading and drainage; sub-base and base; and surface. By default, the program assumes that all of these components will be completed in one year. If the user knows the costs of the construction components and the year they will be completed, these values should be updated. For this project, two categories were added for the grade separation alternatives: the temporary railroad structure (shoo fly) and the replacement railroad work. The other construction cost components and the completion years were also updated to be project specific.

Route Segment Data

Project specific inputs are also required for the route segments (for both existing and proposed). The user must input the following: access control, either full, partial or none; segment length in miles; type and number of intersection/interchange/structure, choosing from 11 types; number of lanes in the inbound and outbound directions; and whether to edit data by roadbed or direction. For this study, data was edited by "roadbed = bi-directional".

Geometric data is required for every route segment including the lane width in feet, shoulder width or lateral clearance in feet, percent grade, and degree curvature. Defaults are provided for lane width and shoulder with, but project specific data for these items are easily obtained and should be utilized.

Traffic operation data required includes: additional local AADT; design speed; speed limit; and capacity per lane per hour. Defaults are provided for design speed, speed limit and capacity, but project specific data for these items are easily obtained and should be utilized. Default values are provided for the average running speed of the segment given the hourly demand/capacity ratio. The user is advised to check this data. During this study, the program produced a top average running speed of 60 miles per hour despite a speed limit of 35 miles per hour.

For bridge segments, the user must enter the following: type of bridge structure; whether traffic can be diverted around the bridge; bridge deck width in feet; whether the approach width is greater than the bridge width; and the bridge length in feet. In addition, for bridge segments, the user has the option to enter bridge rehabilitation costs, otherwise, the defaults are zero. For this study, a rough cost estimate for keeping the bridge open for the duration analysis period was entered.

Roadway User Data

Reduced delay, reduction in accidents, and vehicle operating cost savings are three major benefits associated with roadway improvements. A method for updating the MicroBENCOST default values of travel time, vehicle operating costs, and accident costs to current dollars is presented.

Value of Travel Time

The MicroBENCOST default values of time for passenger cars are from a 1986 TTI study and updated to 1990 dollars using the Consumer Price Index (CPI). The Final Report recommends using about 80 percent of the wage rate as the value of time for all adult drivers and passengers of the state (or other geographic area) that is being considered if the user wants to develop their own values based on income levels. The default values of time were updated to current dollars using the CPI.

Travel time savings for trucks represent savings in market costs for transporting commodities. The default values of time for trucks are from a 1975 TTI study (which updated values from an earlier study) and updated to 1990 dollars using the Producer Price Index (PPI). In turn, the values were updated to current dollars using the PPI.

Vehicle Operating Costs

MicroBENCOST has default values for five cost components in operating a vehicle including: fuel consumption, oil consumption, tire wear, vehicle depreciation, and maintenance and repair. The default values are from a 1982 study and updated to 1990 dollars using appropriate price indexes. The MicroBENCOST default vehicle operating costs were updated to current dollars using the CPI for transportation.

Accident Costs

MicroBENCOST calculates accident costs separately for highway segments, intersections and interchanges, bridges, and railroad grade crossings. The default values are from a 1986 study based on a willingness to pay approach and updated to 1990 using the CPI. The MicroBENCOST default accident costs were updated to current dollars using the CPI.

Roadway Traffic Data Collection

The use of project-specific traffic information where possible lends additional credibility to the outcome of the analysis. The collection of existing traffic data and development of forecasted traffic volumes is not particularly complex, but does merit a brief discussion.

Traffic Volumes

Three forecast methods are available in MicroBENCOST to input or generate traffic volumes over the analysis period. The user may input volumes for each year, or use the program to generate traffic volumes with either the annual growth rate method or the intermediate and forecast volumes method. In the annual growth method, traffic volume for the base year and the annual growth rate are used to calculate future traffic volume over the analysis period. For the intermediate and forecast volumes method, the volumes for the base year, intermediate year and forecast year are used to fit a curve between those points for each year over the analysis period. For this study, traffic volumes were forecasted by factoring the results of the MPO's travel demand model. An annual growth rate was then chosen to produce these volumes within MicroBENCOST.

Traffic Distribution

MicroBENCOST provides two methods to distribute AADT: the first is by hours of the day, the second is by hours of the year. Default distributions are provided for both methods, but they can be changed by the user. Project specific traffic distributions by hours of the day were collected during a 48-hour traffic count.

