# An Economic Analysis Computer Package for Urban Highway Improvements

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ABSTRACT

The structure and operation of an interactive FORTRAN computer package to perform economic analyses on highway improvements are described. The computational methodology of the program is discussed; this includes defining the broad range of alternatives, computing highway segment costs, computing intersection delay costs, computing intersection accident costs, and performing an economic analysis of the alternatives. Next, the overall design and operation of the program are outlined along with descriptions of the inputs and outputs of each program within the package. The various program options available to the user are also presented. In addition, the data file structure within the package and the programs provided to update existing files are discussed. A comparison of a four-way stop sign control with a fully actuated traffic signal is then presented to illustrate one application of the package.

Transportation planners and engineers are confronted daily with the task of identifying the best projects among what may be a never-ending list. In the area of economic evaluation, state-of-the-art tools help the analyst to identify the most economically efficient project (1). However, such tools do not always address the specific range of projects within a given city, nor do such manual methods lend themselves to quick and easy solutions that are consistently reproduced.

Computer programs have also been designed to perform the economic evaluation of alternative highway improvements (2,3). But, again, these programs do not always address the specific needs of the user. Along this line, the city of Lincoln, Nebraska, requested that the University of Nebraska develop a highway economic analysis computer package to operate on their VAX-11/750 minicomputer. The Highway Economic Analysis computer package was the result.

The general specifications for the program included the following items:

1. Program methodology should generally follow that of the AASHTO manual (1);
2. The program should be interactive and user friendly;
3. The methodology should be revised where needed to include a broader range of highway facilities, intersection types, and control strategies;
4. When available, local data should be used instead of national averages; and
5. All data files accessed by the package should be located outside the individual programs and, in addition, the package should provide for quick and easy updating of all data files.

The remainder of this paper includes a discussion of the computational methodology and an outline of the program operation. In addition, a sample application of the package for comparing a four-way stop control with a signalized control is presented.

## GENERAL METHODOLOGY

As mentioned earlier, the package design is based on the AASHTO methodology for estimating highway user benefits. The general steps include (a) defining alternatives and project types, (b) computing highway segment user costs, (c) computing intersection delay costs, (d) computing intersection accident costs, and (e) performing an economic analysis.

### Defining Alternatives and Project Types

The package design permits great flexibility in modeling alternative highway improvements for analysis. First, an alternative improvement might consist solely of highway segments selected from 11 different types of highway segments:

1. One way,
2. Two lane,
3. Two lane with common left-turn lane,
4. Two lane with left-turn lanes,
5. Four lane undivided,
6. Four lane with painted median,
7. Four lane divided,
8. Six lane undivided,
9. Six lane divided,
10. Four-lane expressway, and
11. Six-lane expressway.

Second, the user can specify one or more intersections or railroad crossings for a given alternative. Intersection types include signalized, stop-signed, and railroad crossings. Third, any combination and number of segments, intersections, and railroad crossings up to the program limitations may be specified. The package will accommodate up to 10 alternatives made up of 999 segments and 99 intersections.

The user can analyze a broad array of projects, including the following:

1. Constructing a new facility;
2. Widening an old facility;
3. Eliminating existing horizontal curves;
4. Changing vertical grades;
5. Separating vertical grades;
6. Adding lanes at an intersection;
7. Changing traffic control from stop signs to signals and vice versa;
8. Changing signal type, coordination, or timing;

9. Implementing traffic safety countermeasures; and
10. Eliminating railroad crossings.

## Computing Segment User Costs

User costs on highway segments are a function of the type of facility, traffic characteristics, geometric characteristics, and surface quality. Segment user costs are divided into four categories: vehicle operating costs, travel-time costs, discomfort and inconvenience costs and, accident costs.

### Vehicle Operating Costs

Vehicle operating costs include those for fuel, oil, tires, maintenance, and time-dependent vehicle depreciation. Operating costs are often categorized as tangent running costs, grade costs, curvature costs, and speed-change costs. Tangent running costs (in dollars per 1,000 vehicle miles) are those operating costs incurred at the average running speed on a level tangent section of highway. Grade costs (in dollars per 1,000 vehicle miles) are those additional operating costs incurred when a vehicle travels up or down a vertical grade, and curvature costs (also in dollars per 1,000 vehicle miles) are the additional operating costs incurred as a vehicle travels around a curve. Speed-change costs (in dollars per 1,000 vehicle miles) are the additional operating cost incurred when a vehicle decelerates to a reduced speed and accelerates back to the running speed.

The computer package includes data files of 1980 operating cost tables (4) for the following vehicles: (a) large, medium, and small automobiles; (b) pickup trucks; (c) two- and three-axle single-unit trucks, and (d) four- and five-axle semitrailers. However, the individual programs do not access every operating cost table. Instead, operating cost tables derived for a composite set of vehicles, including a composite automobile, medium truck, and heavy truck, are used. The user periodically produces his own composite cost tables by entering the desired vehicle mix and cost adjustment factors in a separate file-handling program. Thus, the base 1980 vehicle operating cost tables remain unchanged and composite tables can be changed quickly outside the main program structure. The package also includes another file-handling program for loading in new or revised data files as new data become available.

