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FEASIBILITY OF EXCLUSIVE FACILITIES FOR CARS AND TRUCKS

Final Report

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This report is intended for use in the evaluation of exclusive highway facilities for passenger and freight vehicles. It does not constitute a statement of policy recommendations.

16. Abstract

This report describes an analysis format to determine the economic feasibility of separating light vehicles from heavy vehicles on a given section of controlled-access highway by designating existing lanes and/or constructing new lanes to be used exclusively by light or heavy vehicles. Based on user inputs describing characteristics of a highway, a computer program calculates the net present values and benefit/cost ratios of alternative exclusive vehicle facility designs. The analysis program can be run in either of two modes called Level 1 and Level 2. Level 1 provides a sketch evaluation of many alternatives for a given highway section with few user inputs, and Level 2 is used to conduct more thorough evaluations of particular alternatives.

Based on test analyses, exclusive vehicle facilities appear to be most warranted for congested highways where truck volumes exceed 30% of the vehicle mix. Assuming moderate traffic growth over an analysis period of at least 20 years, adding exclusive lanes for light vehicles via highway widening can have a greater net present value than designating existing lanes for light vehicles or adding mixed-vehicle lanes. However, designating one or two existing lanes of a highway with three or more lanes in each direction exclusively for light vehicles can be a very beneficial low-cost strategy.

The analysis format is intended for site specific analyses and not for regional or national network analyses. The scope of the study did not include developing nationwide estimates of exclusive vehicle facility lane miles that might be justified in the decades ahead.

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EXECUTIVE SUMMARY

This study developed an analysis format to determine the economic feasibility of separating light vehicles from heavy vehicles on a given section of controlled-access highway by designating existing lanes and/or constructing new lanes to be used exclusively by light or heavy vehicles. Based on user inputs describing a full range of highway characteristics, a computer program calculates the net present values and benefit/cost ratios of alternative exclusive vehicle facility designs. The analysis program can be run in either of two modes called Level 1 and Level 2. Level 1 provides a sketch evaluation of many alternatives for a given highway section with few user inputs, and Level 2 is used to conduct more thorough evaluations of particular cases with more detailed inputs.

The analysis format accounts for the following potential benefits or cost savings for both person and freight travel:

- travel time savings due to faster traffic flow.
- vehicle operating cost savings due to improved traffic flow.
- injury and property damage savings, due to fewer and less severe accidents, by separating light and heavy vehicles.
- travel delay savings due to fewer accidents causing blockages.

The analysis format also accounts for the following project costs:

- initial construction costs.
- initial right-of-way acquisition and demolition costs.
- periodic pavement resurfacing costs, which may be less frequent and less costly for light-vehicle lanes.

The analysis format is applicable to the evaluation of exclusive vehicle facilities on limited-access highways in urban or rural areas. Exclusive vehicle facilities are most warranted on major urban freeways, since the benefits of vehicle separation increase with overall traffic volumes and truck volume percentages in the vehicle mix. Exclusive vehicle facilities can also be economically feasible for certain rural highway sections with high accident rates due to truck/car interactions, since construction costs per lane mile are lower for rural at-grade highway sections with less developed right-of-ways than for elevated sections in densely built areas.

Although 4R work includes the four options of reconstruction, rehabilitation, resurfacing, and restoration, the analysis format only accounts for costs of periodic resurfacings over the analysis period. The years in which resurfacings are performed depend on cumulative axle loadings, the user's specification of the pavement deterioration function, and the pavement serviceability index at which resurfacings are specified to occur. Three parameters of the pavement deterioration function can be specified by the user that determine the effects of road age and use on pavement condition.

The three possible lane use policies allowed within the analysis format are mixed-vehicle (MV), light-vehicle (LV), and heavy-vehicle (HV) lanes. Mixed-vehicle lanes can be used by all vehicles, subject to state and federal truck size and weight (TSW) limits. Light-vehicle lanes can only be used by motorcycles, automobiles, pickup trucks, light vans, buses, and trucks below 10,000 pounds gross vehicle weight. Although buses are similar in weight and operating characteristics to single-unit vehicles, buses are permitted to use light-vehicle lanes for safety considerations of the bus occupants. All other vehicles are restricted from using the light-vehicle lanes, and must use the mixed-vehicle or heavy-vehicle lanes. These heavy vehicles include all single unit trucks above 10,000 pounds, and all combination trucks.

The analysis format is designed to evaluate any of the following five cases:

Five Exclusive Vehicle Facility Alternatives

- Case 0: Do nothing.
- Case 1: Designate existing lanes for mixed, light and heavy vehicles.
- Case 2: Add mixed-vehicle lanes (no special lane use restrictions).
- Case 3: Add nonbarrier separated lanes and designate new and existing lanes for mixed, light and heavy vehicles.
- Case 4: Add barrier-separated lanes and designate new and existing lanes for mixed, light and heavy vehicles.

The purpose of evaluating Case 0 is to generate base-level estimates of costs and benefits, given that no action is taken, to which other alternatives are compared. The analysis of Case 1 is not warranted for sites where the number of lanes in each direction is less than three, but it may be an attractive alternative for sites with heavy truck traffic and 4 or 5 existing lanes in each direction. Cases 2, 3 and 4 are the alternatives in which lanes are added to an existing facility. Case 2 is conventional highway widening with no lane use restrictions. Cases 3 and 4 both involve highway widening, but they are distinguished by whether the lanes carrying light and heavy vehicles are barrier separated. The combination of mixed-vehicle lanes and exclusive heavy-vehicle lanes (i.e., truck/car lanes and truck-only lanes) is never considered as a practical alternative.

Two assumptions are made with regard to pavement design and resurfacing costs for Cases 3 and 4. First, both light-vehicle lanes and heavy-vehicle lanes are assumed to be built to the same design standards as mixed-vehicle lanes, since it may be necessary to use exclusive lanes for mixed-vehicle traffic at a later date during periods of reconstruction or because of a policy change. Second, if the two sets of lanes are not barrier separated, then road work that alters the road surface height, such as a resurfacing, will have to be done to all lanes together. Hence, savings in resurfacing costs gained by less frequent overlays to barrier-separated light-vehicle lanes will be more than offset by the additional cost of building special ramp and interchange facilities for exclusive lanes.

The economic evaluation approach used in the analysis format is to estimate and compare the net present values (in 1985 dollars) and benefit/cost ratios of alternative facility designs. Cost data obtained for other years are adjusted to 1985 dollars by applying the Consumer Price Index. The analysis format does not address any user charge or cost allocation issues. The analysis format is also not applicable to toll roads, since fee schedule adjustments, special financing arrangements, and toll booth alteration costs are not considered. A major cost consideration in the analysis format is that barrier separation increases the cost of lane and interchange construction for an exclusive vehicle facility by roughly 40%.

The analysis format cannot be used to evaluate the cost effectiveness of high-occupancy vehicle lanes, since passenger vehicles are not differentiated on the basis of occupancy. The analysis format can be used to evaluate reversible lane options by adjusting the inputs and outputs of the program to recognize that the reversible lanes serve only one direction of traffic for one-half of the day, including one peak-period. Other recurrent traffic conditions, such as weekend recreational travel, can also be evaluated by aggregating the results of several analyses representing different days of the year with different traffic volumes and vehicle mixes.

The analysis format is intended for site specific analyses and not for regional or national network analyses. However, results that apply to generic site characterizations can be extrapolated to national totals based on miles of similar highway types and use levels across the country. The scope of this study did not include developing nationwide estimates of exclusive vehicle facility lane miles that might be justified in the decades ahead. Data needed on urban interstates in each of the next several decades in order to make those estimates would include (1) forecasts of traffic volumes, (2) estimates of construction costs, (3) and predictions of accident rates and severities.

As stated earlier, the analysis format was designed to be run in either of two modes called Level 1 and Level 2. Level 1 is used to obtain a sketch evaluation of many alternatives for a given highway section with few user inputs. Level 2 is used to conduct a more thorough evaluation of each case with more detailed inputs. The calculations of costs and benefits are essentially performed by the same program at both levels. However, the Level 1 analysis assumes default values for most all detailed inputs, and only requests the user to provide a quick "sketch" of the highway section being analyzed. The Level 1 program then calculates the net costs and benefits of each of the five facility cases listed above.

The results of Level 1 provide the initial guidance as to which exclusive vehicle facilities are most likely to warrant additional examination with Level 2. This quick analysis of the base case and four other exclusive vehicle facility alternatives yields "first cut" estimates of net benefits, net costs, net present value, and the benefit/cost ratio for each of them so that the analyst can determine which cases to evaluate in greater detail with Level 2. For example, if current and future hourly traffic volumes are not severe, and the percentage of heavy vehicles is about average, then many types of exclusive vehicle facilities may be very uneconomical. If future traffic is expected to increase considerably, and the percentage of heavy vehicles is above average, then several types of separated and unseparated facility alternatives may warrant closer examination.

After completing the sketch assessment of several exclusive vehicle facility alternatives with Level 1, the user must input more detailed data to the Level 2 analysis program in order to evaluate the economic feasibility of any single alternative in greater detail. Cases suggested to be unfavorable by the sketch analysis program can still be evaluated with the Level 2 program, although the user may choose to disregard them. A spreadsheet user interface to the detailed analysis program allows inputs to 57 questions, of which roughly 50 questions have default values that the user can override. Once the inputs to this spreadsheet have been entered for the base case and the spreadsheet has been saved, then very few alterations are required to analyze each alternative case.

Based on test analyses, exclusive vehicle facilities appear to be most warranted for congested highways where truck volumes exceed 30% of the vehicle mix. Assuming moderate traffic growth over an analysis period of at least 20 years, adding exclusive lanes for light vehicles via highway widening can have a greater net present value than designating existing lanes for light vehicles or adding mixed-vehicle lanes. However, designating one or two existing lanes of a highway with three or more lanes in each direction exclusively for light vehicles can be a very beneficial low-cost strategy.

Estimates of costs and benefits from the analysis format should only be viewed as midpoints within very broad ranges. Relatively small differences between alternative cases of less than 5% may not be statistically significant. The analysis format could be improved by imbedding models for freeway simulation, route assignment, and elastic demand within its framework. However, this expansion of the analysis program would require much more extensive data preparation on the part of the user. As currently designed, the analysis format can be used to generate quick-response evaluations of many alternative facilities within a few brief sessions.

Table of Contents

List of Figures

List of Tables

INTRODUCTION

The objective of this study is to develop and apply an analysis format to determine the economic feasibility of separating light vehicles from heavy vehicles on a given section of controlled-access highway by designating existing lanes and/or constructing new lanes to be used exclusively by light or heavy vehicles. Based on user inputs to the analysis format, a computer program calculates the net present values and benefit/cost ratios of alternative exclusive vehicle facilities. The analysis program can be run in either of two modes called Level 1 and Level 2. Level 1 is used to obtain a sketch evaluation of many alternatives for a given highway section with few user inputs. Level 2 is used to conduct a more thorough evaluation of a particular case with more detailed inputs.

The analysis format is designed to evaluate exclusive vehicle facility alternatives for high-volume, limited-access highways in urban or rural areas. Exclusive vehicle facilities are expected to be most warranted in major metropolitan areas, since the benefits of vehicle separation increase with overall traffic volumes and truck volume percentages in the vehicle mix. However, since construction costs per lane mile are lower for rural at-grade highway sections with less developed right-of-ways than for elevated sections in densely built urban areas, exclusive vehicle facilities might also be economically feasible for certain rural highway sections with high accident rates due to truck/car interactions.

The analysis format is not applicable to toll roads, since fee schedule adjustments, special financing arrangements, and toll booth alteration costs are not considered. The analysis format does not address any user charge or cost allocation issues. The analysis format cannot be used in its present form to evaluate the cost effectiveness of high-occupancy vehicle lanes, since passenger vehicles are not differentiated on the basis of occupancy. The analysis format uses a single average occupancy for passenger vehicles in making value-of-time calculations. The analysis format can be used to evaluate reversible lane options by adjusting the inputs and outputs of the program to recognize that the reversible lanes serve only one direction of traffic for one-half of each day, including one peak-period. Other recurrent traffic conditions, such as weekend recreational travel, can also be included by aggregating the results of several analyses for days of the year with different traffic volumes and vehicle mixes.

The analysis format is intended for site specific analyses and not for regional or national network analyses. However, results that apply to generic site characterizations might be extrapolated to national totals based on miles of similar highway types and use levels across the country. The scope of the study does not include developing nationwide estimates of exclusive vehicle facility lane miles that might be justified in the decades ahead. Data needed on urban interstates in each of the next several decades in order to make those estimates would include (1) forecasts of traffic volumes, (2) estimates of construction costs, (3) and predictions of accident rates and severities.

The analysis format accounts for the following potential benefits or cost savings for both person and freight travel:

- travel time savings due to faster traffic flow.
- vehicle operating cost savings due to improved traffic flow.
- injury and property damage savings, due to fewer and less severe accidents, by separating light and heavy vehicles.
- travel delay savings due to fewer accidents causing blockages.

The analysis format also accounts for the following project costs:

- initial construction costs.
- initial right-of-way acquisition and demolition costs.
- periodic pavement resurfacing costs, which may be less frequent and less costly for light-vehicle lanes.

Highway 4R work includes the four options of reconstruction, rehabilitation, resurfacing, and restoration. However, the 4R work costs considered in this analysis format are limited to periodic resurfacings over the analysis period. The years in which resurfacings are performed depend on cumulative axle loadings, the user's specification of the pavement deterioration function, and the pavement serviceability index at which resurfacings are specified to occur. Three parameters of the pavement deterioration function can be specified by the user that determine the degree to which pavement condition depends on road age and use. A more complete explanation of the road resurfacing cost calculations is provided later.

The economic evaluation approach used in the analysis format is to estimate and compare the net present values and benefit/cost ratios of alternative facility designs as generally prescribed for project investment analyses by several engineering economic textbooks such as Au and Au (1983). Many aspects of the cost and benefit calculations performed by the analysis program are described in the manual on benefit/cost analyses published by the Association of State Highway and Transportation Officials (also referred to as the AASHTO Red Book) (AASHTO, 1977). All costs and benefits are calculated in terms of 1985 dollars, and all future amounts are discounted to present values. Cost data obtained for other years are adjusted to 1985 dollars by applying the Consumer Price Index (CPI) or more specific construction costs indices.

The three possible lane use policies allowed within the analysis format are mixed-vehicle (MV), light-vehicle (LV), and heavy-vehicle (HV) lanes. Mixed-vehicle lanes can be used by all vehicles, subject to state and federal truck size and weight (TSW) limits. Light-vehicle lanes can also be referred to as "car-only" lanes, and heavy-vehicle lanes can also be referred to as "truck-only" lanes. Light-vehicle lanes can only be used by motorcycles, automobiles, pickup trucks, light vans, buses, and trucks below 10,000 pounds gross vehicle weight (GVW). GVW is the fully-loaded operating weight of the vehicle. All other vehicles are restricted from using the light-vehicle lanes, and must use the mixed-vehicle or heavy-vehicle lanes. These heavy vehicles include all single unit trucks above 10,000 pounds, and all combination trucks as listed below.

Vehicle Classes:

Vehicles allowed to use light-vehicle lanes:
= automobiles, pick-up trucks, small vans, motorcycles, and buses (school, transit, and intercity).

Vehicles prohibited from using light-vehicle lanes:

SU2	= 2 axle single-unit 6+ tire truck.
SU3	= 3+ axle single-unit truck.
CT4	= 2 axle truck & 1-3 axle trailer.
CT5	= 3 axle truck & 1-2 axle trailer.
CT6	= 3 axle truck & 3 axle trailer.
CS3	= 2 axle tractor & 1 axle semi-trailer.
CS4	= 2 axle tractor & 2 axle trailer.
CS5	= 3 axle tractor & 1-2 axle trailer.
CS6	= 3 axle tractor & 3 axle trailer.
DS5	= 2 axle tractor & 3 or 4 axle double-trailer.
DS7	= 3 axle tractor & 3 or 4 axle double-trailer.
DS9	= 3 axle tractor & 5+ axle double-trailer.
TRI	= 3 axle tractor & 5+ axle triple-trailer; several axle combinations possible.

For informational purposes, the above listed truck classes are traditionally grouped into the following registered GVW classes, although GVW increments of 5000 lbs. may become more standard.

Truck Registered Weight Classes:

10-16	= between 10,000 and 15,999 lbs.
16-26	= between 16,000 and 25,999 lbs.
26-33	= between 26,000 and 32,999 lbs.
33-55	= between 33,000 and 54,999 lbs.
55-80	= between 55,000 and 79,999 lbs.
> 80	= greater than 80,000 lbs.

Although buses are similar in weight and operating characteristics to single-unit vehicles, buses are permitted to use light-vehicle lanes for safety considerations of the bus occupants. Other than adjusting the value of time for light vehicles to correspond with average occupancy, the analysis format does not currently account in any manner for the percentage of buses in the vehicle mix.

The analysis program converts the hourly traffic volume of each vehicle type into "passenger car equivalents" (PCEs) according to the FHWA Report RD-81/156 (Sequin et al., 1982) and the *1985 Highway Capacity Manual* (Transportation Research Board, 1985). In order to use the PCE values from those reports in calculations of practical lane capacities as explained later in more detail, the heavy vehicle classes listed above are grouped into two broader categories (single-unit and combination vehicles). The analyst is only required to specify the average percentages of single-unit vehicles (SU2 and SU3 vehicle classes) and combination vehicles on the highway section being analyzed. Calculations of lane capacity made by the analysis program include adjustments for the passenger car equivalents of those two heavy vehicle categories.