Types of Vehicles

MicroBENCOST provides default percent distributions for vehicle types typically found on highways from the Highway Performance Monitoring System (HPMS). Project specific percent distributions can be obtained through a volume by vehicle type report, though passenger cars are all counted as one

Table of Contents

type. Default values for the percentage of trucks were derived from FHWA's document Highway Statistics. For this study, a project specific value for the percentage of trucks was obtained during the 48-hour traffic count.

Railroad Data

Of greatest importance when considering railroad grade crossing issues are railroad operation values such as train distribution, length, and speed. A methodology for collecting and summarizing this data is described to assist others with this task. MicroBENCOST requires as user input the average train length and average train speed. In addition, a uniform train distribution is the default for the percent of trains crossing during each of the 24 hours. A uniform distribution does not reflect the typical weekday operations of trains. Also, the daily train distribution combined with average speed and length does not capture the delay caused by trains crossing. Therefore, for this study, project-specific railroad operations data was collected and summarized.

The BNSF railroad pulled data from HPX recorder modules over a two-week period. Train direction, date and time, train speed, warning time, and total time of crossing occupation were collected. To be consistent with roadway traffic, only movements from noon Monday to noon Friday were used in further data analysis. Distributions of train speed, length, and closure time were developed to determine median and mean values.

To review how closely they correlated, the hourly distribution of trains was compared to the hourly distribution of crossing occupation time. Although the values were similar, it was determined that just using trains alone was not enough. Using the data summaries, a train of typical length and speed was derived to apply with the hourly distribution based on crossing time.

MicroBENCOST does not allow changes in the daily train volumes over the analysis period. Given the uncertainties associated with long range forecasting of daily train volumes, this limitation did not hamper the methodology. In addition, the public did not feel that forecasting trains in excess of today's values was credible.

Additional Data Options

There are several other data items that can be changed but were not considered important to do so for this study. Default values for the following discomfort cost factors were left unchanged: stopped time discomfort; congestion discomfort; rough pavement discomfort and its associated speed adjustment factor. Other data items left unchanged in this study include: pavement condition data; overlay and pavement rehabilitation costs; routine maintenance costs; accident rates and emissions data.

APPLICATION OF FRAMEWORK TO CASE STUDY

Once the necessary data has been collected, MicroBENCOST can be used to develop an input file and test a variety of alternatives. To demonstrate where this has been done, a specific application of this approach in the St. Cloud, Minnesota metropolitan area (population 100,000) has been included. The case study involves the replacement of a river crossing with or without railroad-highway grade separation.

Background

The St. Cloud Metropolitan Area straddles the Mississippi River in Central Minnesota. Over the past 120 years, river crossings have been constructed to accommodate the increases in population and travel demand. In addition to the river, the mainline corridor of the Burlington Northern Santa Fe railroad also traverses the metro area. This line, which is the highest speed and highest volume rail corridor in Minnesota, serves as a national conduit for intermodal and other freight movement. Carrying up to sixty trains per day (including AMTRAK) at speeds approaching sixty miles per hour, the rail corridor has a significant impact on the St. Cloud area's vehicular traffic.

Since the Mississippi River and the BNSF mainline are parallel in the metro area, river crossings are often accompanied by railroad crossing issues. A study of the oldest Mississippi River crossing in the area has demonstrated this clearly. At the intersection of the roadway and railroad, located on the easterly bridge approach, the highest vehicle/rail conflicts of Minnesota's 5,000 grade crossings can be observed. As a part of the environmental assessment, economic analysis using MicroBENCOST was performed to evaluate the level of benefits and costs associated with grade-separated alternatives compared to the at-grade option and no-build.

Alternatives

The environmental assessment included these four alternatives for further review of social, environmental, and economic impacts: No-Build (existing two-lane bridge, as required by federal law); Alternative 1-A (four-lane bridge, at-grade crossing); Alternative 2-B (four-lane bridge in existing location, underpass of raised railroad); and Alternative 3-E (four-lane bridge in new location, overpass of lowered railroad).

Scenarios

The Year 2020 traffic forecast for the Sauk Rapids Bridge was 40,000 vehicles per day; the railroad reported up to 60 trains per day through the crossing. Some of the stakeholders believed that these values were overstated. In an attempt to address these concerns, reduced vehicular and railroad traffic values were developed for use in a sensitivity analysis. With this information, four scenarios were analyzed for each of the three alternatives. This sensitivity analysis is used to learn how dependent the results are on any one input. The following four scenarios were run:

Traffic = 40,000; Trains = 60
Traffic = 40,000; Trains = 40
Traffic = 30,000; Trains = 60
Traffic = 30,000; Trains = 40

Results

The MicroBENCOST program was run for alternatives 1A, 2B and 3E, comparing all back to the no-build alternative. As stated above, four scenarios were calculated for each alternative to test sensitivity. The results of this analysis are described in general terms in this section. In addition to the benefit-cost (b/c) ratios and net present values for the four scenarios of each alternative, the incremental benefit-cost ratios and net present values are also discussed.