The following operating cost tables are included in the package:

1. Tangent running costs as a function of speed, grade, and present serviceability index (SI = 4.5, 3.0, 1.5);
2. Speed-change costs as a function of volume-to-capacity ratio (v/c) on the highway segment;
3. Excess operating cost tables as a function of approach and slowdown speed (accessed by the intersection delay programs described in the following); and
4. Curvature costs as a function of speed and degree of curvature.

### Travel-Time Costs

Travel-time cost is the value of the drivers' and passengers' travel time (dollars per 1,000 vehicle-hr) to traverse the length of the highway segment at the running speed. The user enters his own value of time (dollars per hour) for automobiles, medium trucks, and heavy trucks. One way to express value of time per vehicle hour is as a function of the time saved per trip and the vehicle occupancy as outlined in Chapter II of the AASHTO manual (1).

### Discomfort and Inconvenience Costs

Discomfort costs (dollars per vehicle hour) are a function of the degree of congestion measured by the v/c. As the v/c increases, discomfort costs increase.

### Accident Costs

Segment accident costs (dollars per 1,000 vehicle miles) include costs due to fatal, injury, and property-damage accidents on the highway segment. The package includes a set of accident rates and costs for the 11 types of highway facilities. Similar to the operating cost tables, the data file for the accident cost data can be updated periodically.

### Procedure for Computing Segment Costs

Highway segment costs are estimated by carrying out the following steps:

1. Estimate or field measure the volume (vehicles per hour per lane) on the highway segment;
2. Estimate or field measure the average vehicle running speed (mph) on the segment (as an option the computer package will compute operating speed as a function of the v/c ratio and design speed);
3. Find the tangent running cost at the given running speed, grade, and surface condition;
4. Find the added curvature costs as a function of speed and degree of curvature;
5. Find the speed-change costs as a function of speed and v/c;
6. Compute the total segment operating costs;
7. Compute the time to travel the length of segment;
8. Compute the time costs;
9. Compute the discomfort and inconvenience costs;
10. Find the accident rate accident cost per accident;
11. Compute the accident costs on the segment; and
12. Compute the total annual segment costs.

## Computing Intersection and Railroad Crossing Delay Costs

Intersection vehicle delay is a function of the type of intersection geometry and control, traffic volume, vehicle mix, and turning volumes. Railroad crossing delay is a function of train volume, train speed, traffic volume, and vehicle mix.

Vehicle delay is divided into the following three components:

1. Stopped or idling delay (hours per vehicle) is that time delay incurred by vehicles stopped at an intersection,
2. Deceleration delay (hours per vehicle) is the time required for a vehicle to decelerate from the approach speed to a stop, and
3. Acceleration delay (hours per vehicle) is the time required for a vehicle to accelerate from a stop to the approach speed.

Total intersection delay is the sum of the stopped, deceleration, and acceleration delays.

Vehicle delay influences both time costs and operating costs as a vehicle enters and leaves an intersection. Time and operating costs will increase as vehicle delay increases and decrease as delay decreases. The vehicle delay costs are divided into the following categories:

1. Stopped or idling delay time cost (dollars per vehicle hour) is the value of time due to the added delay at an intersection,
2. Stopping delay cost (dollars per hour) is the added time cost due to the added delay of decelerating to a stop and accelerating from the stop to approach speed,
3. Idling operating cost (dollars per 1,000 vehicle-hr) is the added vehicle operating cost due to vehicle idling while stopped at the intersection, and
4. Stopping operating cost (dollars per 1,000 stops) is the added vehicle operating cost due to decelerating to a stop and accelerating from the stop to approach speed.

The general steps to compute the delay for each intersection approach follow:

1. Estimate approach volume (vehicles per hour),
2. Compute the average stopped delay per vehicle,
3. Compute stopping delay per vehicle,
4. Compute the number of vehicles stopping,
5. Compute the added time costs due to the stopped delay and accelerating and decelerating,
6. Compute vehicle operating costs due to stopped delay and accelerating and decelerating,
7. Compute total delay time and operating delay costs, and
8. Compute total annual intersection delay costs.

The Highway Economic Analysis computer package computes intersection delay costs for three different types of intersections: signalized, stop-signed (two- or four-way), and railroad crossings. The primary difference in the intersection programs is in the computational algorithms for computing vehicle delay, which are based on available methods (2,3,5). The user's manual for the package includes the computational methods for both the intersection delay and accident costs discussed in the following (6).

## Computing Intersection Accident Costs

Intersection accident costs are a function of the number and type of accidents at the intersection. Each accident is classified as a fatal, injury, or property-damage accident and the total number of accidents is converted to equivalent property-damage only (EPDO) accidents. The EPDO is then multiplied by the average cost of property-damage accidents to find the total intersection accident costs (5).