The analysis format is designed to evaluate any of the following five cases:

Five Exclusive Vehicle Facility Alternatives

- Case 0: Do nothing.
- Case 1: Designate existing lanes for mixed, light and heavy vehicles.
- Case 2: Add mixed-vehicle lanes (no special lane use restrictions).

- Case 3: Add nonbarrier separated lanes and designate new and existing lanes for mixed, light and heavy vehicles.
- Case 4: Add barrier-separated lanes and designate new and existing lanes for mixed, light and heavy vehicles.

The purpose of evaluating Case 0 with the analysis format is to generate base-level estimates of costs and benefits, given that no action is taken, to which other alternatives are compared. These base-level estimates of costs and benefits also indicate whether the input values describing a particular site are producing reasonable results in terms of traffic speeds, travel times, and accident costs. Since the input values prepared and entered for Case 0 are also needed for the other cases, the user interface spreadsheet saved with these base case values can act as a template with which to specify the other alternatives.

The analysis of Case 1 may not be warranted for sites where the number of lanes in each direction is three or less, but it may be an attractive alternative for sites with heavy truck traffic and 4 or 5 existing lanes in each direction. Hence, the user must decide whether to study Case 1 further. The Dan Ryan Expressway in Chicago is one example of Case 1 where heavy vehicles were restricted from using the left-most lane of three lanes in each direction without adding any new lanes or barriers.

Case 2 is the first alternative in which lanes are added to an existing facility. Case 2 is conventional highway widening with no lane use restrictions. Case 2 enables the user to generate baseline estimates of costs and benefits for a particular site given that a more typical capital improvement is made. Again, many of the inputs required for Case 2 will also be needed for Cases 3 and 4. Cases 3 and 4 both involve highway widening, but they are distinguished by whether the lanes carrying light and heavy vehicles are barrier separated. Barrier separation adds greatly to the capital cost of lane and interchange construction, as will be evident in the costs described later.

The New Jersey Turnpike for roughly 40 miles southwest of New York City is an example of Case 4 where barrier-separated mixed-vehicle lanes were added and some of the existing lanes were restricted to light use. Several high-occupancy vehicle lanes have been or are being constructed that provide examples of vehicle separation strategies with and without barriers. Recent construction of an HOV transitway in the median of US-59 southwest of Houston demonstrated the complexity of interchange construction when barrier-separated exclusive vehicle lanes are added to a highway.

Four variations of Cases 3 and 4 that the analyst might consider in varying construction and resurfacing costs are:

1. Add mixed-vehicle lanes and designate original lanes for light vehicles.
2. Add heavy-vehicle lanes and designate original lanes for light vehicles.
3. Add light-vehicle lanes and designate original lanes for mixed vehicles.
4. Add light-vehicle lanes and designate original lanes for heavy vehicles.

Note that the combination of mixed-vehicle lanes and exclusive heavy-vehicle lanes (i.e., truck/car lanes and truck-only lanes) is never considered as a practical alternative.

With certain assumptions, the four variations of Cases 3 and 4 just listed will have very similar construction and resurfacing costs per lane mile. First, it is assumed that both light-vehicle lanes and heavy-vehicle lanes will be built to the same design standards as mixed-vehicle lanes, since it may be necessary to use the exclusive lanes for mixed-vehicle traffic at a later date during periods of reconstruction or because of a policy change. Second, if the two sets of lanes are not barrier separated, then a slower deterioration rate for one set of lanes may not be economically beneficial, since any major road work that alters the road surface height, such as a resurfacing, will have to be done to all lanes together. Note, however, that any savings in resurfacing costs gained by less frequent overlays to barrier-separated light-vehicle lanes may be more than offset by the additional cost of building special ramp and interchange facilities for the separate traffic streams.

THE SKETCH ANALYSIS FORMAT - LEVEL 1

As stated earlier, the analysis format was designed to be run in either of two modes called Level 1 and Level 2. Level 1 is used to obtain a sketch evaluation of many alternatives for a given highway section with few user inputs. Level 2 is used to conduct a more thorough evaluation of each case with more detailed inputs. The calculations of costs and benefits are essentially performed by the same program at both levels. However, the Level 1 analysis assumes default values for most all detailed inputs, and only requests the user to provide a quick "sketch" of the highway section being analyzed. The Level 1 program then calculates the net costs and benefits of each of the five facility cases listed above.

Both the Level 1 and Level 2 analysis programs use data tables and formulas from the AASHTO Red Book (AASHTO, 1977) and the 1985 Highway Capacity Manual (TRB, 1985) to evaluate traffic speeds and vehicle operating costs for the facility alternatives. Although most of the analysis calculations are done by computer programs written in BASIC, all adjustable inputs are entered via spreadsheet user interfaces. After entering the inputs needed to describe a project for Level 1 or 2, the user invokes a spreadsheet macro to create the input data files. These data files are then used by the analysis program to make the engineering economic calculations needed to compare the alternatives.

The results of Level 1 provide the initial guidance as to which exclusive vehicle facilities are most likely to warrant additional examination with Level 2. As shown by Table 1, the spreadsheet user interface to Level 1 requires that the user enter a brief set of inputs concerning general characteristics of the highway facility, traffic conditions, and the surrounding area right-of-way.

The calculations performed by the Level 1 analysis program on the basis of these inputs are explained in the description of the Level 2 inputs and calculations. This quick analysis of the base case and four other exclusive vehicle facility alternatives yields "first cut" estimates of net benefits, net costs, net present value, and the benefit/cost ratio for each of them so that the analyst can determine which cases to evaluate in greater detail with Level 2. For example, if current and future hourly traffic volumes are not severe, and the percentage of heavy vehicles is about average, then many types of exclusive vehicle facilities may be very uneconomical. If future

Table 1: Sketch Analysis Inputs - Level I

General Site Characteristics:

1.	Is this a rural, suburban, or urban highway section?	R/S/U	S
2.	What is the approximate length of this section (miles)?		30.0
3.	How many interchanges are located along this section?		5
4.	How many lanes are there currently in each direction?	(1-4)	3
5.	How many lanes are to be added in each direction?	(1-4)	2
6.	Number of new lanes of right-of-way to acquire?	(0-4)	2
7.	Current average daily traffic (ADT) (one direction)?		80000
8.	Average annual increase in ADT (one direction)?		3000
9.	Current heavy vehicle percentage of total ADT?		30.4%
10.	Heavy vehicle percentage of total ADT in 10 years?		32.8%
11.	Length of the analysis period (number of years)?		20
12.	Present value discount rate?		10.0%

Press Enter

traffic is expected to increase considerably, and the percentage of heavy vehicles is above average, then several types of separated and unseparated facility alternatives may warrant closer examination.

Complete source code listings of the Level 1 and Level 2 programs are provided in Appendix D. As previously mentioned, both programs perform nearly the identical calculations, except that Level 1 assumes the Level 2 input default values for questions not shown in Table 1. However, the Level 1 and Level 2 programs will not yield identical results for benefits and costs even when the inputs entered to both programs are construed to produce identical results. Small differences of less than 1% can occur because Level 1 computes certain default values internally rather than importing these values from the user interface. Also, Level 1 assumes an average split between single-unit and combination vehicles among the current and future heavy-vehicle percentages for all location types, whereas this split varies slightly by location (rural, suburban, or urban) in Level 2.

THE DETAILED ANALYSIS FORMAT - LEVEL II

After completing the sketch assessment of several exclusive vehicle facility alternatives with Level 1, the user must input more detailed data to the Level 2 analysis program in order to evaluate the economic feasibility of any single alternative in greater detail. Cases suggested to be unfavorable by the sketch analysis program can still be evaluated with the Level 2 program, although the user may choose to disregard them. A spreadsheet user interface to the detailed analysis program allows inputs to 57 questions, of which roughly 50 questions have default values that the user can override. Once the inputs to this spreadsheet have been entered for the base case and the spreadsheet has been saved, then very few alterations are required to analyze each alternative case. A printing option allows all Level 2 inputs to the spreadsheet to be printed automatically.

All inputs required of the user by the detailed analysis program are listed in Table 2. These inputs are listed as they are arranged in the spreadsheet user interface. The spreadsheet offers default values based on nationwide averages for many of the input items, although the analyst has the option to replace any of these defaults with preferred values.

The detailed analysis format also allows the user to evaluate an exclusive vehicle facility for entire highway section in terms of shorter subsections so that differences in the number of lanes, gradient, curvature, speed limits, and traffic volumes can be specified. Then, a combined evaluation of all subsections can be produced by summing the subsection results.

The detailed analysis format can be used to perform sensitivity analyses of the critical points at which a particular exclusive vehicle facility becomes economically feasible depending on (1) future traffic volumes on the highway, (2) existing and proposed number of lanes of each type, (3) percentages of heavy and light vehicles in the traffic stream, (4) costs of interchange and lane construction, (5) the pavement resurfacing cost, (6) vehicle operating costs, (7) person and freight values-of-time, and (8) accident rates, costs, and lane closures.

Table 2: Detailed Analysis Inputs - Level 2

General Site Information:

1.	Is this a rural, suburban, or urban highway section R/S/U?	S
2.	Current mixed-vehicle lanes in each direction (0-6)?	3
3.	Future mixed-vehicle lanes in each direction (0-6)?	3
4.	Future light-vehicle lanes in each direction (0-6)?	2
5.	Future heavy-vehicle lanes in each direction (0-4)?	0
6.	Number of new lanes of right-of-way to acquire (0-4)?	2
7.	Will exclusive vehicle lanes be barrier separated (Y/N)?	N
8.	Length of section in miles (including decimal places)?	30.0
9.	Number of interchanges along this section?	5
10.	Average road gradient along section (typical value = 0%)?	0%
11.	Average curvature along section (typical value = 2 deg.)?	2

Press Enter

Traffic Characteristics:

		Defaults	
12.	Current average daily traffic (ADT) (one direction)?		80000
13.	Average annual increase in ADT (one direction)?		3000
14.	Current peak-period volume/hr (3 hours/day)?	6667	0
15.	Future peak-period volume/hr in 10 years?	9167	0
16.	Current off-peak volume/hr (15 hours/day)?	4000	0
17.	Future off-peak volume/hr in 10 years?	5500	0
18.	Speed limit for LV along this section (mph)?	65	0
19.	Speed limit for SU and CV along this section (mph)?	55	65
20.	Current LV percentage of total ADT?	69.6%	0.0%
21.	Future LV percentage of ADT in 10 years?	63.0%	0.0%
22.	Current SU percentage of total ADT?	23.8%	0.0%
23.	Future SU percentage of ADT in 10 years?	29.8%	0.0%
24.	Current CV percentage of total ADT?	6.6%	0.0%
25.	Future CV percentage of ADT in 10 years?	7.3%	0.0%

ADT - Average Daily Traffic SU - Single-Unit Vehicle

LV - Light Vehicle CV - Combination Vehicle

Press Enter

Other Factors:

26.	Length of the analysis period (number of years)?	20
27.	How many years of this period are construction?	3
28.	Present value discount rate?	10.0%

Press Enter

Table 2: Detailed Analysis Inputs - Level 2 (cont.)

Facility Construction and 4R Work Cost (in 10^3 dollars):

	Defaults	
29. Construction cost per lane mile (unseparated)?	$1,900	$0
30. Construction cost per interchange (unseparated)?	$500	$0
31. Right-of-way acquisition cost/mile (unseparated)?	$810	$0
32. Construction cost per lane mile (w/ barriers)?	$2,660	$0
33. Construction cost per interchange (w/ barriers)?	$700	$0
34. Right-of-way acquisition cost/mile (w/ barriers)?	$1,134	$0
35. Average cost per lane mile for major resurfacing?	$108	$0
36. PSI parameter (delta) (in million 18-kip ESALs)?	2.0	0
37. PSI parameter (beta) used as the power exponent?	1.2	0
38. Minimum allowable PSI (lower bound on PSI curve)?	1.5	0
39. PSI at which resurfacing is desired (0-5 scale)?	2.5	0
40. Average ESALs per light vehicle?	0.0003	0
41. Average ESALs per single-unit vehicle?	0.06	0
42. Average ESALs per combination vehicle?	1.5	0

Press Enter

Value-of-Time and Accident Costs (in dollars):

	Defaults	
43. Light vehicle value-of-time per hour?	$5.00	$0.00
44. Single-unit vehicle value-of-time per hour?	$10.00	$0.00
45. Combination vehicle value-of-time per hour?	$15.00	$0.00
46. Light vehicle accident rate per LV MVM?	0.986	0.000
47. Single-Unit vehicle accident rate per SU MVM?	1.697	0.000
48. Combination vehicle accident rate per CV MVM?	1.555	0.000
49. Accident costs per fatality accident?	$226,800	$0
50. Accident costs per injury accident?	$9,288	$0
51. Accident costs per PDO accident?	$1,242	$0
52. Percent of total accidents blocking no lanes?	59%	0%
53. Percent of total accidents blocking one lane?	28%	0%
54. Percent of total accidents blocking two lanes?	13%	0%
55. Average minutes to clear non-truck involvements?	39	0
56. Average minutes to clear truck involvements?	63	0
57. Maximum queue length before diversion (miles)?	3.0	0.0

Press Enter

DESCRIPTION OF LEVEL 2 INPUTS AND CALCULATIONS

The Level 1 and Level 2 analysis programs use many data tables and formulas to calculate the costs and benefits of each exclusive vehicle facility described by user inputs to the spreadsheet user interfaces for these programs. Some of these data tables and formulas are utilized by the spreadsheets to calculate certain parameters based on user inputs, and others are used by the analysis programs for benefit/cost calculations. As previously mentioned, both programs perform similar calculations, except that Level 1 assumes the Level 2 default values for questions not shown in Table 1. For this reason, the calculations performed by the Level 1 analysis program are explained in this section with the description of Level 2 inputs and calculations.

This section explains the data tables and formulas used by the analysis program and where each of them was obtained. The analysis program calculations are explained in the exact same order as the input questions are listed above and presented in the spreadsheet. Appendix A indicates the page number of this section on which the discussion of each question begins.

```
1. Is this a rural, suburban, or urban highway section R/S/U?
```

Highway construction costs and accident rates vary by whether a highway section is in a rural, suburban, or urban area. Area definitions used by some references are central business district (CBD), urban fringe, and residential. Some highway datasets, such as the Highway Performance Monitoring System, use only rural and urban classifications. Data values that depend on these area definitions are shown in tables for other questions, and these values were sometimes adjusted from the data sources to fit the rural, suburban, and urban categories that are used in this analysis format.

```
2. Current mixed-vehicle lanes in each direction (0-6)?
3. Future  mixed-vehicle lanes in each direction (0-6)?
4. Future  light-vehicle lanes in each direction (0-6)?
5. Future  heavy-vehicle lanes in each direction (0-4)?
6. Number of new lanes of right-of-way to acquire (0-4)?
7. Will exclusive vehicle lanes be barrier separated (Y/N)?
```

Questions 2-5 need little explanation. The traffic capacity of a highway in each direction depends on the number of lanes and their lane use policies. Construction costs are assumed to be directly proportional to the number of newly constructed lanes, and resurfacing costs are assumed to be proportional to the total number of new and existing lanes. Construction costs are higher for Case 4 in which the exclusive vehicle lanes are barrier separated.

The number of lanes of right-of-way that need to be acquired for new lane construction must be specified by the user. This number of lanes is multiplied by the average cost of acquisition and demolition in rural, suburban, or urban areas. The right-of-way acquisition cost per mile of construction (not per lane mile) as calculated by the spreadsheet is given as the default value to Question 31, for which the user may substitute another value. The user can specify the inputs to Questions 6 and 31 in many ways so as to represent the desired amount of additional construction cost per mile for land acquisition, preparation, and any other unique costs to the project. Note that there is no default value given for any question in this first frame of the spreadsheet user interface.

```
8. Length of section in miles (including decimal places)?
9. Number of interchanges along this section?
```

Nearly every cost and benefit calculation made within the analysis format is assumed to be directly proportional to the length of the highway section being analyzed. One exception is the total cost of interchange construction, since interchange spacing is independent of the section length.

```
10. Average road gradient along section (typical value = 0%)?
11. Average curvature along section (typical value = 2 deg.)?
```

The curvature and gradient of a highway section affect its traffic capacity and average travel speeds. As a result, they also affect vehicle operating costs and travel times. The ways in which these two factors are used in calculating traffic capacity and vehicle operating costs are explained below. No default values are given in the spreadsheet user interface for these two inputs because (1) they are rather specific and difficult to determine without a site survey, and (2) the analysis results may be significantly affected by small changes in these values. Instead, typical values are suggested to the user.

The default gradient (specified as a percentage) is 0%, where 100% equals a 45° incline. The analysis format is limited to average gradients of between -8% and +8%

because of data availability and the approximations needed to adjust for gradient effects. However, an average gradient of more than 2% would be unusual for high-volume highways in major metropolitan areas of the type to which this analysis program is intended to be applied.

The default curvature (given in degrees) is 2°. Although design standards vary by state and have changed over time, the typical practice is to limit curves to less than 3° on most all principal arterials and interstates. The degree of curvature is defined by the following equation:

$$D = 100 * 360° / 2\Pi R$$

where,

D = degrees of highway curvature.

R = radius to center of circle fitting the curve (in feet).