The benefit-cost ratios for the three alternatives, all scenarios, are over one. The b/c ratios for alternative 1A are the highest for two scenarios; alternative 2B had the highest b/c ratios for the other two alternatives. Alternative 3E never had the highest b/c ratio, but did have net present values essentially equal to 2B for all scenarios. The results are summarized below:

30,000 vehicles/40 trains
B/C ratio for 1A is the highest (less than 2.0)
Net present values are essentially equal for all three (approximately $4 million)

30,000 vehicles/60 trains
B/C ratio for 2B is the highest (approximately 3.0)
Net present values essentially equal for 2B and 3E
(approximately $20 million greater than 1A)

40,000 vehicles/40 trains
B/C ratio for 1A is the highest (approximately 3.0)
Net present values are essentially equal for 2B and 3E
(approximately $7 million greater than 1A)

40,000 vehicles/60 trains
B/C ratio for 2B is the highest (greater than 4.0)
Net present values are essentially equal for 2B and 3E
(approximately $30 million greater than 1A)

Incremental benefit-cost ratios and net present values were calculated for going from 1A to 2B, from 1A to 3E, and from 2B to 3E. All of the incremental benefit-cost ratios are approximately one for the 30,000 vehicles/40 trains scenario. The incremental B/C ratios for going from 1A to 2B and from 1A to 3E for the other three scenarios are over one, with 1A to 2B consistently higher than 1A to 3E. The incremental B/C ratio of going from 2B to 3E is approximately one for all four vehicle/train scenarios.

The incremental net present values for going from 1A to 2B and from 1A to 3E are essentially equal for each vehicle/train scenario. The incremental net present value for going from 2B to 3E is between -$600,000 and $1,000,000 for all four vehicle/train scenarios.

LESSONS LEARNED

Software

The current version of MicroBENCOST has several problems that will hopefully be corrected in the next release. Various difficulties/design flaws that were encountered while using the software for this study are described below.

The user must enter all of the required user input data before the file can be saved. The data input can be very time consuming and therefore this presents obvious difficulties. Another problem has to do with the default values. The default values called up by the program based on user input are not necessarily updated when the user makes a change to the input. For example, the author encountered accident rates that were not updated after changing a segment from a two lane to a four lane road. The program has a command that allows the user to retrieve the default values, but this replaces values that the user has changed that he wants different from the defaults, such as traffic distribution.

The program sometimes generated specious results. The program presents detailed results by segment and a summary of the discounted benefits. In certain cases, the detailed results and the summary results were not consistent. The problem appeared in an early scenario with a differing number of segments in the existing and proposed routes. In this case, there were four segments in the existing route and seven in the proposed route. This problem was not encountered again after further refinement of the alternative resulted in five segments in the existing route and seven in the proposed.

A difficulty/design flaw mentioned earlier is that certain default values called up by the program based on user input do not appear to vary based on user input. This problem was found with the speed-volume data when MicroBENCOST produced a top running speed of 60 mph when the speed limit for the segment was 35 mph.

The user should be aware that the default capacities in MicroBENCOST are actually adjusted capacities, already multiplied by factors from the 1985 Highway Capacity Manual. If the user overrides the defaults by entering a different value, the program will not calculate an adjusted capacity and the results will be faulty.

Assumptions

Certain difficulties were also encountered with some of the assumptions in MicroBENCOST. The program assumes that the existing condition will remain intact for the entire analysis period. This was a problem for this study because the existing bridge is expected to be unusable in 8 years. To solve the problem, a rough bridge rehabilitation cost was assumed to keep the bridge open for the 20 year analysis period.

Another difficulty/design flaw mentioned earlier has to do with the railroad data. MicroBENCOST's default uniform train distribution combined with an average speed and length of trains does not capture the delay caused by trains crossing. Therefore, a train of typical length and speed were derived based on the hourly distribution of delay.

Recommendations

Despite the criticisms discussed above, the authors found that MicroBENCOST is a useful tool for project level analysis. Most users will find that it is not appropriate as a sketch planning/screening tool due to the level of effort required. The user is advised to review all of the input and output (i.e. open the black box) which should avoid faulty results. Finally, the learning curve is relatively quick, especially if the user has an understanding of transportation and benefit-cost analysis.

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