In the case where a safety countermeasure such as intersection channelization is implemented, the number of accidents under the improved condition is estimated by the package and a new EPDO is computed. To estimate the number of accidents under the improved condition, the program first accesses a data file of accident reduction factors for each type of correctable accident and countermeasure. The intersection types included in the package are as follows:

1. Major/major, signalized;
2. Major/collector, signalized;
3. Collector/collector, signalized;
4. Major/major, stop-signed;
5. Major/collector, stop-signed;
6. Major/collector, stop-signed;
7. Local/local, stop-signed;
8. Local/local, stop-signed;
9. Local/local, yield-signed;
10. Local/local, no signal.

The following safety countermeasures are included:

1. Markings
   a. Arrows and ONLY's
   b. Stop bars
2. Signs
   a. Advisory
   b. Warning
   c. Regulatory
   d. Sight hazard
   e. Speed limit
3. New signals
   a. Intersection signal
   b. Intersection beacon
   c. Approach beacon
4. Modified signals
   a. 12-in. signal heads
   b. Exclusive right turn
   c. Protected left turn
   d. Remove permissive red
   e. Two-phase to multiphase
   f. Yellow clearance
   g. All red
   h. Progression
5. Geometrics
   a. Intersection widening
   b. Approach widening
   c. Concrete median
   d. Remove median

The accident reduction factors are then multiplied by the existing correctable accidents to compute the number of accidents under the improved condition, which is used to compute a new EPDO, and the new accident costs are computed by multiplying the new EPDO by the average cost of property-damage accidents.

The general steps to compute intersection accidents are summarized as follows:

1. Find the existing fatal, injury, and property-damage accidents for the year under consideration (the user also has the option to use the internal intersection accident default values);
2. Find the number of rear-end, right-angle, left-turn, right-turn, and fixed-object accidents for the year under consideration;
3. Estimate the average daily traffic;
4. Compute the EPDO;
5. If no safety improvement is made, compute the annual accident costs under existing conditions;
6. If a safety improvement is made, estimate the number of accidents reduced as a result of the improvement;
7. If accidents are reduced, compute the new EPDO; and
8. Compute the estimated annual accident costs under the safety improvement.

## Performing the Economic Analysis

This computer package carries out a present-worth economic analysis on each project alternative. First the package computes the total segment and intersection user costs for each alternative for a first and last analysis year. On the basis that user costs grow uniformly between the first and the last analysis year and a stated discount rate, the program computes the present worth of the user costs over the analysis period with respect to a given base year. The package also computes the present worth of the build costs for each alternative (input by the user) with respect to the same base year. The net present worth and a benefit-cost ratio are then computed for each alternative with respect to the null alternative.

## PROGRAM DESIGN AND OPERATION

The computer package is written in FORTRAN for the Digital Equipment Corporation's VAX-11/750 minicomputer. Written in version 2.0 of VAX FORTRAN, the package also operates on the VAX-11/780. The following programs make up the main structure of the package: (a) main driving, (b) segment user cost, (c) signalized-intersection delay cost, (d) stop-signed intersection delay cost, (e) railroad crossing delay cost, (f) intersection accident cost, (g) build cost, and (h) output formatting. All the programs and data files for the package take approximately 3,000 blocks of permanent disk storage. Additional permanent storage is required because the package produces several data files as it runs; the amount of storage required varies according to the total number of alternatives and the total number of segments and intersections for each alternative.

Generally, each program produces one file for the input data and one file for the output data, which are organized by indexed "keys" that uniquely identify each stored record. For instance, the keys for the signal data files include the following: project name, alternative name, alternative number, intersection number, approach number, and analysis year (first or second). Input and output data files produced by the package are permanent files that are opened and closed each time a particular program is run. New data are inserted into the appropriate position within a file according to the keys while the old data are maintained. Files are accessed later by using the same keys. When finished with the files, the user may either delete them or rename and retain them in storage by using standard VAX commands.

In the following section a description is given of how the user runs the package, and the inputs and outputs of each program within the package are discussed.

## RUNNING THE PACKAGE

The first menu in the package asks the user to enter a project name and alternative name (up to 10 characters each) and the number of alternatives (up to 10). For instance, the user may have a project entitled Lincoln, an alternative name Test, and two alternative projects. The user also enters the desired discount rate in decimal form to be used in the economic analysis, a base year, a first year, and a last year of the analysis period.

The next menu asks the user to select one of the five user cost categories: segment cost, signalized-intersection delay cost, stop-signed intersection delay cost, railroad crossing delay cost, or intersection accident cost. Upon selection, the program control is transferred to the appropriate user cost program, which is further described in the following. Each time the user completes the data entry for a particular user cost category, the program computes the user costs for that particular segment or intersection and writes them into a file.

Upon termination of the user cost session for a given alternative, program control is transferred to the cost menu. The number of years, calendar years, and costs for engineering, construction, right-of-way, periodic maintenance, traffic control devices, and routine annual maintenance are entered on a series of menus. After the data for the build costs have been entered, the program computes the net present worth and benefit-cost ratio of each alternative.