Although survey measurements of chords across a curve are used in practice to calculate a road's curvature, survey calculations will agree closely with the above formula depending on the chord length that is used and the measurement accuracy.

```
12. Current average daily traffic (ADT) (one direction)?
13. Average annual increase in ADT (one direction)?
14. Current peak-period volume/hr (3 hours/day)?
15. Future peak-period volume/hr in 10 years?
16. Current off-peak volume/hr (15 hours/day)?
17. Future off-peak volume/hr in 10 years?
```

Estimation of all user costs (value of time, vehicle operating costs, accident costs) and the resurfacing frequency requires knowledge of current and future traffic volumes, and the vehicle mixes in these traffic volumes as explained below. The user can either specify the current average daily traffic (ADT) for all lanes in the direction of traffic being analyzed and the average annual increase in this ADT, or specify current and future hourly traffic volumes for peak and off-peak periods, where traffic volumes are always given for all lanes in the direction of traffic being analyzed.

The analysis format allocates ADT specified by the user to peak and off-peak hours in a very approximate manner according to the AASHTO Red Book (1977). In order to adequately represent the congestion experienced by each trip, the common assumption is that all travel occurs between 6 AM and 12 midnight. Then, 5% of the

24-hour ADT is allocated to each of the 15 off-peak hours, and 8.33% of the 24-hour ADT is allocated to each of the 3 peak hours. The user may accept the default values by leaving zeros entered for Questions 14-17, or may substitute preferred nonzero values. The user can also alter the ADT to search for an acceptable split of peak and off-peak volumes.

The analysis format does not include demand forecasting. Thus, the user must take into account the relative attraction or diversion of traffic to a highway because of more or less capacity compared to alternate routes in the traffic corridor in specifying future traffic volumes. Ideally, the prediction of travel demand should be brought into equilibrium with the levels of service supplied by all alternate routes in a travel corridor. However, this analysis format would need to be integrated with a combined equilibrium assignment and elastic demand model in order to achieve that result. For example, Janson et al. (1987) developed a Network Performance Evaluation Model for evaluating the impacts of adding high-occupancy vehicle lanes to a transportation corridor that does equilibrate route volumes and travel costs with elastic demand.

```
18. Speed limit for LV along this section (mph)?
19. Speed limit for SU and CV along this section (mph)?
```

The standard FHWA impedance function is used to calculate travel times from traffic volumes. Impedance is a function of a highway section's free-flow travel, which is assumed to equal the section length divided by the speed limit. Impedance is also a function of a section's practical capacity as measured in terms of passenger car equivalents for the various vehicle types. The form of the impedance function used in the analysis format is:

$$t = t_o \,[1.0 + 0.15\,(v/c)^4]$$

where,

t = travel time to traverse the highway section.

t_o = free-flow travel time = section length/speed limit.

v = traffic volume (in vehicles per lane-hr).

c = traffic capacity (in vehicles per lane-hr).

Table 3: Passenger Car Equivalents for Urban Freeways

Vehicles per Lane-Hour	Light Vehicles	Single-Unit Vehicles	Combination Vehicles
0-599	1.0	1.1	1.1
599-999	1.0	1.2	1.2
1000-1499	1.0	1.3	1.4
1500-1799	1.0	1.4	1.8
1800+	1.0	1.6	2.0

Source: Sequin et al. (1982). These values assume an average grade of less than 4% for single-unit vehicles, and less than 2% for combination vehicles.

Based on the description of the highway section provided by the user, the analysis program computes practical lane capacities for the highway section in the peak and off-peak hours of each year in the planning horizon. These lane capacities are calculated for an assumed lane width of 12 feet and an average vehicle mix as given by the user in response to Questions 20-25. These calculations of lane capacities are made according to the *1985 Highway Capacity Manual* (TRB, 1985). The capacity formula used by the analysis format is:

$$c = 2000(W)(T_{SU})(T_{CV})$$

where,

c = lane capacity (in vehicles per lane-hr).

W = lane width and clearance adjustment factor.

T_{SU} = truck adjustment factor for single-unit vehicles.

T_{CV} = truck adjustment factor for combination vehicles.

$T_{SU} = 100/[100+(E_{SU}-1)P_{SU}]$

$T_{CV} = 100/[100+(E_{CV}-1)P_{CV}]$

E_{SU} = passenger car equivalent for single-unit vehicles.

E_{CV} = passenger car equivalent for combination vehicles.

P_{SU} = percentage of single-unit vehicles in traffic flow.

P_{CV} = percentage of combination vehicles in traffic flow.

The passenger car equivalents listed in Table 3 are used in the calculation of lane capacities according to the vehicle mix percentages and traffic volumes specified by the user. This set of passenger car equivalents was recommended for urban freeways by FHWA Report RD-81/156 (Sequin et al., 1982). The analyst is only required to specify the average percentages of single-unit vehicles (SU2 and SU3 classes) and combination vehicles on the highway section being analyzed, and the analysis program computes the total volume of passenger car equivalents on the highway section. The PCE values are adjusted for hourly peak and off-peak traffic volumes in each year of the analysis period.

The PCE values shown in Table 3 assume an average section gradient of less than 3% for single-unit vehicles, and less than 1% for combination vehicles. The following formulas were estimated on the basis of the *1985 Highway Capacity Manual* to account for highway sections with steeper average grades. PCE values in Table 3 are not adjusted for negative grades.

$$\text{grade adjusted } PCE_{SU} = PCE_{SU} + (PCE_{SU}/1.6)\ (GRADE - 3\%)$$

$$\text{grade adjusted } PCE_{CV} = PCE_{CV} + (PCE_{CV}/2.0)\ (GRADE - 1\%)$$

Thus, for an average grade of 6% and an hourly vehicle volume per lane of 1200, PCE_{SU} equals 4.0 and PCE_{CV} equals 5.0, where GRADE is the average section gradient of between 0% and 8%. PCE values that vary by grade are only given by the *1985 Highway Capacity Manual* for highway section lengths of less than 2 miles. For longer highway sections over which the grade varies significantly, the analyst is advised to specify 0% as the net average grade for the initial evaluation of exclusive vehicle lanes, and then to examine the sensitivity of the analysis to changes in the average grade assumption.

Note that the analysis program cannot be used in its current form to evaluate the need for a hill climbing lane on a steep highway section, although this is similar to adding a heavy-vehicle lane without barrier separation. The reason is that truck speeds are not sufficiently reduced to reflect their slower hill climbing speeds. As explained above, the impedances of slower trucks on grades are reflected in their PCE's, which are used to adjust the travel speeds of both cars and trucks. The effect of the gradient is taken into account in calculating the operating costs of all vehicle types. However, the analysis format does not adequately represent the dramatic queuing that can occur behind trucks on highway sections where hill climbing lanes are needed.

For cases being analyzed in which there are both light-vehicle (LV) and mixed-vehicle (MV) lanes, the LV volume in the MV lanes is estimated by equating the vehicle-to-capacity (v/c) ratios of the LV and MV lanes. This estimate assumes that LV travelers will choose between the LV and MV lanes so as to satisfy the user-equilibrium principle of equal travel times for LV travelers in both sets of lanes. This assumption of equal LV travel times does not account for other factors that may cause a different proportion of LV travelers to use the MV lanes, such as the perceived risk of traveling with heavy vehicles, and the uncertainty of egress options from both the LV and MV lanes. However, equating the LV travel times (or v/c ratios) does allow the PCE values used in calculating the practical capacity of each set of lanes to depend on traffic volume, vehicle mix, and road gradient. The equation is as follows:

$$V_{LVLV}/C_{LV} = (V_{LVMV}+V_{SUMV}+V_{CVMV})/C_{MV}$$

where,

V_{LVLV} = LV volume per lane-hr in the light-vehicle lanes.

V_{LVMV} = LV volume per lane-hr in the mixed-vehicle lanes.

V_{SUMV} = SU volume per lane-hr in the mixed-vehicle lanes.

V_{CVMV} = CV volume per lane-hr in the mixed-vehicle lanes.

C_{LV} = vehicle capacity per lane-hr of light-vehicle lanes.

C_{MV} = vehicle capacity per lane-hr of mixed-vehicle lanes;

Both V_{LVLV} and C_{LV} can be computed without any adjustments for the passenger car equivalents of other vehicles. However, the split of light vehicles between the LV and MV lanes depends on the volume of trucks in the mixed-vehicle lanes, which means that the PCE values and vehicle mix percentages used to compute c_{MV} must be brought into balance with the volume of light vehicles in the mixed-vehicle lanes. Due to the rather large volume increments given by Table 3, the balance of light vehicles to use the mixed-vehicle lanes can be found within a very few iterations of calculations and comparisons.

Vehicle travel times by vehicle and lane type are used to calculate the total value-of-time difference between cases of with and without the exclusive vehicle lanes, and these travel times are converted to speeds for running cost calculations. The running costs of light vehicles, single-unit trucks, and combination vehicles for different road grades and curves were obtained from AASHTO (1977) and are included here as tables in the appendix. These running costs are updated to 1985 dollars based on the Consumer Price Index (CPI), and are multiplied by the volumes of light, single-unit and combination vehicles in each year of the analysis period. The value-of-time and running cost totals computed for each year are discounted and summed to 1985 present values on the basis of the specified discount rate.

20. Current LV percentage of total ADT?
21. Future LV percentage of ADT in 10 years?
22. Current SU percentage of total ADT?
23. Future SU percentage of ADT in 10 years?
24. Current CV percentage of total ADT?
25. Future CV percentage of ADT in 10 years?

Traffic flow conditions and travel speeds depend on the average mix of vehicles on a highway section. Note that vehicle mix percentages computed from statistics in which all counted vehicles do not travel the same distance must be computed on the basis of vehicle miles of travel (VMT). Accident rates and severities depend on the vehicle mix, and the total value-of-time computed for all vehicles must also account for the VMT mix of freight and passenger vehicles. The frequency of resurfacing, as affected by cumulative axle loadings, also depends on the vehicle mix. Default values of VMT mix obtained from FHWA (1988) and used in the analysis format are shown in Table 4. The user may accept the default values by leaving zeros entered for Questions 20-25, or may substitute any preferred nonzero values.

26. Length of the analysis period (number of years)?
27. How many years of this period are construction?
28. Present value discount rate?

User inputs to Questions 26-28 are entirely specific to the particular analysis being made. Both lengths of time given by Questions 26 and 27 are assumed to begin at time 0 (i.e., the beginning of the first year), and all future benefits and costs are discounted to time 0. All benefit and cost calculations made by the analysis format are in 1985 dollars. With the assumption that inflation affects all goods at the same rate,

Table 4: Average VMT Mix Percentages on Interstate Highways

Area Type	Light Vehicles	Single-Unit Vehicles	Combination Vehicles
Rural	64.2%	28.6%	7.2%
Suburban	69.6%	23.8%	6.6%
Urban	75.0%	19.0%	6.0%

Source: Rural and urban values from FHWA (1988). Suburban values were computed here as the averages of the rural and urban values.

the discounted costs and benefits generated by the analysis format can be inflated or deflated to an alternate year based on the CPI. Needless to say, the benefit/cost ratio would be unaffected by this adjustment.

The present value discount rate is assumed to be 10% according to Federal Circular 76 published by the U.S. Office of Management and Budget. Sensitivity of public investment analyses to the discount rate are usually performed with alternative values of 8% and 12%, which the user may enter as substitutes to Question 28.

```
29. Construction cost per lane mile    (unseparated)?
30. Construction cost per interchange  (unseparated)?
31. Right-of-way acquisition cost/mile (unseparated)?
32. Construction cost per lane mile    (w/ barriers)?
33. Construction cost per interchange  (w/ barriers)?
34. Right-of-way acquisition cost/mile (w/ barriers)?
```

The default values of construction and right-of-way acquisition costs for Questions 29-34 shown in Table 5 were obtained from the *1985 Characteristics of Urban Transportation Systems* (also referred to as the CUTS manual) (UMTA, 1985). Construction costs per lane mile as given by the CUTS manual assume that average percentages of the highway section are elevated, at-grade, or depressed for rural, suburban, and urban areas, although these percentages are not documented in the CUTS manual. The user may accept the default values by leaving zeros entered for Questions 29-34, or may substitute any preferred nonzero values.

Table 5: Construction Costs per Lane Mile for Freeway Improvements

	Rural	Suburban	Urban
New 4 Lane Freeway	1.11	1.49	1.88
New 6 Lane Freeway	1.22	1.73	2.24
Major Widening	1.50	1.90	2.30
Right-of-Way Costs	0.39	0.41	0.42
Cost per Interchange	0.40	0.50	0.60

Note: All values are in millions of 1983 dollars, which are multiplied by 1.08 for the 1983-1985 CPI change.

Source: Rural and urban values from UMTA (1985). Suburban values were computed here as averages of rural and urban values. Right-of-way costs are assumed equal to the cost difference per lane mile of new 4 lane freeway construction and major widening. Cost per interchange estimated from Roy Jorgensen (1975).

Note that the right-of-way acquisition cost is per mile and not per lane mile. This default cost is computed in the spreadsheet as the necessary lanes of right-of-way to acquire (Question 6) times the average right-of-way cost per lane mile in rural, suburban and urban areas as given by the CUTS manual. Any nonzero value substituted for this default value in the optional column must also be per mile.

35. Average cost per lane mile for major resurfacing?
36. PSI parameter (delta) (in million 18-kip ESALs)?
37. PSI parameter (beta) used as the power exponent?
38. Minimum allowable PSI (lower bound on PSI curve)?
39. PSI at which resurfacing is desired (0-5 scale)?

Highway 4R work includes the four options of reconstruction, rehabilitation, resurfacing, and restoration. The frequency and cost of each particular 4R work option can vary greatly by location because of many site specific factors such as climate, soils, subbase, and axle loadings. Highway pavements are usually designed to provide 20 years of service before reconstruction is required, although greater than expected heavy vehicle volumes can often make earlier 4R work necessary.

Some type of 4R work ought to be taken at various times of a road's life in order to maintain its pavement serviceability index (PSI) above a minimum acceptable level. The PSI gauges the functional performance of a road's pavement as it affects quality of ride and safety to the traveling public. The PSI is a weighted composite index of pavement distress observations collected via mechanical, visual, and photographic means. These distress observations also include a significant amount of measurement variability depending on the survey method. When 4R work is needed, a trade-off exists between longer lasting, more costly remedial actions and less durable, lower cost actions. In this analysis format, the estimation of 4R work costs over the analysis period is limited to periodic asphalt resurfacings.

Although the PSI index actually depends on several variables with interdependent effects, the PSI of heavily traveled roads depends most significantly on the accumulation of equivalent single-axle loadings (ESALs) since it was last resurfaced. As such, the PSI is usually modeled as a function of ESALs, with an adjustment factor to normalize for road differences by functional class, construction, and location. The rate of PSI deterioration also depends to less of a degree on a road's age since it was first constructed or completely reconstructed due to changes in the structural integrity of the underlying layers, but this effect is not considered here.

The definition and modeling of the PSI has evolved over the past 25 years since the first AASHO Road Test. Different indices and ranges of values are sometimes used for pavement ratings. Other common indices are the pavement condition index (PCI), and the pavement condition rating (PCR). Common scales are 100 to 0, 10 to 0, 1 to 0, or 5 to 0, including decimal fractions, where the highest value always reflects the best condition. In this analysis format, we define the PSI on a scale of 5 to 0. The AASHO design equation for this index can be written as follows:

$$PSI = P_i - (P_i - P_f)\,(Q/\sigma)^{\beta}$$

where,

P_i = initial PSI of the pavement.

P_f = minimum acceptable PSI of the pavement.

Q = quantity of normalized load to pavement surface, usually expressed in millions of 18-kip ESALs.

σ = quantity of normalized load to pavement surface that reduces PSI from P_i to P_f.

β = parameter affecting the S-shape of the PSI curve.

Research performed at the Texas Transportation Institute (TTI) on improving the fit of the PSI equation to observations of pavement deterioration over time and use found that a modified version of the above AASHO equation had superior properties (see Garcia-Diaz and Riggins, 1984) . Most notably, the TTI equation asymptotically approaches a minimum pavement condition, as pavement sections are observed to do, rather than degrade into negative values as the AASHO equation does. The TTI equation is an S-shaped function defined as follows, where all terms are defined the same as above.

$$PSI = P_i - (P_i - P_f) \exp[-(\sigma/Q)^{\beta}]$$

In the TTI equation, σ is a quantity of normalized load that is used to fit the equation, but σ does not equal the amount of load that reduces the PSI from PSI_i to PSI_f because it is part of the exponential term. The TTI equation has been fit fairly closely to observed data using nonlinear regression to estimate the best fitting values of σ and β. Note that these two parameters will not have the same best fitting values in both the AASHO and TTI equations.

Figure 1 shows a family of three TTI curves for asphalt overlays with σ and β equal to 2.0 and 1.2, respectfully. These parameters were estimated by Garcia-Diaz and Riggins (1984) on the basis of 77 sample asphalt overlay sections. These three curves are for newly resurfaced roads with three different average annual loadings of 500,000, 700,000 and 900,000 ESALs. In each case, the pavement deteriorates to a PSI of 2.5 during the year in which the cumulative quantity of ESALs exceeds 5 million. For a road with an average annual loading of 700,000 ESALs, the newly resurfaced pavement with a PSI of 5.0 degrades to a PSI of 2.5 in 7.1 years.