Step-by-step procedures for running the individual programs and a discussion of the inputs and outputs for each program are covered in the following sections.

### Segment Cost Program

The segment cost program computes highway users' costs for each separate segment of the highway. In order to run the program the user must input the following data for each segment: facility type (11 categories); area type (urban or rural); segment length (miles); capacity (vehicles per hour per lane); peak and off-peak lane volume (vehicles per hour); number of peak and off-peak hours; operating or design speed (miles per hour); percentage of accident reduction on the segment; percentage of vehicle mix; value of time (dollars per vehicle hour) for automobiles, medium trucks, and heavy trucks; percentage of grade; surface quality (1 = poor, 2 = fair, 3 = good); and degree of horizontal curvature.

If the user enters design speed, the segment cost program computes the operating speed as a function of v/c, design speed, and facility type. Otherwise the program uses the operating speed input by the user. Users also have the option of either entering their own figures for capacity or defaulting to the internal capacity tables. On the basis of operating speed, grade, and curvature, the program computes the travel-time costs, tangent running costs, speed-change costs, curvature costs, discomfort and inconvenience costs, and the total segment user costs.

The program output includes the following items:

1. Echo of the program input of facility type, area type, capacity, volume, speed data, accident reduction, vehicle mix, and value of time, grade, surface quality, and curvature;
2. Output of the yearly costs for travel time, tangent running, discomfort and inconvenience, speed change, curvature, and total segment for each highway segment.

### Signalized-Intersection Delay Cost Program

The signalized-intersection delay cost program computes the delay costs for signalized intersections under pretimed and full or semiactuated control with or without coordination. In order to run the program the user enters the following data for each approach of the intersection: signal cycle time (seconds); through, left, and right green times (seconds); type of left- and right-turning movements (prohibited, permissive, protective, or protective/permissive); traffic signal control type; signal coordination type based on platoon arrival patterns; number of through, right, and left lanes; peak-hour factor; approach speed (miles per hour); number of peak and off-peak hours; peak and off-peak volume (vehicles per hour) for each lane in the approach; vehicle mix; and value of time (dollars per vehicle hour) for automobiles, medium trucks, and heavy trucks. The user also has the option of entering his own average delay (seconds per vehicle) and number of vehicles stopping per lane rather than computing delay and vehicles stopping.

The signalized-intersection delay cost program first computes the average vehicle delay (seconds per vehicle) on a lane-by-lane basis for each approach, beginning with the right lane and moving toward the left lane. The program then computes vehicle idling time and operating costs, vehicle accelerating and decelerating time and operating costs, and the total signalized-intersection delay costs.

The program outputs include the following items:

1. Echo of the program inputs, including volume data, geometry data, speed data, signal-phasing data, left-turn type, control type, and arrival pattern type; and
2. Average vehicle delay (seconds per vehicle) for the intersection, idling delay time and stopping time costs, idling operating cost and stopping operating cost, and total delay cost for each intersection. All costs are in dollars per year.

## Stop-Signed Intersection Delay Cost Program

The stop-signed intersection delay cost program computes the delay costs for both two-way and four-way stop-controlled intersections. The user enters the following data for each approach: number of approach lanes, number of opposing lanes, approach speed (miles per hour), number of peak and off-peak hours, peak and off-peak approach volume (vehicles per hour), peak and off-peak opposing volume (vehicles per hour), vehicle mix, and value of time (dollars per vehicle hour) for automobiles, medium trucks, and heavy trucks. For a two-way stop-controlled intersection and a T-intersection the user enters data only for the approaches that are signed. The user has the option of entering his own average approach delay (seconds per vehicle) rather than computing vehicle delay.

The program first computes the average vehicle delay (seconds per vehicle) on each approach, the vehicle idling time and operating costs, the vehicle time and operating costs due to accelerating and decelerating, and the total stop-signed intersection delay costs.

The outputs of the stop-signed intersection delay cost program include

1. Echo of the program inputs of approach and opposing volumes and geometry for the intersection and
2. Output of the average vehicle delay (seconds per vehicle), idling and stopping time costs, and idling and stopping operating costs for each approach and for the intersection. All costs are in dollars per year.

## Railroad Crossing Delay Cost Program

The railroad crossing delay cost program computes the vehicle delay costs due to train blockage at railroad grade crossings. The user enters the following data: number of trains per day, number of cars per train, average car length, train speed, vehicle approach speed (miles per hour), vehicle slowdown speed due to the railroad crossing, average daily traffic, vehicle mix, and value of time (dollars per vehicle hour) for automobiles, medium trucks, and heavy trucks. The user can also enter his own average approach delay (seconds per vehicle) and number of daily vehicles stopping instead of computing delay and vehicles stopping.

The railroad crossing delay cost program computes the train blockage (seconds) of the intersection, the average vehicle delay (seconds per vehicle), the vehicle idling and stopping time costs, the vehicle idling and stopping operating costs, and the total yearly railroad crossing delay costs. The program outputs include the following:

1. Echo of the program inputs of vehicle and train volume, vehicle and train speed, and average daily traffic, and
2. Output of average vehicle delay (seconds per vehicle), idling and stopping time costs, idling and stopping operating costs, and the total railroad crossing delay costs in both directions for the approach. All costs are in dollars per year.

## Intersection Accident Cost Program

The intersection accident cost program computes the accident costs of either an unimproved or an improved intersection. To run the program, the user enters the following items: intersection type; average daily traffic; number of fatal, injury, and property-damage accidents; number of right-turn, left-turn, rear-end, right-angle, and fixed-object accidents per year; and number and type of safety countermeasures. The user has several options in running this program. First, if specific accident data are not known, an estimated accident reduction factor can be entered. Second, the program will estimate the accidents for the last analysis year if the user choses not to enter his own accidents in the last year.

The intersection accident cost program first computes the EPDO and then computes the yearly intersection accident cost as a function of the average cost of a property-damage accident.

The output includes

1. Echo of the input data of intersection type; number of fatal, injury, and property-damage accidents; number of right-turn, left-turn, rear-end, right-angle, and fixed-object accidents; average daily traffic; and the number and type of safety countermeasures; and
2. EPDO, accident rate, and accident costs (dollars per year).

**TABLE 1 Sample Input Data**

| | 48th Street | | R Street | |
|---|---|---|---|---|
| Location | NB | SB | EB | WB |
| *Geometry* | | | | |
| Right lane | 0 | 0 | 0 | 0 |
| Through lane | 2 | 2 | 1 | 1 |
| Left lane | 1 | 1 | 1 | 1 |
| *Volume[a] (vph)* | | | | |
| Through lane 1 | 275 | 392 | 112 | 196 |
| Through lane 2 | 275 | 392 | 71 | 30 |
| Left lane | 54 | 180 | - | - |
| Total | 604 | 964 | 183 | 226 |
| *Signal Timing[b] (sec)* | | | | |
| Green | 77 | 91 | 19 | 19 |
| Left-turn green | 7 | 7 | 0 | 0 |
| Right-turn green | 0 | 0 | 0 | 0 |

[a]Peak-hour factor = 0.90.
[b]120-sec cycle, good progression; NB and SB lefts are protective or permissive; EB and WB lefts are permissive.

## Build Costs

When the user has finished entering user cost data for a given alternative, he then enters build cost data for that alternative. After all the build cost data have been entered for an alternative, program control transfers back to the user cost programs to enter input data for the next alternative. The program terminates when the build costs for the last alternative are entered.

The following cost data are entered for each alternative:

1. The number of engineering years and the engineering cost (dollars) for each year,
2. The number of construction years and the construction cost (dollars) for each year,
3. The number of years for which right-of-way will be acquired and the right-of-way cost (dollars) for each year,
4. The number of years for which traffic control devices will be installed and the installation cost (dollars) for each year,
5. The number of years of periodic maintenance and the periodic maintenance costs (dollars) for each year (e.g., resurfacing costs), and
6. The annual routine maintenance costs (dollars per mile).

## Sample Application

The following example illustrates the use of the Highway Economic Analysis computer package to compare two alternative types of traffic control at the intersection of 48th and R Streets in the city of Lincoln, Nebraska. Due to large-vehicle delays experienced at the intersection, the city proposes to replace the existing four-way stop control (Alternative 1) with a fully actuated traffic signal (Alternative 2). The new traffic situation consists of the same basic geometry but with improved channelization and widening.

The existing geometry, existing volume data, and proposed signal timing are given in Table 1. It is assumed that there will be no traffic growth, and the normal (off-peak) and peak traffic are assumed to be equal. The analysis also assumes a vehicle mix of 97 percent automobiles, 2 percent medium trucks, and 1 percent heavy trucks and a value of time of $6, $14, and $16 per vehicle hour for automobiles, medium trucks, and heavy trucks, respectively.

For this analysis, the base year is 1984, the first analysis year is 1984, the last analysis year is 2004, and the discount rate is 10 percent. Construction costs of $250,000 are assumed to be expended in 1984 and $60,000 of the signalization costs is expended in 1984 and the same amount in 1999, on the assumption that the signals will be replaced within 15 years.

Figures 1, 2, and 3 are printouts of the input data for the stop-signed and signalized intersections for both analysis years of 1984 and 2004. The program outputs for the stop-signed and signalized intersections are given in Figures 4 and 5, respectively. (In Figure 1, N > F stands for near lanes or volume, F > N stands for far lanes or volume, L > R stands for opposing lanes or volume from the left, and R > L stands for opposing lanes or volume from the right.)