The user has the option of entering any of three parameters that affect the shape of the PSI curve used to predict the frequency of pavement resurfacing. These values are σ (or delta), β (or beta), and P_f entered to Questions 36-38, respectfully. The years in which resurfacings are performed are predicted in the analysis program by using the PSI deterioration curves shown in Figure 1. Resurfacing is assumed to be performed at a default PSI of 2.5, although a different value can be substituted in response to Question 39. The user may accept the default value to any of these parameters by leaving a zero entered in the optional column, or may substitute a preferred nonzero

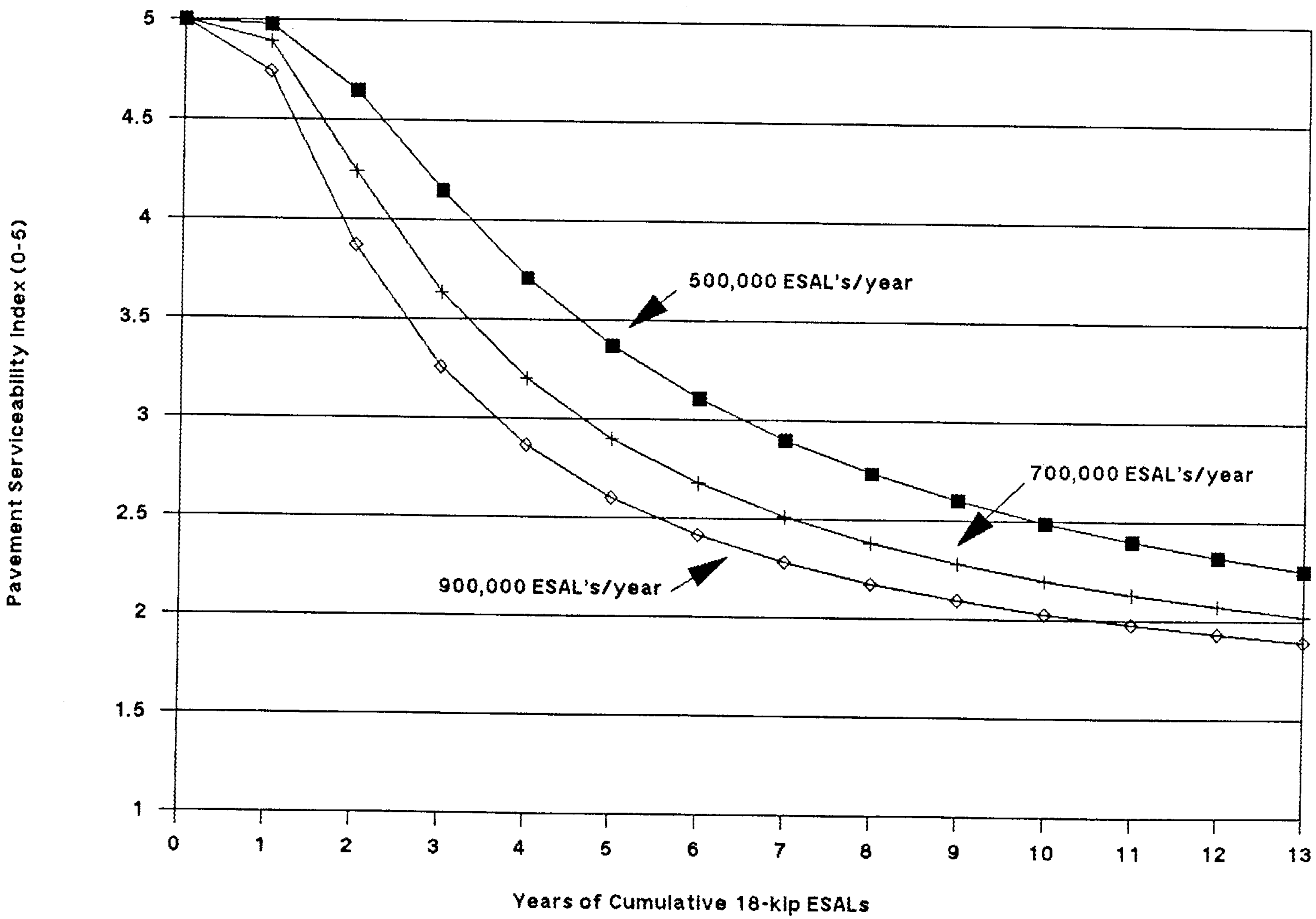

FIGURE 1. PAVEMENT SERVICEABILITY INDEX FOR ASPHALT OVERLAYS

value. Several U.S. transportation departments that use the PSI to schedule and budget resurfacings have found 3.2 to be a cost-effective PSI at which to resurface. This experience varies by region of the country, and depends on the agency's pavement management objective.

```
40. Average ESALs per light vehicle?
41. Average ESALs per single-unit vehicle?
42. Average ESALs per combination vehicle?
```

The average ESAL loading per vehicle of each type was estimated on the basis of values given by The Asphalt Institute (1981) and Wright and Paquette (1987) for different truck configurations on concrete pavements. The user can override the default value of ESALs per vehicle in each category (LV, SU, and CV), which are:

1. Each light vehicle exerts 0.0003 ESALs.
2. Each single-unit vehicle exerts 0.06 ESALs.
3. Each combination vehicle exerts 1.5 ESALs.

Uzarski and Darter (1986) report average resurfacing costs (in 1983 dollars) for different road classes and PSI values when the overlay is performed. These costs were estimated for interstates and urban freeways in ongoing research on the PAVER pavement management system. These costs are shown in Table 6 for PSI values between 1.0 and 4.0 for primary highways. These values show an average resurfacing cost of about $100,000 (in 1983 dollars) per lane mile of 6" overlay to a highway with a 2.5 PSI. This estimate generally agrees with other data sources, including the 1985 CUTS manual (UMTA, 1985).

A default resurfacing cost of $108,000 (including an adjustment of 1.08 for the 1983-1985 CPI change) per lane mile of highway with a PSI of 2.5 is used by the analysis format to calculate resurfacing costs. This cost is adjusted for PSI values other than 2.5 in scale proportion to the costs shown in the 6" overlay column. However, any alternative resurfacing cost entered by the user will not be scaled, and must correspond exactly to the PSI level at which resurfacing is specified to be performed.

The following example explains how the analysis format estimates resurfacing costs for all lanes over the analysis period. An interstate lane with an ADT of 20,000 distributed 72% light vehicles, 20% single-unit vehicles and 8% combination vehicles

Table 6: Resurfacing Costs per Lane Mile of Freeway by PSI

PSI	2" overlay	4" overlay	6" overlay
4.0	26822	53574	80397
3.5	27526	54278	81101
3.0	28934	55686	82509
2.5	46746	73427	100320
2.0	63782	90534	117357
1.5	75258	102010	128832
1.0	86662	113414	140237

Note: All values are in 1983 dollars, which are multiplied by 1.08 for the 1983-1985 CPI change.

will experience roughly 730,000 18-kip ESALs per year. At that loading rate, and the policy to resurface when the PSI reaches 2.5, the road will need to be resurfaced every 7 years, assuming no growth in traffic or change in the vehicle mix during that time. The calculation of cumulative ESALs by the analysis program accounts for changes from current to future traffic volumes per lane of the three vehicle types. Additional consideration might be given to the relative proportions of LV, SU, and CV traffic that use the faster or slower traffic lanes of a mixed traffic freeway, since the resurfacing frequency depends on the most rapidly deteriorating lane.

After 20 to 30 years, most urban interstates require extensive rehabilitation and reconstruction. The analysis format assumes that all existing lanes will be resurfaced at the time that new lanes are added (i.e., all lanes begin the analysis period with a PSI of 5.0), and that the analysis period terminates prior to major reconstruction. This assumption can easily be removed by adding an average cost per lane mile of reconstruction into the average resurfacing cost. The CUTS manual (UMTA, 1985) suggests a value of $1,000,000 per lane mile of interstate reconstruction in 1985 dollars. For example, if reconstruction were to be performed in place of every third resurfacing, then the average resurfacing cost should be increased from $100,000 to $400,000 in response to Question 35 to account for two resurfacings and one reconstruction in each cycle.

The frequency of resurfacing for non-barrier-separated lanes depends on which set of lanes requires it first, and all lanes are assumed to be resurfaced at that time.

The analysis program determines the frequency of resurfacing separately for each set of barrier-separated lanes, since the timing of resurfacing may vary between these sets of lanes depending on the ESALs. The costs of routine maintenance activities are not included by the analysis program in the calculation of facility costs, since these activities will generally be the same regardless of the lane use policies.

```
43. Light vehicle value-of-time per hour?
44. Single-unit vehicle value-of-time per hour?
45. Combination vehicle value-of-time per hour?
```

Values of time used as defaults in the analysis format were used in a 1979 application of the FHWA Highway Investment Analysis Package (Batchelder, 1979). These values are $3.20, $7.00 and $10.00 per hour for light vehicles, single-unit vehicles, and combination vehicles, respectively. Adjusting for price changes from 1979 to 1985 with a Consumer Price Index of 1.482 increases these default values to roughly $5, $10, and $15, respectively. The user may accept these default values by leaving zeros entered for Questions 43-45, or may substitute any preferred nonzero values.

The default value-of-time for light vehicles assumes an average occupancy of roughly 1.3 persons per vehicle. Since buses are included with light vehicles, the average occupancy may be higher for highways serving several bus routes that have a significant number of buses in the traffic stream. Highways leading to central business districts and large employment centers can also attract more car pools and van pools. Accounting for these factors, the user must enter a value of time for light vehicles that corresponds to the average occupancy observed for a particular highway section.

```
46. Light vehicle accident rate per LV MVM?
47. Single-Unit vehicle accident rate per SU MVM?
48. Combination vehicle accident rate per CV MVM?
```

Average accident rates requested by Questions 46-48 are assumed to include the three standard accident categories: fatal, injury, and property damage only (PDO). Unfortunately, most compilations of accident data do not disaggregate the data by vehicle involvement type in the way that is needed to estimate the effects of separating light and heavy vehicles. For example, a recent study on twin-trailer trucks by the Transportation Research Board reported fatal and injury accident rates for single-trailer and multi-trailer trucks, but their rates of involvement with other vehicle types were not indicated (TRB, 1986). Studies that do distinguish between accidents involving light, single-unit, and combination vehicles (or similar categories) generally do not report the complete cross tabulation of that data.

A few recent studies, including Alassar (1988) and Khasnabis and Al-Assar (1989), have fitted alternative functional relationships to accident rates and traffic densities of different vehicle types on major highways. The relationship that we developed and use in the analysis program to predict the effects of separating light and heavy vehicles is that the total number of accidents of all types equals the sum of nine terms representing single and multiple vehicle accidents within and between vehicle types according to the following equation.

$$\begin{aligned} ACC &= V_{LV} R_{LV1} + V_{LV} R_{LV2} \\ &+ V_{SU} R_{SU1} + V_{SU} R_{SU2} \\ &+ V_{CV} R_{CV1} + V_{CV} R_{CV2} \\ &+ \frac{2 V_{LV} R_{LV3} V_{SU} R_{SU3}}{(V_{LV} + V_{SU}) R_{LVSU}} \\ &+ \frac{2 V_{LV} R_{LV4} V_{CV} R_{CV3}}{(V_{LV} + V_{CV}) R_{LVCV}} \\ &+ \frac{2 V_{SU} R_{SU4} V_{CV} R_{CV4}}{(V_{SU} + V_{CV}) R_{SUCV}} \end{aligned}$$

where,

ACC = total number of accidents of all types.

V_{LV} = total light vehicle MVM.

V_{SU} = single-unit vehicle MVM.

V_{CV} = combination vehicle MVM.

R_{LV1} = single LV accident rate per LV MVM (0.199).

R_{LV2} = multiple LV accident rate per LV MVM (0.671).

R_{LV3} = LV with SU accident rate per LV MVM (0.020).

R_{LV4} = LV with CV accident rate per LV MVM (0.069).

R_{SU1} = single SU accident rate per SU MVM (0.061).

R_{SU2} = multiple SU accident rate per SU MVM (0.019).

R_{SU3} = SU with LV accident rate per SU MVM (0.566).

R_{SU4} = SU with CV accident rate per SU MVM (0.044).

Table 7: Total Accident Rates on Controlled-Access Highway Sections

Area Type	AASHTO (1977)	Pigman (1981)[a]	Pigman (1981)[b]
Rural	0.79	0.57	0.49
Suburban	1.07	0.77	0.61
Urban	1.43	3.05	2.07
Total	1.23	1.22	0.90

Note: Accident rates are per million vehicle miles, and include all accidents causing fatalities, injuries, and property damage only.

a) rates are with bridges and interchanges.

b) rates are without bridges and interchanges.

Sources: Shown by column headings.

R_{CV1} = single CV accident rate per CV MVM (0.099).

R_{CV2} = multiple CV accident rate per CV MVM (0.035).

R_{CV3} = CV with LV accident rate per CV MVM (0.849).

R_{CV4} = CV with SU accident rate per CV MVM (0.019).

R_{LVSU} = LV with SU accident rate per (LV+SU) MVM (0.019).

R_{LVCV} = LV with CV accident rate per (LV+CV) MVM (0.064).

R_{SUCV} = SU with CV accident rate per (SU+CV) MVM (0.013).

A study by Goodell-Grivas (1989) for FHWA reports accidents for these nine different types of vehicle interactions, and we were able to convert that data into rates per million vehicle miles (MVM) by vehicle type. These rates are shown in parentheses in the above list, and they result in a total accident rate of 0.876 per MVM of all vehicle types. These rates are used in the analysis program to disaggregate the total accident rates input for Questions 46-48 by vehicle involvement type.

Implicit in the above equation is that all vehicle miles of travel (VMT) are generated on a given highway section within a certain time period. Hence, for a given highway section, more accidents are predicted to occur when greater traffic volumes or greater speeds generate greater VMT within a given period of time. The data in the

Table 8: Accidents Rates by Vehicle Type on Controlled-Access Expressways

	Accident Type			
	Fatal	Injury	PDO	Total
Vehicle Type				
Passenger	0.013	0.373	0.748	1.134
Single-Unit	0.032	0.579	1.340	1.951
Combination	0.028	0.510	1.249	1.787

Note: Accident rates are per million vehicle miles, and include all accidents causing fatalities, injuries, and property damage only.

Source: Meyers (1981).

Goodell-Grivas study represented a relatively small sample along a specific section of freeway, so rates calculated from that data may not be generally applicable to other highway sections. Additional studies are needed to determine the transferability of accident rates in an equation of this form to predict accidents on other highway sections.

Accident rates vary widely by the type of highway surroundings, and also by the study in which they are found. For example, accident rates from two different sources are shown in Table 7. Rates from Pigman (1981) are shown for interstate sections with and without bridges and interchanges. Some of the variation between these rates is due to the classification of sample highway sections as freeways, expressways, or interstates, and the criteria by which they were defined to be rural, suburban, or urban. Other differences in highway sections that affect accident rates are number of lanes, number of interchanges, number of bridges or tunnels, curvature, grade, and the percent mix of vehicle types.

Meyers (1981) compiled the accident statistics shown in Table 8 for controlled-access expressways for the above three vehicle types and by whether the accident caused a fatality, injury, or property damage only. By comparison, a recent article by Giuliano (1989) examines incident durations caused by accidents on the I-10 Freeway in Los Angeles, California. That data showed that 63% of all accidents involve no injuries, which agrees closely with the value of 67% computed on the basis of Meyers' (1981) data.

Highway Statistics Summary to 1985 (FHWA, 1987) reports that, from 1975 to 1985, fatalities per 100 MVM decreased from 1.22 to 0.93 on all urban interstates, and from 2.44 to 1.84 on all urban roads. The fatality rates shown in Table 8 would result in a comparable total fatality rate of 1.83 per 100 MVM assuming a vehicle mix of 70% light vehicles, 20% single-unit vehicles, and 10% combination vehicles. Meyers' (1981) data results in a higher total fatality rate than the rate reported by FHWA for urban interstates because it also includes many urban expressways where more accidents occur. Since the analysis program only uses Meyers' rates to proportion the AASHTO rates to different accident types, this disparity does not affect the calculations made by the analysis program.

The analysis program applies the AASHTO (1977) accident rates by area type, and Meyers' (1981) total accident rates by vehicle type, to generate default values to Questions 46-48 that user may use or replace with preferred values. Meyers' (1981) total accident rates, which are averages assumed to represent suburban highways, are multiplied by 0.79/1.07 for rural highways, and by 1.43/1.07 for urban highways. The Goodell-Grivas rates listed earlier are then used to disaggregate the accident rates by vehicle involvement type. Other studies of accident rates may provide the analyst with alternative rates to be substituted as nonzero values for the default rates. In either case, the default rates, or their substitutes, are proportioned to accident types according to Table 8, and these rates are proportioned to the nine vehicle involvement types according to the values listed earlier from the Goodell-Grivas study.

Studies have shown that fewer and less severe accidents occur per VMT on congested highways than on uncongested highways of similar design. The main reason here is that slower travel speeds result in less serious collisions. Contributing factors may be that drivers are more alert on congested roads, and that they are more able to avoid collisions at slower speeds by having greater control of their vehicles. Whatever the causes, these factors are not taken into account in the accident calculations of the analysis program, since no data exists with which to properly quantify their effects.

One assumption that must be noted is that numbers of accidents by different vehicle types are assumed to be directly proportional to the VMT of these vehicles. However, historical data shows that combination truck involvements in fatal and

Table 9: Accident Costs by Accident Type

	Accident Costs				
	NHTSA (1975$)	NSC (1976$)	HIAP (1979$)	NSC (1983$)	NSC (1985$)
Fatal	287,175	125,000	122,000	210,000	226,800
Injury	3,185	4,700	7,550	8,600	9,288
PDO	520	670	600	1,150	1,242

Sources: Shown by column headings; 1985 NSC costs equal 1983 NSC costs updated to 1985 dollars with a CPI factor of 1.08.

nonfatal accidents may be growing less rapidly than combination truck VMT. An accident rate statistic that is not distorted by the vehicle mix is the vehicle involvement rate (VIR), which is the number of vehicles of a given type involved in certain accidents per VMT of that vehicle type. The VIR will be greater than both the fatality rate and the accident rate, but does not have the misrepresentation difficulties of those statistics. From 1979 to 1983, the VIR of combination trucks in all reported accidents declined from 0.40 to 0.35 per million vehicle miles during a period in which combination truck VMT was increasing (TRB, 1986). The assumed proportional relationship between accidents or vehicle involvements and VMT by vehicle type requires further investigation to validate its use in accident prediction.

49. Accident costs per fatality accident?
50. Accident costs per injury accident?
51. Accident costs per PDO accident?

Average accident costs for each accident type (fatal, injury, and property damage only) are shown in Table 9 from a variety of sources such as the National Highway Traffic Safety Administration (NHTSA) (1975), the National Safety Council (NSC) (1976, 1983), and the Highway Investment Analysis Package (HIAP) (Batchelder, 1979). Some of these accident costs are summarized by Fleischer (1981). These valuations can vary widely depending on their source and application.

Average numbers of fatalities and injuries per accident have already been factored into the costs shown in Table 9 by their sources such that these costs are given per accident. For example, data examined by Giuliano (1989) showed that, among injury causing accidents on the I-10 Freeway in Los Angeles, 66% caused injuries to one person, 22% caused injuries to 2 persons, and 12% caused injuries to 3 or more persons.

The analysis program calculates total accident costs per MVM for mixed and exclusive vehicle lanes as follows. The 1985 NSC accident costs are multiplied by the accident rates per MVM just described by area, accident and vehicle involvement type. The total accident cost of light-vehicle lanes equals the LV only accident rate per LV MVM times the average LV accident cost. The total accident cost of mixed-vehicle lanes equals the sum of the products of the accident rates per MVM for the different vehicle involvement types times their respective average accident costs. The total accident cost for each heavy-vehicle lane is computed similarly to mixed-vehicle lanes except that only single-unit and combination vehicles are taken into account.

52. Percent of total accidents blocking no lanes?
53. Percent of total accidents blocking one lane?
54. Percent of total accidents blocking two lanes?
55. Average minutes to clear non-truck involvements?
56. Average minutes to clear truck involvements?
57. Maximum queue length before diversion (miles)?

The analysis program uses a deterministic queuing model to estimate the total delay caused by accidents predicted to occur on both mixed and exclusive vehicle facilities. Morales (1987) found this type of queuing model to yield close estimates of accident delays on freeways in an study for FHWA. The total delay caused by an accident depends heavily on traffic volumes at the time of an accident, the number of blocked and unblocked lanes, the duration of lane blockage, and the number of route diversion options available to vehicles upstream from the accident scene. A study by Goodell-Grivas (1989) concluded that travel time delays on urban freeways due to truck accidents can cost more than twice the total fatality, injury and property damage cost of those accidents.

An accident causes queuing and vehicle delays because the vehicle arrival rate (hourly vehicle volume) exceeds the vehicle service rate (unblocked lane capacity) during the accident clearing and queue dissipation stages of an incident. The accident clearing stage is the time from when an accident first occurs to the time at which all accident wreckage and emergency equipment is cleared from blocking any lanes. The queue dissipation stage is the time from when the accident is cleared from blocking any lanes to the time at which the residual traffic queue disappears and normal freeway operations are restored. Figure 2 shows a graph of the queuing delays caused by a lane blocking accident as estimated by the deterministic queuing model.

The total delay time caused by an accident equals the shaded area in Figure 2. Lines A and B have slopes equal to the vehicle service rates of a highway during the accident clearing and queue dissipation stages, respectively. The accident clearing stage is from time t_0 when the accident occurs (assumed to be time 0) to time t_2 when all lanes are cleared. The queue dissipation stage is from time t_2 to time t_3 when the queue disappears. At time t_2, when the accident is cleared from blocking any lanes, the service rate returns to its preaccident level (denoted as C_2), which exceeds the current arrival rate, and the queue begins to dissipate. Morales (1987) found that a highway may not return to its preaccident service rate at one time, and that short intermediate steps or piecewise linear segments between lines A and B can be used to represent certain accident clearing processes in more detail. However, most of the accidents reported by Morales (1987) do not require this additional detail, and this additional detail altered the total delay by less than 10% in cases where it was used.

Goodell-Grivas (1989) input data on 15 truck accidents that they sampled on 46.5 miles of urban freeway with 3, 4, and 5 mixed traffic lanes to the Morales queuing model and found that it generated reasonable estimates of total delay. The model shown in Figure 2 is identical to that model in 10 of the 15 cases, and only slightly different in the other 5 cases, resulting in an estimated total delay of within 4% of the full model. The only difference in the other 5 cases was whether the capacity of the highway returned to normal in one or two steps. Using only average input values for these accidents, the model shown above was also able to predict total delay to within 10% of the full model's estimate based on individual accident data. Thus, the model defined below is considered to generate sufficiently valid estimates of total delay for this analysis format.

The vehicle service rate of unblocked lanes during the accident clearing stage (denoted as C_1) depends on the number of open lanes, plus other factors that affect vehicle flow such as smoke, debris, visible wreckage, and emergency equipment. This lower vehicle service rate can be estimated by adjusting the capacity of open lanes for the merging and caution exhibited by vehicles in passing an accident. The accident data reported by Goodell-Grivas (1989) show the open lanes beside accidents to have an

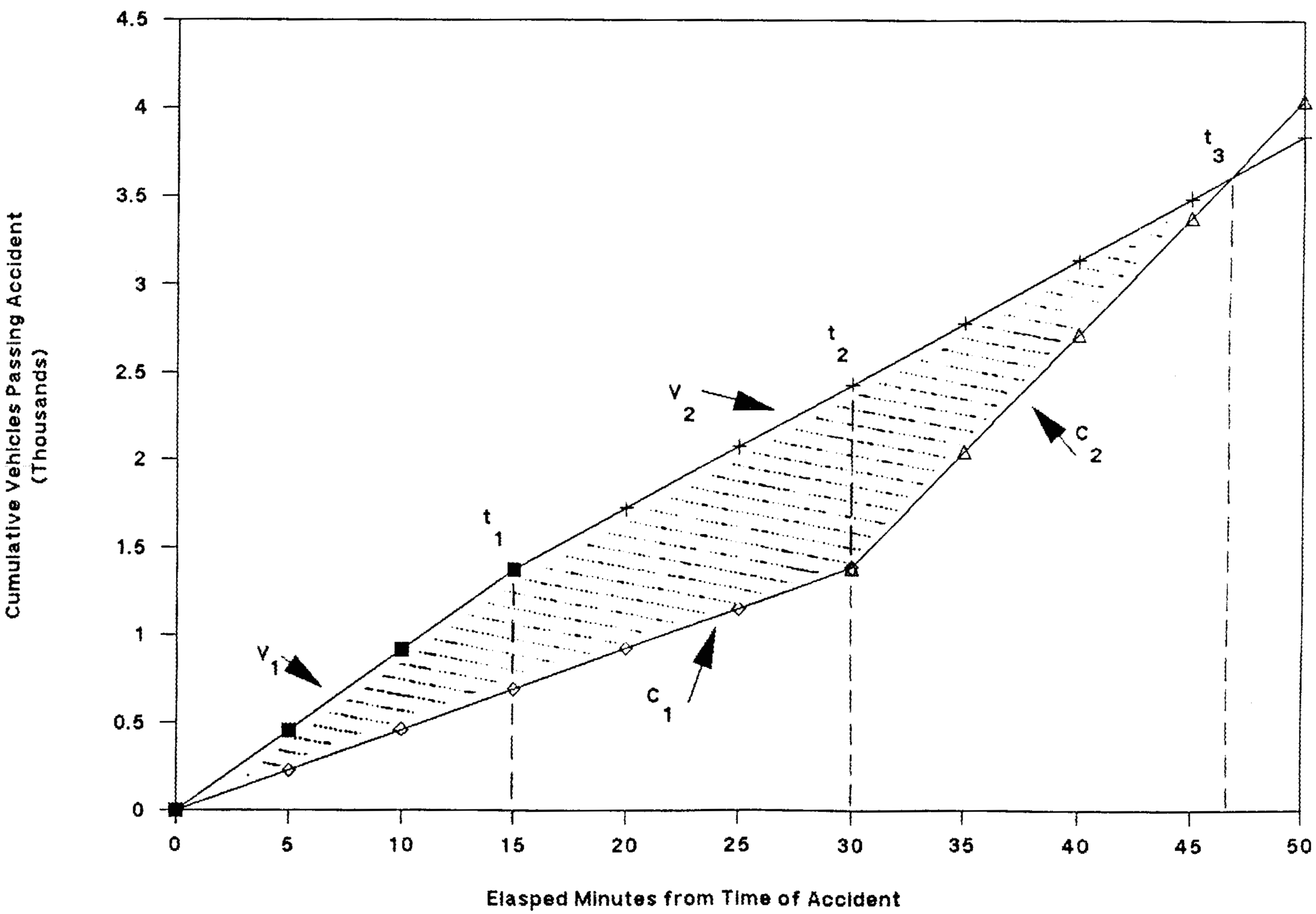

FIGURE 2. DETERMINISTIC QUEUING MODEL OF ACCIDENT DELAYS

average service rate of 80% of their usual capacity. For example, if only two of four lanes remain open (where the usual capacity of each lane is 2000 vehicles per hour), the vehicle service rate of the open lanes will, on average, reduce to 3200 vehicles per hour due to the effects of driving behavior near an accident scene.

With regard to vehicle arrival rates, the queuing model used in the analysis program allows the arrival rate of vehicles at the rear of the queue to decrease at time t_1 during the accident clearing stage due to excessive queue length, route diversion options, and advanced warnings. In Figure 2, lines C and D have slopes equal to the vehicle arrival rates from time t_0 to time t_1 and from time t_1 to time t_3, respectively. The time t_1 at which the arrival rate decreases depends on how quickly the queue lengthens to the point where drivers consider the route diversion options available to them. The analysis program assumes that the arrival rate will decrease when the queue length equals one-half the average distance between interchanges on the highway section being evaluated. The basis for this assumption is that the nearest upstream interchange where drivers can divert to other routes will, on average, be one-half the average distance between interchanges if accidents are randomly distributed between interchanges. Even if accidents occur more frequently near interchanges, equal numbers of accidents just before and after interchanges will result in the same average distance to the nearest upstream interchange. However, with more specific data on accident locations, the analyst may alter this queue length assumption as input to the program.

The arrival rate is expected to decrease prior to or at time t_2, since the queue begins to shorten after then. The extent of route diversion depends on the availability and reliability of alternate routes. A reasonable assumption supported by the data in Goodell-Grivas (1989) is that the initial vehicle arrival rate V_1 will not decrease to a rate V_2 below the service rate C_1 of the unblocked lanes. The accident data reported by Goodell-Grivas (1989) show an average reduction in the arrival rate at time t_1 equal to 33% of the difference between V_1 and C_1. This route diversion percentage will be greater on barrier-separated facilities where vehicles can divert to alternate lanes that are clear of the accident, but not exit the highway entirely. Janson et al. (1986) showed that a network model of alternative routes, or even a sketch planning model of adjacent route capacities, can be use to estimate route diversions from a construction zones quite effectively.

Computationally, the total travel time delay of an accident is equal to the shaded area in Figure 2 as given by the following equation.

$$\text{Delay} = 0.5\ [\ t_1^2\ (V_1 - C_1) - (t_2 - t_1)^2\ (C_2 - C_1)\ ]$$

$$+\ 0.5\ (t_3 - t_1)\ [\ t_1\ (V_1 - C_1) + (t_2 - t_1)\ (C_2 - C_1)\ ]$$

where,

$$t_1 = \text{minimum}\ [\ t_2\ ,\ (105.6\ N_l\ L_q)\ /\ (V_1 - C_1)\ ]$$

$$t_3 = t_1 + [\ t_1\ (V_1 - C_1) + (t_2 - t_1)\ (C_2 - C_1)\ ]\ /\ (C_2 - V_2)$$

and,

Delay = total queuing delay (hours; not weighted by value of time or occupancy)

N_l = number of highway section lanes (blocked or unblocked).

L_q = length of queue (in miles) at which vehicle arrival rate decreases; assumed equal to one-half the average distance between interchanges unless analyst inputs a different value.

t_1 = hours after accident when vehicle arrival rate changes due to queue length, diversion options, and advanced warnings; assumed to occur at t_1 or when the queue in all lanes N_l reaches length L_q, allowing 50 feet per vehicle in slow traffic.

t_2 = hours after accident when all lanes are cleared (input).

t_3 = hours after accident when queue disappears (calculated).

V_1 = vehicle arrival rate per hour until time t_1; assumed equal to the hourly vehicle volume at the time of the accident.

V_2 = vehicle arrival rate per hour from time t_1 to time t_3; assumed equal to V_1 - 0.35 (V_1 - C_1) for unseparated facilities, and equal to V_1 - 0.70 (V_1 - C_1) for barrier-separated facilities.

C_1 = vehicle service rate per hour until t_2 when all lanes are cleared; assumed to equal 80% of the unblocked lane capacity weighted by PCE's for vehicle mix and volume.

C_2 = vehicle service rate per hour after t_2 when all lanes are cleared; assumed to equal the total lane capacity weighted by PCE's for vehicle mix and volume.

A recent analysis of accidents on the I-10 Freeway in Los Angeles by Giuliano (1989) showed that 59% caused no lane closures, 28% caused one lane to be closed, and 13% caused two or more lanes to be closed. The analysis program accounts for the percentages of accidents that cause zero, one, or two lanes to be closed. The user may accept the default values obtained from Giuliano (1989) or input substitutes. Although truck involvement also affects the severity of lane blockage, specific data on that relationship could not be found. Thus, the analysis program currently assumes the same lane blockage percentages for all accidents regardless of the vehicle type involvement.

An analysis of variance performed by Giuliano (1989) did show that incident duration was very significantly affected by truck involvement. The average incident duration of accidents involving trucks was 63 minutes, versus only 39 minutes for non-truck involvements. The variance of incident duration for accidents involving trucks was also much greater than for non-truck involvements. Incident duration was defined in that study as the time from when an accident is first reported to the time at which the accident is reported to be cleared. Incident duration by this definition does not include the queue dissipation time from t_2 to t_3 when normal traffic speeds and densities are restored.

Accident rates may also vary by time-of-day because of traffic densities, speeds, and visibility conditions. Since data on this relationship for urban freeways was not available, the analysis program assumes the same accident rates per MVM for both peak and off-peak hours. The analysis program does compute the number of accidents and queuing delays separately for both the peak and off-peak periods, and sums these delays according to the number of accidents occurring in each period. As such, a greater number of accidents per hour are predicted to occur during peak periods because of greater VMT being generated per hour.

Since most of the cases being analyzed with the analysis format will involve mixes of lane types, certain lane use assumptions must be made in order to estimate the vehicle mix, volume, and queuing delay in the unblocked lanes because of a lane blocking accident. The number of vehicles diverted into unblocked lanes depends on whether the two types of lanes are barrier separated, and also on the use of changeable message signs to direct lane use. If the two lane types are not barrier separated, then the assumption is made that all vehicle types will use the unblocked lanes to maneuver around the accident. However, if the two lane types are barrier separated, then it depends a great deal on how changeable message signs are used to divert traffic.

Weckesser and Kraft (1981) describe the effects of using changeable message signs to divert vehicles from an accident scene and control capacity utilization along the northern portion of the New Jersey Turnpike where light-vehicle and mixed-vehicle lanes are barrier separated. The two incidents that they describe are quite different, and it might be concluded that every accident situation is somewhat unique depending on its severity, location, and lane blockage. Ideally, the percentage of light vehicles in the mixed-vehicle lanes could be controlled by the message signs so that all unblocked lanes on either side of the barrier separation had comparable travel speeds during the accident clearing and queue dissipation stages.

The policy of the New Jersey Turnpike message control center is to revise the lane use directives given by changeable message signs ahead of the accident location if the degree of unblocked lane capacity utilization warrants such an action. For example, signs located at entrance ramps and crossover points between barrier-separated lanes several miles prior to an accident might be used to direct all upstream and entering traffic to divert away from the lanes with the accident. Despite the use of message signs, some volume of traffic will still enter the lanes with the accident, especially before the message signs are changed, and much of the usual traffic volume will be stuck in those lanes by the barrier for several miles upstream from the accident location. If the accident can be cleared quickly, then no changes are made to the message signs, since indiscriminate changes to lane use directives over-induces disruptions to the capacity utilization of the separate lanes.

The following assumptions are made in the analysis program to approximate lane use diversions on barrier-separated facilities due to accidents. Vehicles only divert to adjacent lanes of a barrier-separated facility if the queue length extends upstream to the point where vehicles have that option. This required queue length is assumed to be one-half the average distance between interchanges, unless a nonzero value is substituted for the default in Question 57. Once the queue reaches this length, the arrival rate declines to V_1 - 0.70 (V_1 - C_1), which is a higher diversion percentage than to alternate routes from highways with unseparated lanes. These assumptions produce a balanced estimate between the number of vehicles entering a queue and the amount of traffic able to divert from barrier-separated lanes with an accident.

The analysis format requires the user to specify the percentages of total accidents blocking zero, one, or two lanes. Accidents blocking more than two lanes are treated the same as accidents causing two lanes to be blocked. Total delay time is composed of delay time for both light and heavy vehicles, so vehicle mix is used to calculate a weighted value of delay time. The user can substitute preferred values for the mean accident clearing durations of accidents that do and do not involve trucks, or accept the default values by leaving zeros entered for Questions 55 and 56. With sufficient data, the analysis program could be modified to allow for variations in lane closure and accident clearing duration by vehicle involvement, accident type (fatal, injury, or PDO), or time of day. Giuliano (1989) examines some of these variations, but not in a manner that is usable within the analysis format.