As indicated in Figure 4, the average intersection vehicle delay under the four-way control (Al-

PROJECT: LINCOLN ALTERNATE NAME: TEST ALTERNATE NUM: 01

STOP SIGNED INTERSECTION INPUT

1984

| | | | | | | | | | NORMAL PERIOD | | | | | | | | | PEAK PERIOD | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | VALUE OR TIME | | | VOLUME | | | | | LANES | | | | VOLUME | | | | | LANES | | | |
| Int | App | App Spd | Stop Type | %MT | %HT | Auto | Mtrk | Htrk | Hrs | Thru N>F | Thru F>N | Opp L>R | Opp R>L | Thru N>F | Thru F>N | Opp L>R | Opp R>L | Hrs | Thru N>F | Thru F>N | Opp L>R | Opp R>L | Thru N>F | Thru F>N | Opp L>R | Opp R>L |
| 01 | 01 | 35. | 4 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 604. | 964. | 183. | 226. | 3 | 3 | 2 | 2 | 2 | 604. | 964. | 183. | 226. | 3 | 3 | 2 | 2 |
| 01 | 02 | 35. | 4 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 964. | 604. | 226. | 183. | 3 | 3 | 2 | 2 | 2 | 964. | 604. | 226. | 183. | 3 | 3 | 2 | 2 |
| 01 | 03 | 35. | 4 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 183. | 226. | 964. | 604. | 2 | 2 | 3 | 3 | 2 | 183. | 226. | 964. | 604. | 2 | 2 | 3 | 3 |
| 01 | 04 | 35. | 4 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 226. | 183. | 604. | 964. | 2 | 2 | 3 | 3 | 2 | 226. | 183. | 604. | 964. | 2 | 2 | 3 | 3 |

PROJECT: LINCOLN ALTERNATE NAME: TEST ALTERNATE NUM: 01

STOP SIGNED INTERSECTION INPUT

.2004

| | | | | | | | | | NORMAL PERIOD | | | | | | | | | PEAK PERIOD | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | VALUE OR TIME | | | VOLUME | | | | | LANES | | | | VOLUME | | | | | LANES | | | |
| Int | App | App Spd | Stop Type | %MT | %HT | Auto | Mtrk | Htrk | Hrs | Thru N>F | Thru F>N | Opp L>R | Opp R>L | Thru N>F | Thru F>N | Opp L>R | Opp R>L | Hrs | Thru N>F | Thru F>N | Opp L>R | Opp R>L | Thru N>F | Thru F>N | Opp L>R | Opp R>L |
| 01 | 01 | 35. | 4 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 604. | 964. | 183. | 226. | 3 | 3 | 2 | 2 | 2 | 604. | 964. | 183. | 226. | 3 | 3 | 2 | 2 |
| 01 | 02 | 35. | 4 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 964. | 604. | 226. | 183. | 3 | 3 | 2 | 2 | 2 | 964. | 604. | 226. | 183. | 3 | 3 | 2 | 2 |
| 01 | 03 | 35. | 4 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 183. | 226. | 964. | 604. | 2 | 2 | 3 | 3 | 2 | 183. | 226. | 964. | 604. | 2 | 2 | 3 | 3 |
| 01 | 04 | 35. | 4 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 226. | 183. | 604. | 964. | 2 | 2 | 3 | 3 | 2 | 226. | 183. | 604. | 964. | 2 | 2 | 3 | 3 |

FIGURE 1 Input for stop-signed intersection, 1984 and 2004.

PROJECT: LINCOLN ALTERNATE NAME: TEST ALTERNATE NUM: 02

SIGNALIZED INTERSECTION INPUT
SIGNAL PHASING DATA
2004

| | | NORMAL PERIOD | | | | | | | | PEAK PERIOD | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Int | App | Cycle | Green | Left Green | Right Green | Left Type | Right Type | Ctrl Type | Arr Type | Cycle | Green | Left Green | Right Green | Left Type | Right Type | Ctrl Type | Arr Type |
| 01 | 01 | 120. | 77. | 7. | 0. | 4 | 2 | 3 | 4 | 120. | 77. | 7. | 0. | 4 | 2 | 3 | 4 |
| 01 | 02 | 120. | 91. | 7. | 0. | 4 | 2 | 3 | 4 | 120. | 91. | 7. | 0. | 4 | 2 | 3 | 4 |
| 01 | 03 | 120. | 19. | 0. | 0. | 2 | 2 | 4 | 4 | 120. | 19. | 0. | 0. | 2 | 2 | 4 | 4 |
| 01 | 04 | 120. | 19. | 0. | 0. | 2 | 2 | 4 | 4 | 120. | 19. | 0. | 0. | 2 | 2 | 4 | 4 |

PROJECT: LINCOLN ALTERNATE NAME: TEST ALTERNATE NUM: 02

SIGNALIZED INTERSECTION INPUT
VOLUME AND LANE INPUT
2004

| | | | | VALUE OF TIME | | | NORMAL PERIOD VOLUME | | | | NORMAL PERIOD LANES | | | PEAK PERIOD VOLUME | | | | PEAK PERIOD LANES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Int | App | %MT | %HT | Auto | Mtrk | Htrk | Hrs | Vol | PHF | Spd | Rt | Th | Lt | Hrs | Vol | PHF | Spd | Rt | Th | Lt |
| 01 | 01 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 604. | 0.90 | 35. | 0 | 2 | 1 | 2 | 604. | 0.90 | 35. | 0 | 2 | 1 |
| 01 | 02 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 964. | 0.90 | 35. | 0 | 2 | 1 | 2 | 964. | 0.90 | 35. | 0 | 2 | 1 |
| 01 | 03 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 183. | 0.90 | 35. | 0 | 1 | 1 | 2 | 183. | 0.90 | 35. | 0 | 1 | 1 |
| 01 | 04 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 226. | 0.90 | 35. | 0 | 1 | 1 | 2 | 226. | 0.90 | 35. | 0 | 1 | 1 |

FIGURE 2 Input for signalized intersection, 2004.

PROJECT: LINCOLN ALTERNATE NAME: TEST ALTERNATE NUM: 02

SIGNALIZED INTERSECTION INPUT
SIGNAL PHASING DATA

1984

| | | NORMAL PERIOD | | | | | | | | PEAK PERIOD | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Int | App | Cycle | Green | Left Green | Right Green | Left Type | Right Type | Ctrl Type | Arr Type | Cycle | Green | Left Green | Right Green | Left Type | Right Type | Ctrl Type | Arr Type |
| 01 | 01 | 120. | 77. | 7. | 0. | 4 | 2 | 3 | 4 | 120. | 77. | 7. | 0. | 4 | 2 | 3 | 4 |
| 01 | 02 | 120. | 91. | 7. | 0. | 4 | 2 | 3 | 4 | 120. | 91. | 7. | 0. | 4 | 2 | 3 | 4 |
| 01 | 03 | 120. | 19. | 0. | 0. | 2 | 2 | 4 | 4 | 120. | 19. | 0. | 0. | 2 | 2 | 4 | 4 |
| 01 | 04 | 120. | 19. | 0. | 0. | 2 | 2 | 4 | 4 | 120. | 19. | 0. | 0. | 2 | 2 | 4 | 4 |

PROJECT: LINCOLN ALTERNATE NAME: TEST ALTERNATE NUM: 02

SIGNALIZED INTERSECTION INPUT
VOLUME AND LANE INPUT
1984

| | | | | VALUE OF TIME | | | NORMAL PERIOD VOLUME | | | | NORMAL PERIOD LANES | | | PEAK PERIOD VOLUME | | | | PEAK PERIOD LANES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Int | App | %MT | %HT | Auto | Mtrk | Htrk | Hrs | Vol | PHF | Spd | Rt | Th | Lt | Hrs | Vol | PHF | Spd | Rt | Th | Lt |
| 01 | 01 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 604. | 0.90 | 35. | 0 | 2 | 1 | 2 | 604. | 0.90 | 35. | 0 | 2 | 1 |
| 01 | 02 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 964. | 0.90 | 35. | 0 | 2 | 1 | 2 | 964. | 0.90 | 35. | 0 | 2 | 1 |
| 01 | 03 | 0.02 | 0.01 | 6.0 | 14.0 | 16.0 | 22 | 183. | 0.90 | 35. | 0 | 1 | 1 | 2 | 183. | 0.90 | 35. | 0 | 1 | 1 |

FIGURE 3 Input for signalized intersection, 1984.

PROJECT: LINCOLN ALTERNATE NAME: TEST ALTERNATE NUM: 01

STOP SIGNED INTERSECTION OUTPUT

| | 1984 | | | | | | | 2004 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | TIME COSTS | | OPER. COSTS | | | | | TIME COSTS | | OPER.COSTS | | |
| Int | Int Volume | Ave Delay | Idle | Stop | Idle | Stop | Total | Int Volume | Ave Delay | Idle | Stop | Idle | Stop | Total |
| 01 | 47448. | 57.0 | 1718047. | 605848. | 184309. | 344322. | 2852525. | 47448. | 57.0 | 1718047. | 605848. | 184309. | 344322. | 2852525. |

PROJECT: LINCOLN ALTERNATE NAME: TEST ALTERNATE NUM: 01

TRANSPORTATION COST/BENEFIT ANALYSIS
SUMMARY REPORT

BASE YEAR: 1984 DISCOUNT RATE: 0.10
FIRST YEAR: 1984
LAST YEAR: 2004

HIGHWAY USER COSTS

| SEGMENT COSTS | FIRST YEAR | LAST YEAR |
|---|---|---|
| ACCIDENT COSTS | 0. | 0. |
| TIME COSTS | 0. | 0. |
| D&I COSTS | 0. | 0. |
| RUNNING COSTS | 0. | 0. |
| SPD CHN COSTS | 0. | 0. |
| CURV COSTS | 0. | 0. |
| TOTAL SEG COSTS | 0. | 0. |
| INTERSECTIONS | | |
| SIGNALIZED | 0. | 0. |
| STOP SIGNED | 2852525. | 2852525. |
| RAIL CROSSINGS | 0. | 0. |
| ACCIDENT COST | 0. | 0. |
| TOTAL INT COST | 2852525. | 2852525. |
| TOTAL USER COST | 2852525. | 2852525. |

HIGHWAY BUILD COSTS

| | PRESENT WORTH |
|---|---|
| PRELIM. ENGINEERING | 0. |
| CONSTUCTION | 0. |
| PERIODIC MAINTENANCE | 0. |
| RIGHT-OF-WAY | 0. |
| TRAFFIC CONTROL | 0. |
| ROUTINE MAINTENANCE | 0. |
| TOTAL COST | 0. |

FIGURE 4 Output for stop-signed intersection.