The deterministic queuing calculations of travel time delay are only applied to lanes on the accident side of barrier-separated lanes, and no travel time adjustments are made for increased traffic on the other side of the barrier, since those impacts are assumed to be negligible. Travel time impacts on alternate routes are not estimated for any cases, since they are also treated as negligible and beyond the scope of this model. In all cases (both barrier-separated and unseparated), the vehicle mix in lanes with an accident is held equal to the vehicle mix under normal operating conditions, despite diversions of some vehicles to other lanes or routes. Operating costs for vehicles caught in accident queues are adjusted for slower speeds.

Lastly, clean-up and reporting costs are estimated to be $1000, $5000 and $10,000 per accident for light, single-unit, and combination vehicle accidents, respectively. These incidental costs are included in the calculation of total accident cost by the analysis program. Again, the default values to Questions 52-57 are used by the analysis program unless alternate nonzero values are entered by the user as substitutes.

EXAMPLE APPLICATION OF THE ANALYSIS PROGRAMS

This section presents an example analysis of five alternative facility designs for a 30-mile highway section that currently has three mixed-vehicle lanes in each direction. The development of this example is based on the recent widening of US-59 that runs southwest from Houston to Richmond, Texas. This freeway is a major commuting artery feeding downtown Houston, and also a major truck route to and around Houston. The highway passes through both densely developed and less constructed areas, so its location has been designated as suburban in the following analysis.

Starting in 1987, parts of this highway section were widened from 3 to 5 mixed-vehicle lanes in each direction. In addition, a 2-lane transitway was constructed in the median area of the highway that will carry buses, vanpools and carpools. Traffic volumes on this highway section averaged about 80,000 vehicles per day in each direction in 1987, projected to increase to 110,000 vehicles per day in each direction in 10 years. The five alternative facility designs considered here correspond to the five cases listed in the first section. In addition to Case 0 (the base or do-nothing case), the four facility expansion alternatives are:

- Case 0: Do nothing.
- Case 1: Designate 1 of 3 existing lanes for light vehicles only.
- Case 2: Widen from 3 mixed-vehicle lanes to 5 mixed-vehicle lanes.
- Case 3: Widen from 3 mixed-vehicle lanes to 2 LV and 3 MV lanes.
- Case 4: Same as Case 3 except with LV and MV lanes barrier separated.

The Level 1 analysis program was applied first to determine which alternatives were likely to be economically acceptable. Table 10 lists the inputs to Level 1 for this example.

Table 11 shows a complete listing of results as they appear by executing the Level 1 analysis program. The results are shown with and without vehicle operating costs. Vehicle operating costs are the only costs used by the analysis program that cannot be modified by way of the spreadsheet user interface because of their many values. These costs can be altered by editing the data files containing them that are read by the analysis program. A revised version of the AASHTO Red Book containing updated costs is soon to be released that can be used to revise these values.

Table 10: Inputs to the Level 1 Sketch Analysis Example

General Site Characteristics:

1.	Is this a rural, suburban, or urban highway section?	R/S/U	S
2.	What is the approximate length of this section (miles)?		30.0
3.	How many interchanges are located along this section?		5
4.	How many lanes are there currently in each direction?	(1-4)	3
5.	How many lanes are to be added in each direction?	(1-4)	2
6.	Number of new lanes of right-of-way to acquire?	(0-4)	2
7.	Current average daily traffic (ADT) (one direction)?		80000
8.	Average annual increase in ADT (one direction)?		3000
9.	Current heavy vehicle percentage of total ADT?		30.4%
10.	Heavy vehicle percentage of total ADT in 10 years?		32.8%
11.	Length of the analysis period (number of years)?		20
12.	Present value discount rate?		10.0%

Press Enter

Another reason for reporting the analysis results both with and without vehicle operating costs is the question of how these costs ought to be viewed in the evaluation. Although highway facilities are expanded to ease congestion, fuel consumption and equipment costs are lowest for many cars and trucks at constant speeds between 40 and 50 miles per hour. Although these costs increase with speed for average speeds above this range, the appropriate economic trade-off between travel time and operating costs is unclear. Thus, the analysis results are presented in both ways.

Table 11 lists the Level 1 analysis program results for this example. Note that the net benefits and net costs reported for each of Cases 1-4 are the differences in benefits and costs of these cases from the raw benefits and costs estimated for the base case (Case 0). Thus, net benefits and net costs would equal zero if reported for the base case. Benefits are listed as user costs since they represent accident and travel time costs. Hence, neither the net present value nor benefit/cost ratio of Case 0 can be computed.

Case 1 indicates substantial benefits relative to costs for simply restricting heavy vehicles from one of the existing three lanes in each direction. Note that the benefits and costs are the same for Case 1 both with and without vehicle operating costs, because the traffic is predicted to operate at roughly the same speed in either case.

Table 11: Results from the Level 1 Sketch Analysis Example

With Vehicle Operating Costs			Without Vehicle Operating Costs		
CASE 0 MVL = 3		LVL = 0	HVL = 0		
Benefits (user costs)	=	$1860792	Benefits (user costs)	=	$1860792
Veh. & Facility Costs	=	$2149521	Veh. & Facility Costs	=	$57117
CASE 1 MVL = 2		LVL = 1	HVL = 0		
Net Benefits	=	$46321	Net Benefits	=	$46321
Net Costs	=	$34877	Net Costs	=	$34877
Net Present Value	=	$11444	Net Present Value	=	$11444
Benefit/Cost Ratio	=	1.328	Benefit/Cost Ratio	=	1.328
CASE 2 MVL = 5		LVL = 0	HVL = 0		
Net Benefits	=	$516022	Net Benefits	=	$516022
Net Costs	=	$437342	Net Costs	=	$153230
Net Present Value	=	$78680	Net Present Value	=	$362792
Benefit/Cost Ratio	=	1.180	Benefit/Cost Ratio	=	3.368
CASE 3 MVL = 3		LVL = 2	HVL = 0		
Net Benefits	=	$541687	Net Benefits	=	$541687
Net Costs	=	$475327	Net Costs	=	$191215
Net Present Value	=	$66360	Net Present Value	=	$350472
Benefit/Cost Ratio	=	1.140	Benefit/Cost Ratio	=	2.833
CASE 4 MVL = 3		LVL = 2	HVL = 0		
Net Benefits	=	$541687	Net Benefits	=	$541687
Net Costs	=	$495355	Net Costs	=	$211243
Net Present Value	=	$46332	Net Present Value	=	$330443
Benefit/Cost Ratio	=	1.094	Benefit/Cost Ratio	=	2.564

Note: All values are shown in 1000's of dollars.

The main benefit of Case 1 results from fewer accidents due to having a special lane for light vehicles. The benefit/cost ratios of Cases 2-4 are only slightly greater than 1 when vehicle operating costs are included, but they are much greater than 1 without vehicle operating costs. The reason for this is that the widening of this congested highway allows vehicles to travel at faster speeds, which according to the AASHTO Red Book results in much greater vehicle operating costs per mile for both light and heavy vehicles.

Cases 2-4 have lower benefit/cost ratios than Case 1 because of the low cost of Case 1. The net present values of Cases 2-4 are each much larger than the net present value of Case 1. The conclusion of this initial sketch analysis might be that Case 2 is

Table 12: Inputs to the Level 2 Detailed Analysis Example

Level 2 - Traffic Characteristics:

	Defaults	
12. Current average daily traffic (ADT) (one direction)?		80000
13. Average annual increase in ADT (one direction)?		3000
14. Current peak-period volume/hr (3 hours/day)?	6667	0
15. Future peak-period volume/hr in 10 years?	9167	0
16. Current off-peak volume/hr (15 hours/day)?	4000	0
17. Future off-peak volume/hr in 10 years?	5500	0
18. Speed limit for LV along this section (mph)?	65	0
19. Speed limit for SU and CV along this section (mph)?	55	65
20. Current LV percentage of total ADT?	69.6%	0.0%
21. Future LV percentage of ADT in 10 years?	62.3%	0.0%
22. Current SU percentage of total ADT?	23.8%	0.0%
23. Future SU percentage of ADT in 10 years?	29.8%	0.0%
24. Current CV percentage of total ADT?	6.0%	0.0%
25. Future CV percentage of ADT in 10 years?	7.3%	0.0%

ADT - Average Daily Traffic   SU - Single-Unit Vehicle   Press Enter
LV - Light Vehicle   CV - Combination Vehicle

the preferred alternative since it has the greatest net present value, although Cases 3 and 4 are sufficiently close that further examination is required with the Level 2 program. In addition, the Level 2 analysis may show that small changes in some input values, such as the growth in future truck traffic may cause, significant changes in the net present values of these cases.

Table 12 lists the traffic characteristics for Case 2 of this example. The general site information for each case is given with its detailed table of results, where the only differences are the number of future lanes of each type, and whether or not lanes of different types are barrier separated.

As shown in Table 12, two changes were made to the default traffic characteristics from the values used in Level 1. First, the default future truck percentages of the vehicle mix were accepted in the Level 2 analysis. Thus, heavy truck volumes were assumed to increase in future years to 37.7% of all traffic, instead of the 32.4% input to Level 1. Second, the heavy vehicle speed limit was increased to 65 miles per hour instead of 55 miles per hour.

Table 13: Results from the Level 2 Detailed Analysis - All Cases

	Benefits	Costs		
Case 0	1796154	2390025		
	Net Benefits	Net Costs	Net Present Value	B/C Ratio
Case 1	64336	27156	37180	2.369
Case 2	518993	398391	120602	1.303
Case 3	551301	457605	93696	1.205
Case 4	552238	470031	82207	1.175

Note: All values are shown in 1000's of dollars.
Costs include vehicle operating costs.

Table 13 lists the results of Level 2 analysis program for Cases 0-4 of this example. The net benefits and costs reported for Cases 1-4 are differences from raw benefits and costs estimated for the Case 0. The few changes made to the default values assumed in Level 1 were sufficient to cause all cases to have higher net present values and benefit/cost ratios. Case 2, which is to widen the highway with additional mixed-vehicle lanes, is still the preferred alternative with the highest net present value. Cases 3 and 4 would be more competitive with Case 2 if the cost per accident fatality were increased to $500,000 or higher.

Although Case 1 has the highest benefit/cost ratio of the four cases shown above, it also has a very small net benefit for a very small net cost. Although allocating one lane to light vehicles is helpful, it makes a relatively small reduction on congestion. Thus, without expanding the highway, travel times and costs will remain at intolerably high levels. Detailed tables of results for Cases 1-4 are given on the following pages in which the base case is always the same. Note in these tables that the accident costs and delays for Cases 3 and 4 are much lower than for Case 2, but not enough to offset the higher cost of construction.

Table 14: Results from the Level 2 Detailed Analysis - Case 1

General Site Information:

1.	Is this a rural, suburban, or urban highway section?	R/S/U	S
2.	Current mixed-vehicle lanes in each direction?	(1-6)	3
3.	Future mixed-vehicle lanes in each direction?	(0-6)	2
4.	Future light-vehicle lanes in each direction?	(0-4)	1
5.	Future heavy-vehicle lanes in each direction?	(0-4)	0
6.	Number of new lanes of right-of-way to acquire?	(0-4)	0
7.	Will exclusive vehicle lanes be barrier-separated?	(Y/N)	N
8.	Section length in miles (including decimal places)?		30.0
9.	Number of interchanges along this section?		5
10.	Average road gradient along section (typical value = 0%)?		0%
11.	Average curvature along section (typical value = 2 deg.)?		2

COST SUMMARY (in $1000s)

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Costs
Resurfacing Lanes	$43318	$68529	$95685	$27156
Vehicle Operation	$1884437	$2321496	$2321496	-$0
New Construction	$0	$0	$0	$0
Right Of Way	$0	$0	$0	$0
Total	$1927755	$2390025	$2417181	$27156

BENEFIT SUMMARY (in $1000s)

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Benefits
Travel Time	$848781	$1345819	$1345820	-$1
Accident Costs	$128761	$172461	$151804	$20657
Accident Delays	$41609	$277874	$234193	$43681
Total	$1019150	$1796154	$1731818	$64336

BENEFIT/COST RATIOS

With Vehicle Operating Costs		Without Vehicle Operating Costs	
Net Present Value =	$37180	Net Present Value =	$37180
Benefit/Cost Ratio =	2.369	Benefit/Cost Ratio =	2.369

STATISTICS SUMMARY

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Diff.
Total VMT (in 1000s)	17520218	24418718	24418718	0
Total Accidents	30507	44258	38590	-5668
Avg. Accident Cost	$9915	$10094	$10019	-$75
Avg. Delay Cost	$3204	$22841	$21767	-$1075
Avg. Travel Speed	61.33	54.04	54.04	0.00

Table 15: Results from the Level 2 Detailed Analysis - Case 2

General Site Information:

1.	Is this a rural, suburban, or urban highway section?	R/S/U	S
2.	Current mixed-vehicle lanes in each direction?	(1-6)	3
3.	Future mixed-vehicle lanes in each direction?	(0-6)	5
4.	Future light-vehicle lanes in each direction?	(0-4)	0
5.	Future heavy-vehicle lanes in each direction?	(0-4)	0
6.	Number of new lanes of right-of-way to acquire?	(0-4)	2
7.	Will exclusive vehicle lanes be barrier-separated?	(Y/N)	N
8.	Section length in miles (including decimal places)?		30.0
9.	Number of interchanges along this section?		5
10.	Average road gradient along section (typical value = 0%)?		0%
11.	Average curvature along section (typical value = 2 deg.)?		2

COST SUMMARY (in $1000s)

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Costs
Resurfacing Lanes	$43318	$68529	$54894	-$13635
Vehicle Operation	$1884437	$2321496	$2580292	$258796
New Construction	$0	$0	$104630	$104630
Right Of Way	$0	$0	$48600	$48600
Total	$1927755	$2390025	$2788416	$398391

BENEFIT SUMMARY (in $1000s)

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Benefits
Travel Time	$848781	$1345819	$1089779	$256040
Accident Costs	$128761	$172461	$172461	$0
Accident Delays	$41609	$277874	$14921	$262953
Total	$1019150	$1796154	$1277161	$518993

BENEFIT/COST RATIOS

With Vehicle Operating Costs		Without Vehicle Operating Costs	
Net Present Value =	$120602	Net Present Value =	$379398
Benefit/Cost Ratio =	1.303	Benefit/Cost Ratio =	3.718

STATISTICS SUMMARY

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Diff.
Total VMT (in 1000s)	17520218	24418718	24418718	0
Total Accidents	30507	44258	44258	0
Avg. Accident Cost	$9915	$10094	$10094	$0
Avg. Delay Cost	$3204	$22841	$1477	-$21364
Avg. Travel Speed	61.33	54.04	62.97	8.92

Table 16: Results from the Level 2 Detailed Analysis - Case 3

General Site Information:

1.	Is this a rural, suburban, or urban highway section?	R/S/U	S
2.	Current mixed-vehicle lanes in each direction?	(1-6)	3
3.	Future mixed-vehicle lanes in each direction?	(0-6)	3
4.	Future light-vehicle lanes in each direction?	(0-4)	2
5.	Future heavy-vehicle lanes in each direction?	(0-4)	0
6.	Number of new lanes of right-of-way to acquire?	(0-4)	2
7.	Will exclusive vehicle lanes be barrier-separated?	(Y/N)	N
8.	Section length in miles (including decimal places)?		30.0
9.	Number of interchanges along this section?		5
10.	Average road gradient along section (typical value = 0%)?		0%
11.	Average curvature along section (typical value = 2 deg.)?		2

COST SUMMARY (in $1000s)

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Costs
Resurfacing Lanes	$43318	$68529	$114108	$45579
Vehicle Operation	$1884437	$2321496	$2580292	$258796
New Construction	$0	$0	$104630	$104630
Right Of Way	$0	$0	$48600	$48600
Total	$1927755	$2390025	$2847630	$457605

BENEFIT SUMMARY in $1000s)

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Benefits
Travel Time	$848781	$1345819	$1089779	$256040
Accident Costs	$128761	$172461	$143765	$28696
Accident Delays	$41609	$277874	$11309	$266565
Total	$1019150	$1796154	$1244853	$551301

BENEFIT/COST RATIOS

With Vehicle Operating Costs			Without Vehicle Operating Costs		
Net Present Value	=	$93696	Net Present Value	=	$352491
Benefit/Cost Ratio	=	1.205	Benefit/Cost Ratio	=	2.773

STATISTICS SUMMARY

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Diff.
Total VMT (in 1000s)	17520218	24418718	24418718	0
Total Accidents	30507	44258	36384	-7873
Avg. Accident Cost	$9915	$10094	$9973	-$121
Avg. Delay Cost	$3204	$22841	$1340	-$21501
Avg. Travel Speed	61.33	54.04	62.97	8.93

Table 17: Results from the Level 2 Detailed Analysis - Case 4

General Site Information:

1.	Is this a rural, suburban, or urban highway section?	R/S/U	S
2.	Current mixed-vehicle lanes in each direction?	(1-6)	3
3.	Future mixed-vehicle lanes in each direction?	(0-6)	3
4.	Future light-vehicle lanes in each direction?	(0-4)	2
5.	Future heavy-vehicle lanes in each direction?	(0-4)	0
6.	Number of new lanes of right-of-way to acquire?	(0-4)	2
7.	Will exclusive vehicle lanes be barrier-separated?	(Y/N)	Y
8.	Section length in miles (including decimal places)?		30.0
9.	Number of interchanges along this section?		5
10.	Average road gradient along section (typical value = 0%)?		0%
11.	Average curvature along section (typical value = 2 deg.)?		2

COST SUMMARY (in $1000s)

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Costs
Resurfacing Lanes	$43318	$68529	$68465	-$64
Vehicle Operation	$1884437	$2321496	$2580292	$258796
New Construction	$0	$0	$143259	$143259
Right Of Way	$0	$0	$68040	$68040
Total	$1927755	$2390025	$2860056	$470031

BENEFIT SUMMARY (in $1000s)

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Benefits
Travel Time	$848781	$1345819	$1089779	$256040
Accident Costs	$128761	$172461	$143765	$28696
Accident Delays	$41609	$277874	$10372	$267502
Total	$1019150	$1796154	$1243916	$552238

BENEFIT/COST RATIOS

With Vehicle Operating Costs		Without Vehicle Operating Costs	
Net Present Value =	$82207	Net Present Value =	$341003
Benefit/Cost Ratio =	1.175	Benefit/Cost Ratio =	2.614

STATISTICS SUMMARY

	Base Case		Alternative Case	
	No Traffic incr.	Traffic incr.	Traffic incr.	Net Diff.
Total VMT (in 1000s)	17520218	24418718	24418718	0
Total Accidents	30507	44258	36384	-7873
Avg. Accident Cost	$9915	$10094	$9973	-$121
Avg. Delay Cost	$3204	$22841	$1205	-$21636
Avg. Travel Speed	61.33	54.04	62.97	8.93

CONCLUDING REMARKS

The analysis format is shown to have a great deal of flexibility in evaluating the economic feasibility of separating light vehicles from heavy vehicles on controlled-access highways by designating existing lanes and/or constructing new lanes to be used exclusively by light or heavy vehicles. A wide variety of example analyses must be performed by the analyst in order to understand and appreciate the versatility of the program and its sensitivity to each of the input parameters. The analyst must experiment heavily with the program before this can be achieved.

The example in the previous section indicated that certain exclusive vehicle facilities may be warranted for high-volume highways with significant percentages of single-unit and combination vehicles in the traffic stream. In these and other test analyses, a few key factors were observed to be needed in order for a barrier-separated exclusive facility to warrant any further consideration. First, peak-hour volumes must exceed 1800 vehicles per lane-hour, and off-peak volumes must exceed 1200 vehicles per lane-hour. Second, total trucks (single-units and combinations) must exceed 30% of the vehicle mix. Otherwise, the net present value of any barrier-separated facility will be negative regardless of all the other reasonable input values.

However, exclusive facilities without barrier separation appear to be warranted for a range of traffic volumes depending on the other input values. On congested highways, particularly during peak travel hours, designating one or two existing lanes exclusively for light vehicles can be a very cost effective traffic management strategy. The example of the previous section showed this case to have a positive net present value. However, if a highway is more severely congested, then widening the highway in order to add an exclusive lane for light vehicles can have a greater net benefit than simply designating existing lanes. Assuming a more rapid growth in traffic, or extending the analysis period into future years of greater congestion, will cause the unseparated exclusive facility case to have the greatest net present value.

The main weaknesses in the analysis format are the many assumptions needed to simplify the many site-specific complexities of a freeway traffic system. For this reason, estimates of costs and benefits from even the detailed analysis program should only be viewed as midpoints within very broad ranges. Relatively small differences between alternative cases of less than 5% may not be statistically significant. However, the general rankings of alternative cases as determined by many test cases for a given site may be robust. As with the example of the previous section, although the Level 1 and Level 2 results were different, the rankings of the alternatives according to their net present values were unchanged.

The analysis format could also be improved by imbedding models for freeway simulation, route assignment, and elastic demand within its framework. This expansion of the analysis program would enable an improved modeling of route diversion alternatives during incidents, and of traffic attracted from alternate routes because of adding capacity to an existing highway. However, this expansion of the analysis program would require much more extensive data preparation on the part of the user. As currently designed, the analysis format can be used to generate quick-response evaluations of many alternative facilities within just a few brief sessions.

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APPENDIX A: PAGES OF LEVEL 2 INPUT DESCRIPTIONS

General Site Information:

Traffic Characteristics:

Other Factors:

Facility Construction and 4R Work Cost (in 10^3 dollars):

Value-of-Time and Accident Costs (in dollars):

APPENDIX B: VEHICLE OPERATING COSTS AND PRICE INDICES

The following six tables of vehicle operating costs were obtained from *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements - 1977* (AASHTO, 1977). Tables B1-B3 show vehicle operating costs by speed and highway gradient for light, single-unit, and combination vehicles, respectively. These costs are read by the analysis program from disk files LRUNCOST.DAT, SRUNCOST.DAT, and CRUNCOST.DAT, respectively. Tables B4-B6 show additional vehicle operating costs by speed and highway curvature for these same vehicle classes. These additional costs are read by the analysis program from disk files LCRVCOST.DAT, CCRVCOST.DAT, and SCRVCOST.DAT, respectively. For all tables, if the estimated speed in the analysis program exceeds the maximum speed for which a cost is shown, then cost of highest speed shown is applied by the analysis program.

Table B7 lists all Consumer Price Index (CPI) values needed to convert dollars costs in any year other than 1985 to 1985 dollars.

Table B1

RUNNING COST AT UNIFORM SPEED ON GRADES
FOR 4-KIP PASSENGER CARS
(Dollars per 1,000 Vehicle-Miles)

Speed	Minus Grade (Percent)									Plus Grade (Percent)							
(mph)	-8	-7	-6	-5	-4	-3	-2	-1	Level	+1	+2	+3	+4	+5	+6	+7	+8
5	$86.89	$84.50	$83.28	$82.42	$81.96	$81.49	$85.04	$98.34	$108.95	$112.20	$118.00	$123.33	$128.34	$134.96	$136.37	$143.36	$147.60
10	70.15	68.31	67.15	66.55	66.11	65.93	65.83	75.24	81.28	85.35	89.10	93.53	97.29	102.07	106.52	112.10	117.98
15	64.10	62.12	61.34	60.86	60.42	60.36	62.06	68.57	73.43	78.24	83.25	86.78	91.43	94.73	100.00	105.27	112.04
20	60.79	59.65	58.65	58.05	57.97	57.86	60.06	65.96	70.72	74.66	80.37	83.45	88.31	92.34	97.16	103.00	109.20
25	58.95	57.91	57.14	56.61	56.67	57.10	59.49	64.42	70.00	73.62	78.62	81.98	87.07	91.66	96.28	102.61	108.60
30	58.04	57.16	56.54	56.16	56.24	56.93	59.64	64.83	70.06	73.58	77.96	81.94	86.89	91.47	95.90	102.66	108.83
35	58.05	57.27	56.77	56.39	56.67	57.79	60.46	65.74	70.81	74.21	78.49	82.62	86.98	91.57	95.94	102.69	108.98
40	58.18	57.31	57.37	57.23	56.67	59.30	61.65	66.94	72.03	75.24	79.75	83.59	87.63	91.87	96.36	103.16	109.28
45	58.37	58.27	58.11	58.42	59.15	60.71	63.62	68.34	73.20	76.55	81.08	84.56	88.32	92.63	97.20	103.94	109.83
50	59.16	59.19	59.34	60.02	61.00	62.48	64.92	69.83	74.50	78.00	82.81	86.16	89.73	93.85	98.76	105.12	110.91
55	60.16	60.23	60.88	61.97	63.02	64.70	66.96	71.56	76.23	80.10	84.72	88.00	91.85	96.28	101.11	107.30	113.03
60	61.60	61.72	63.18	64.20	65.71	67.16	69.39	74.03	78.49	82.46	86.74	90.49	94.49	98.74	103.85	110.21	115.96
65			65.65	67.17	68.48	70.25	72.59	77.13	81.37	85.39	89.48	93.59	97.86	102.32	107.05		
70					71.66	73.54	76.04	80.54	84.57	88.32	92.35	96.71	100.87				
75						77.46	80.57	84.97	88.81	92.20	96.36	100.65					
80							85.62	90.02	93.87	96.77	100.89						

Note: If speed exceeds maximum speed for which a cost is shown, then cost of highest speed is assumed by the analysis program.

Table B2

RUNNING COST AT UNIFORM SPEED ON GRADES
FOR 12-KIP SINGLE-UNIT TRUCKS
(Dollars per 1,000 Vehicle-Miles)

Speed	Minus Grade (Percent)									Plus Grade (Percent)							
(mph)	-8	-7	-6	-5	-4	-3	-2	-1	Level	+1	+2	+3	+4	+5	+6	+7	+8
5	$120.07	$119.68	$119.29	$119.04	$118.48	$118.46	$122.89	$126.07	$133.55	$144.74	$163.59	$174.93	$206.63	$211.41	$233.01	$280.00	$268.54
10	106.85	106.38	105.81	105.26	104.62	105.67	105.40	114.14	122.22	139.42	154.06	170.09	192.26	206.71	228.02	280.36	275.89
15	97.15	96.38	95.53	94.76	93.98	96.59	99.18	105.85	114.08	136.66	147.81	168.47	180.78	206.05	225.29	284.31	286.46
20	92.85	91.81	90.72	89.73	89.03	91.13	92.58	103.13	112.67	134.65	150.00	172.21	193.06	211.93	232.93	267.30	304.97
25	92.69	91.35	85.95	89.03	88.38	91.66	95.72	105.07	116.68	140.90	156.81	178.58	203.37	226.75	250.69	294.29	
30		91.67	90.08	74.27	89.91	94.20	99.00	109.85	122.45	147.26	165.39	189.98	217.78	248.36	275.73		
35		93.01	91.52	76.57	93.54	99.11	104.40	117.88	131.14	155.90	177.64	205.79	239.36	272.63			
40			97.29	97.71	98.82	104.34	114.80	127.83	139.58	165.89	191.56	222.56	268.23				
45					105.37	112.28	120.58	136.51	149.76	177.22	206.54	241.81					
50						112.35	133.11	149.02	161.13	191.23	222.17	260.17					
55						131.31	142.92	159.90	172.02	204.70							
60							156.27	171.51	186.68	218.08							

Note: If speed exceeds maximum speed for which a cost is shown, then cost of highest speed is assumed by the analysis program.

Table B3

RUNNING COST AT UNIFORM SPEED ON GRADES
FOR 54-KIP, 3-S2 DIESEL TRUCKS
(Dollars per 1,000 Vehicle-Miles)

Speed	Minus Grade (Percent)									Plus Grade (Percent)							
(mph)	-8	-7	-6	-5	-4	-3	-2	-1	Level	+1	+2	+3	+4	+5	+6	+7	+8
5	$92.00	$91.34	$90.69	$90.15	$89.47	$ 89.04	$ 89.49	$ 89.80	$270.42	$282.98	$296.32	$308.82	$321.47	$333.30	$345.47	$356.28	$369.22
10	89.41	88.51	87.46	86.42	85.27	84.63	85.29	85.91	182.69	210.42	237.66	264.61	290.55	316.23	342.35	365.70	391.72
15	89.56	88.54	86.99	85.49	84.14	83.34	84.00	85.01	156.02	189.10	222.20	255.14	287.57	320.23	351.70	386.16	426.96
20		89.22	87.61	85.78	84.33	83.20	83.90	86.04	145.75	182.00	218.59	256.04	294.73	334.47	375.47	420.42	460.01
25			90.37	88.28	86.92	85.96	86.00	88.78	143.22	181.24	222.06	264.24	310.33	361.39	415.01		
30				92.22	91.02	89.85	89.44	92.91	145.66	187.45	230.88	276.94	335.45	399.90			
35						94.88	94.60	121.29	151.33	195.72	243.69	290.00	370.52				
40						101.06	112.46	132.09	160.00	207.57	260.90	326.41					
45						114.41	123.50	141.59	171.85	223.12	283.74						
50							154.31	156.99	189.91	248.84							
55								166.96	204.19	267.16							
60									216.48								

Note: If speed exceeds maximum speed for which a cost is shown, then cost of highest speed is assumed by the analysis program.

Table B4

EXCESS RUNNING COST AT UNIFORM SPEED ON HORIZONTAL CURVES
ABOVE COST ON TANGENTS FOR 4-KIP PASSENGER CARS
(Dollars per 1,000 Vehicle-Miles)

Speed	Degree of Horizontal Curvature													
(mph)	1	2	3	4	5	6	8	10	12	14	16	20	25	30
5	$ 0.54	$ 1.06	$ 1.48	$ 1.77	$ 2.01	$ 2.20	$ 2.55	$ 3.29	$ 4.52	$ 5.91	$ 7.29	$ 11.76	$ 5.58	$ 19.40
10	0.99	1.85	2.50	2.99	3.28	3.53	4.58	5.71	7.21	9.42	11.63	17.20	22.99	28.78
15	1.20	2.27	2.86	3.51	4.30	5.04	6.62	8.29	10.93	13.44	15.95	23.17	29.74	36.30
20	1.24	2.42	3.20	4.22	5.27	6.22	8.21	10.70	14.61	18.93	23.25	31.45	46.53	61.91
25	1.29	2.64	3.75	4.93	6.19	7.54	10.06	14.02	18.96	24.37	29.78	47.93	70.17	92.40
30	1.38	2.87	4.30	5.71	7.19	8.57	12.26	18.57	28.83	31.04	41.78	69.51	96.46	132.40
35	1.57	3.18	4.79	6.41	8.11	10.32	18.30	29.77	45.48	47.67	59.85	99.96		
40	1.72	3.55	6.12	9.16	12.78	17.18	28.12	43.38	61.62	79.34	93.06	129.09		
45	2.65	5.91	9.76	14.04	19.17	25.21	40.63	60.91	83.55	103.93	124.30			
50	3.97	8.59	13.86	19.58	26.57	34.23	55.83	81.37	108.22					
55	5.55	11.66	18.64	26.31	35.31	44.87								
60	7.34	15.24	24.09	33.94	42.29	57.13								
65	9.47	19.56	30.56	42.99										
70	12.08	24.85	38.38	54.30										

Note: If speed exceeds maximum speed for which a cost is shown, then cost of highest speed is assumed by the analysis program.

Table B5

EXCESS RUNNING COST AT UNIFORM SPEED ON HORIZONTAL CURVES ABOVE COST ON TANGENTS FOR 12-KIP SINGLE-UNIT TRUCKS
(Dollars per 1,000 Vehicle-Miles)

Speed	Degree of Horizontal Curvature														
(mph)	1	2	3	4	5	6	8	10	12	14	16	18	20	25	30
5	$ 1.45	$ 2.72	$ 3.67	$ 4.43	$ 4.90	$ 5.20	$ 6.03	$ 7.43	$ 8.83	$ 10.18	$ 11.55	$ 12.86	$ 14.15	$ 17.15	$ 19.73
10	2.63	4.81	6.50	7.76	8.49	9.12	11.86	14.59	17.43	20.21	22.96	25.77	27.81	35.09	41.60
15	3.26	5.92	7.89	9.30	11.84	14.28	18.40	22.62	27.13	31.34	36.43	40.96	45.78	57.51	71.88
20	3.15	5.65	8.38	11.18	14.46	17.29	23.22	29.62	35.88	42.28	48.86	55.41	62.88	87.42	117.63
25	3.23	5.79	9.59	12.77	16.56	19.94	28.16	36.96	45.78	56.11	71.94	87.92	104.96	149.72	163.36
30	3.42	7.25	10.78	14.38	18.89	23.14	33.98	47.98	70.89	95.55	120.41	146.73	174.19		
35	3.77	7.68	11.47	15.94	21.48	28.02	51.28	77.33	110.63	144.73	180.19	217.97	259.67		
40	3.97	8.24	14.28	23.13	34.64	47.03	76.94	113.77	160.43	208.02	259.08	309.36			
45	6.41	14.18	24.30	36.80	52.91	70.66	110.68	156.32	220.97	305.95					
50	9.84	21.24	35.99	54.40	76.68	99.99	152.12	210.70	292.87						
55	13.98	29.84	49.33	67.12	103.60	135.24	203.81	270.37							
60	18.67	39.74	64.24	90.84	135.53	179.79	257.36								

Note: If speed exceeds maximum speed for which a cost is shown, then cost of highest speed is assumed by the analysis program.

Table B6

EXCESS RUNNING COST AT UNIFORM SPEED ON HORIZONTAL CURVES ABOVE COST ON TANGENTS FOR 54-KIP, 3-S2 DIESEL TRUCKS
(Dollars per 1,000 Vehicle-Miles)

Speed	Degree of Horizontal Curvature													
(mph)	1	2	3	4	5	6	8	10	12	14	16	20	25	30
5	$ 4.06	$ 7.99	$ 11.47	$ 14.51	$ 16.71	$ 18.73	$ 23.59	$ 27.26	$ 31.21	$ 35.07	$ 38.87	$ 46.33	$ 54.94	$ 76.00
10	6.98	13.06	18.12	22.04	24.66	27.00	35.08	42.72	50.21	57.24	64.33	78.95	95.21	188.14
15	8.67	15.68	21.09	24.95	30.64	36.09	47.12	57.87	68.68	79.63	90.60	113.23	142.37	193.45
20	8.26	14.86	22.18	29.30	36.53	43.16	56.78	70.42	85.67	99.09	115.21	148.10	211.64	290.66
25	8.59	15.26	25.40	33.53	46.02	49.72	66.17	82.26	102.00	124.40	162.72	244.40	362.58	493.42
30	9.00	18.95	28.33	37.40	47.15	56.21	75.87	104.15	154.92	208.67	266.13	386.78		
35	10.09	20.38	30.50	39.80	51.59	64.67	112.64	170.95	240.53	314.01	391.72			
40	10.88	22.41	38.90	59.04	83.68	111.21	213.74	257.39	350.24	450.97	557.51			
45	17.61	39.33	64.79	94.56	129.52	167.64	257.41	363.40	487.69	605.74				
50	27.59	59.83	96.54	136.48	185.01	236.20	351.41	585.96						
55	40.11	85.08	134.86	174.29	253.78	321.40								
60	54.88	115.02	181.87											

Note: If speed exceeds maximum speed for which a cost is shown, then cost of highest speed is assumed by the analysis program.