PROJECT: LINCOLN ALTERNATE NAME: TEST ALTERNATE NUM: 02

SIGNALIZED INTERSECTION OUTPUT

| | 1984 | | | | | | | 2004 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | TIME COSTS | | OPER. COSTS | | | | | TIME COSTS | | OPER.COSTS | | |
| Int | Int Volume | Ave Delay | Idle | Stop | Idle | Stop | Total | Int Volume | Ave Delay | Idle | Stop | Idle | Stop | Total |
| 01 | 47448. | 15.2 | 337660. | 273049. | 37920. | 155182. | 803810. | 47448. | 15.2 | 337660. | 273049. | 37920. | 155182. | 803810. |

PROJECT: LINCOLN ALTERNATE NAME: TEST ALTERNATE NUM: 02

TRANSPORTATION COST/BENEFIT ANALYSIS
SUMMARY REPORT

BASE YEAR: 1984 DISCOUNT RATE: 0.10
FIRST YEAR: 1984
LAST YEAR: 2004

HIGHWAY USER COSTS

| SEGMENT COSTS | FIRST YEAR | LAST YEAR |
|---|---|---|
| ACCIDENT COSTS | 0. | 0. |
| TIME COSTS | 0. | 0. |
| D&I COSTS | 0. | 0. |
| RUNNING COSTS | 0. | 0. |
| SPD CHN COSTS | 0. | 0. |
| CURV COSTS | 0. | 0. |
| TOTAL SEG COSTS | 0. | 0. |
| INTERSECTIONS | | |
| SIGNALIZED | 803810. | 803810. |
| STOP SIGNED | 0. | 0. |
| RAIL CROSSINGS | 0. | 0. |
| ACCIDENT COST | 0. | 0. |
| TOTAL INT COST | 803810. | 803810. |
| TOTAL USER COST | 803810. | 803810. |

HIGHWAY BUILD COSTS

| | PRESENT WORTH |
|---|---|
| PRELIM. ENGINEERING | 0. |
| CONSTUCTION | 250000. |
| PERIODIC MAINTENANCE | 0. |
| RIGHT-OF-WAY | 0. |
| TRAFFIC CONTROL | 74364. |
| ROUTINE MAINTENANCE | 0. |
| TOTAL COST | 324364. |

FIGURE 5 Output for signalized intersection.

ternative 1) is approximately 57.0 sec and the total annual delay costs for the intersection are $2,852,525. Figure 4 also shows a summary report for Alternative 1. Because the alternative does not include any segments, all segment costs listed in the summary report are equal to zero, whereas annual intersection delay costs are equal to $2,852,525. Build costs for this alternative, the "null alternative", are all equal to zero.

Figure 5 shows that the signalization of the intersection would greatly reduce the average intersection vehicle delay from 57.0 to 15.2 sec and thereby reduce the annual intersection delay costs to $803,810. The present worth of the build costs for the signal alternative includes a $250,000 construction cost and a $74,364 traffic control cost.

The economic comparison of the two alternatives is given as follows:

| Alternative | Net Present Worth ($) | Benefit-Cost Ratio | Present-Worth Costs ($) User | Build |
|---|---|---|---|---|
| 1 | 0. | 1.00 | 24,664,778. | 0. |
| 2 | 17,390,150. | 54.61 | 6,950,265. | 324,364. |

It may be seen that the present worth of the user costs for Alternative 1 is approximately $24.7 million compared with a present worth of approximately $7.0 million for Alternative 2. Thus, the benefit-cost ratio for Alternative 2 compared with that for Alternative 1 is approximately 55, reflecting the high savings in user travel time due to reduced vehicle delay and the relatively low implementation cost of Alternative 2.

## SUMMARY

The foregoing example illustrates only one application among scores of potential applications of the Highway Economic Analysis computer package. This package is a highly versatile tool that permits the user to evaluate urban as well as rural highway projects ranging from traffic control measures and intersection widening to surface rehabilitation and major new construction. Alternatives may include single highway segments or isolated intersections or many segments and many intersections with different types of control. In addition, the level of analysis may vary from planning applications to detailed traffic control or final design applications. Moreover, the user is afforded great flexibility in changing all the internal tables as needed. For this, special file-handling programs permit the user to update existing operating cost tables within the package by changing the specific values, the vehicle mix, or the cost update factors. Other tables such as capacities and intersection accident costs can also be easily changed by the user to reflect local needs.

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