Table B7

Consumer Price Inflation (CPI) Index

From	To																		
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1970	1.000	1.043	1.078	1.144	1.270	1.386	1.466	1.561	1.680	1.869	2.122	2.342	2.486	2.566	2.675	2.770	2.824	2.927	3.046
1971	0.958	1.000	1.033	1.097	1.217	1.328	1.405	1.496	1.609	1.791	2.035	2.245	2.382	2.458	2.563	2.654	2.708	2.806	2.921
1972	0.928	0.968	1.000	1.062	1.179	1.286	1.361	1.448	1.559	1.735	1.971	2.174	2.307	2.381	2.482	2.571	2.620	2.717	2.828
1973	0.874	0.911	0.941	1.000	1.110	1.211	1.281	1.364	1.467	1.633	1.856	2.047	2.173	2.243	2.338	2.421	2.469	2.558	2.662
1974	0.787	0.821	0.848	0.901	1.000	1.091	1.154	1.229	1.322	1.472	1.672	1.844	1.956	2.019	2.105	2.180	2.224	2.305	2.399
1975	0.721	0.752	0.777	0.826	0.916	1.000	1.058	1.126	1.212	1.349	1.532	1.690	1.792	1.850	1.929	1.997	2.038	2.112	2.198
1976	0.682	0.712	0.736	0.781	0.866	0.945	1.000	1.065	1.145	1.275	1.449	1.598	1.696	1.750	1.824	1.889	1.926	1.997	2.078
1977	0.641	0.668	0.690	0.733	0.814	0.888	0.939	1.000	1.076	1.198	1.361	1.501	1.594	1.645	1.715	1.776	1.809	1.876	1.952
1978	0.595	0.621	0.642	0.682	0.756	0.825	0.873	0.929	1.000	1.113	1.265	1.395	1.479	1.527	1.592	1.648	1.681	1.742	1.813
1979	0.535	0.558	0.576	0.612	0.679	0.741	0.784	0.835	0.898	1.000	1.135	1.253	1.330	1.373	1.431	1.482	1.511	1.566	1.630
1980	0.471	0.491	0.508	0.539	0.598	0.653	0.690	0.735	0.791	0.881	1.000	1.103	1.171	1.209	1.260	1.305	1.331	1.379	1.436
1981	0.427	0.445	0.460	0.489	0.542	0.592	0.626	0.666	0.717	0.798	0.907	1.000	1.062	1.096	1.142	1.183	1.206	1.250	1.301
1982	0.402	0.420	0.434	0.460	0.511	0.558	0.590	0.628	0.676	0.752	0.853	0.942	1.000	1.032	1.075	1.114	1.136	1.178	1.226
1983	0.390	0.406	0.420	0.446	0.495	0.540	0.571	0.608	0.655	0.728	0.827	0.913	0.970	1.000	1.043	1.080	1.100	1.141	1.187
1984	0.374	0.390	0.403	0.428	0.475	0.518	0.548	0.584	0.628	0.699	0.793	0.876	0.930	0.960	1.000	1.036	1.056	1.094	1.139
1985	0.361	0.376	0.389	0.413	0.458	0.500	0.529	0.564	0.606	0.675	0.766	0.846	0.898	0.926	0.966	1.000	1.019	1.057	1.100
1986	0.354	0.369	0.382	0.405	0.450	0.491	0.519	0.553	0.595	0.662	0.751	0.829	0.880	0.909	0.947	0.981	1.000	1.037	1.079
1987	0.342	0.356	0.368	0.391	0.434	0.474	0.501	0.533	0.574	0.639	0.725	0.800	0.849	0.876	0.914	0.946	0.964	1.000	1.041
1988	0.328	0.342	0.354	0.376	0.417	0.455	0.481	0.512	0.552	0.614	0.697	0.769	0.816	0.842	0.878	0.909	0.927	0.961	1.000

Source:

U.S. Department of Labor, Bureau of Labor Statistics, Monthly Labor Review, Washington, DC, monthly.

APPENDIX C: USER'S GUIDE TO THE ANALYSIS PROGRAMS

This section explains how to use the exclusive vehicle facility analysis program. The analysis program can be run in either of two modes called Level 1 and Level 2. Level 1 is used to obtain a sketch evaluation of many alternatives for a given highway section with few user inputs. Level 2 is used to conduct a more thorough evaluation of a particular case with more detailed inputs.

The analysis programs were written in BASIC and compiled into .EXE executable files. Both the Level 1 and Level 2 programs operate in essentially the same manner. They both read data input files with .PRN and .DAT extensions, and they both write to output files with .OUT extensions. The .PRN files are written from each spreadsheet user interface based on user inputs. The .DAT files contain the tables of vehicle operating costs from AASHTO (1977) as shown in Appendix B. Both programs write results to screen display and to disk files. The output files are called LEVEL1.OUT and LEVEL2.OUT from the Level 1 and Level 2 programs, respectively. Results are sent to disk files so that they can be saved. Each of these output files contains the same information written by these programs to the screen display.

Below are listed all files on the two 360 kilobyte distribution diskettes for the Level 1 and Level 2 analysis programs. Create a program subdirectory on the hard disk (probably C:\EVFS), and copy all files from these distribution diskettes into it.

filename	ext	bytes	description
LRUNCOST	DAT	2464	LV running cost as affected by grades
SRUNCOST	DAT	2470	SU running cost as affected by grades
CRUNCOST	DAT	2464	CV running cost as affected by grades
LCRVCOST	DAT	3856	LV running cost as affected by curves
CCRVCOST	DAT	3856	SU running cost as affected by curves
SCRVCOST	DAT	3854	CV running cost as affected by curves
LEVEL1	BAT	139	Level 1 DOS batch file to execute
LEVEL1	WK1	8759	Level 1 spreadsheet user interface
LEVEL1	PRN	84	Level 1 user inputs as a disk file
LEVEL1	BAS	62750	Level 1 source code written in BASIC
LV1	EXE	80709	Level 1 compiled executable program
LV1EXD	BAS	62050	Level 1 program without screen display
LV1EXD	EXE	68753	Level 1 program compiled w/o display
LEVEL1	OUT	1776	Level 1 results output as a disk file

LEVEL2	BAT	130	Level 2 DOS batch file to execute
LEVEL2	WK1	40777	Level 2 spreadsheet user interface
CASE	PRN	1024	Level 2 case description as a disk file
SITEINFO	PRN	110	Level 2 site information as a disk file
TRAFFIC	PRN	266	Level 2 traffic char's as a disk file
OTHER	PRN	30	Level 2 other parameters as a disk file
FACILITY	PRN	266	Level 2 facility costs as a disk file
USERCOST	PRN	285	Level 2 user cost inputs as a disk file
LEVEL2	BAS	68754	Level 2 source code written in BASIC
LV2	EXE	90785	Level 2 compiled executable program
LV2EXD	BAS	62683	Level 2 program without screen display
LV2EXD	EXE	72673	Level 2 program compiled w/o display
LEVEL2	OUT	2737	Level 2 results output as a disk file

An extra version of each program is listed above that does not produce any screen display of results. Each version with screen display was written for a VGA monitor. Each version with screen display will produce an error message and terminate if run on a computer without a VGA monitor. To run the program without a VGA monitor, execute LV1EXD and LV2EXD instead of LV1 and LV2 after entering your inputs and exiting the spreadsheets. The output files from either program can be viewed with any sort of screen list utility or the DOS "type" command.

Instructions to Using the Level 1 Analysis Program

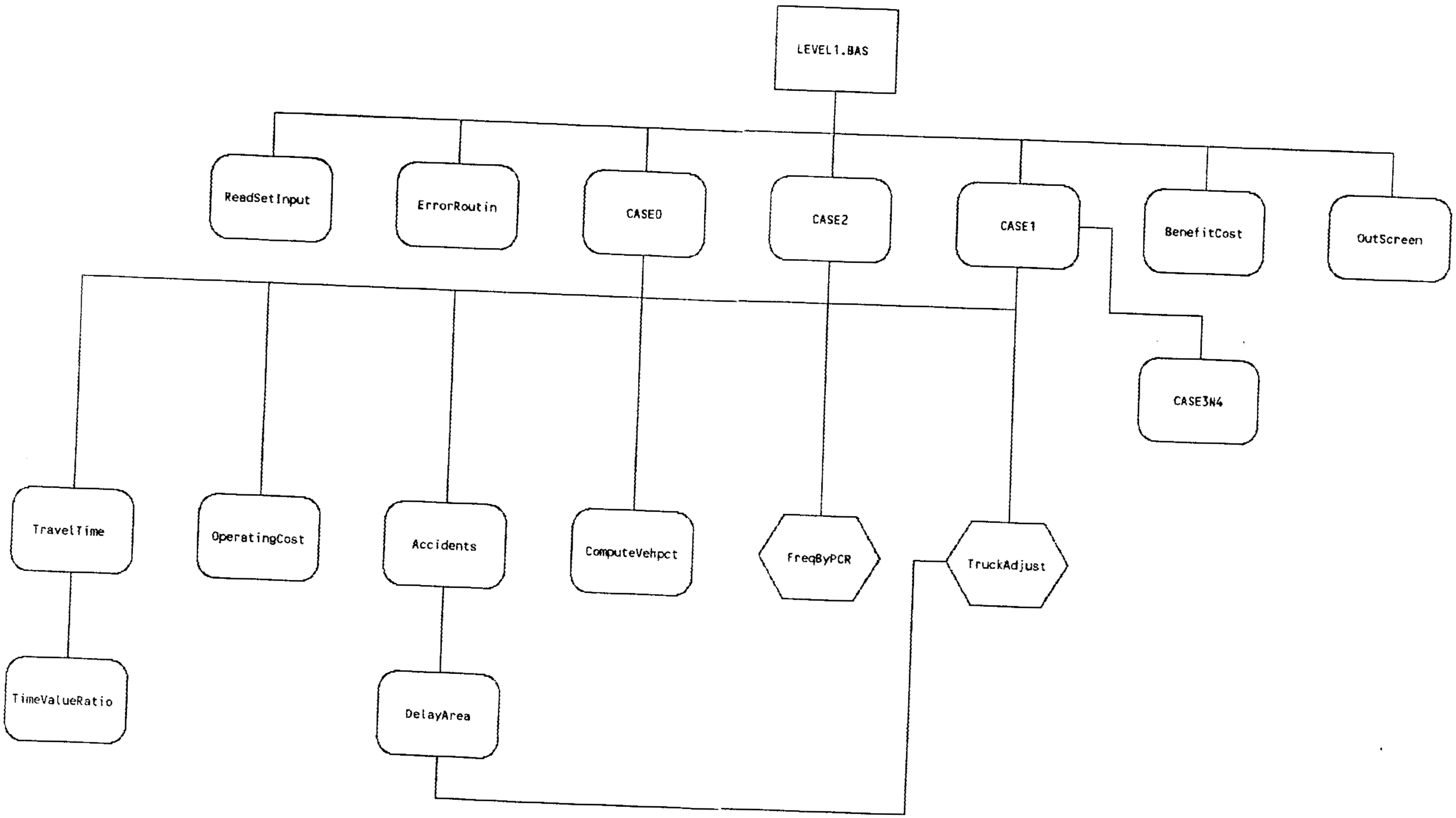
- **Step 1**: Enter the command "Level1", which will enter you into Lotus 1-2-3 if it is on the path. If Lotus 1-2-3 is not on the path, or has not been set up to be accessed in a different manner such as with the SUBST command, then get help in configuring your system.
- **Step 2**: Use the /FD command in Lotus 1-2-3 to set your default file directory to C:\EVFS, or whatever you called it.
- **Step 3**: Use the /FR command in Lotus 1-2-3 to retrieve the Level1 spreadsheet user interface, and follow menu instructions for entering data.
- **Step 4**: After entering data to the Level1 spreadsheet user interface, decide whether to save the spreadsheet with your most current inputs. Then, exit the spreadsheet and enter the command LV1 or LV1EXD to execute the Level 1 analysis program with or without VGA display. View the results, and return to Step 1 to make another run of Level 1 if desired. Before making another run of Level 1, rename the LEVEL1.OUT file to something else if you want to save the current results, or print the file to hardcopy.

Instructions to Using the Level 2 Analysis Program

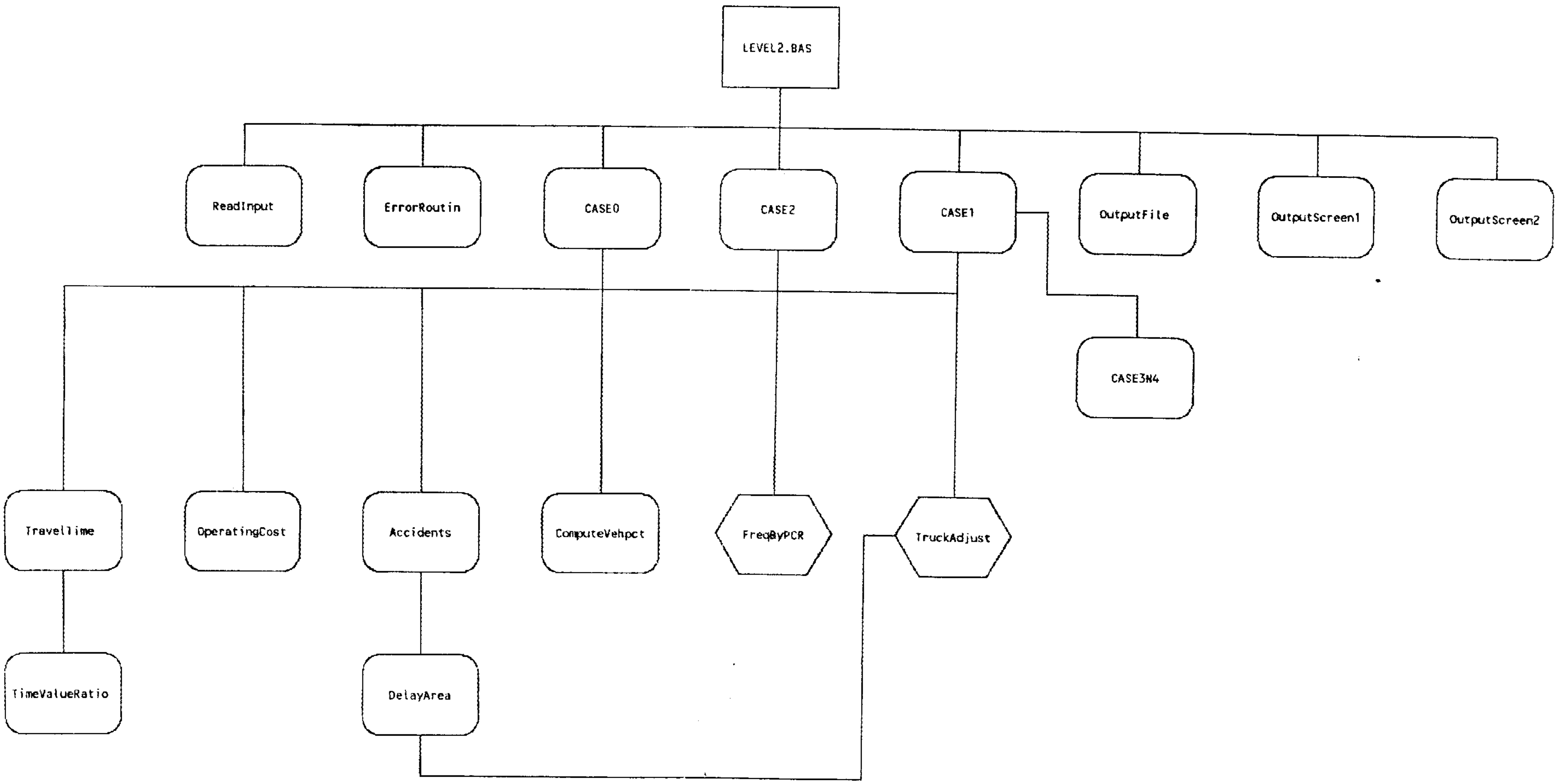
- **Step 1**: Enter the command "Level2", which will enter you into Lotus 1-2-3 if it is on the path. If Lotus 1-2-3 is not on the path, or has not been set up to be accessed in a different manner such as with the SUBST command, then get help in configuring your system.
- **Step 2**: Use the /FD command in Lotus 1-2-3 to set your default file directory to C:\EVFS, or whatever you called it.
- **Step 3**: Use the /FR command in Lotus 1-2-3 to retrieve the Level2 spreadsheet user interface, and follow menu instructions for entering data.
- **Step 4**: After entering data to the Level2 spreadsheet user interface, use the CREATE PRN FILES main menu option to create all new input files to the analysis program. Then, prepare to use the RUN ANALYSIS main menu option to shell out of the spreadsheet and run the Level 2 analysis program. Unlike Level 1, you will be able to reenter the spreadsheet with all current inputs intake, so you may not want to save the spreadsheet with your most current inputs at this time until after viewing the results.
- **Step 5**: Having shelled out of the spreadsheet, enter command LV2 or LV2EXD to execute the Level 2 analysis program with or without VGA display. After examining the results, reenter the spreadsheet to make further input adjustments by entering the "EXIT" command at the DOS prompt. Before making another run of Level 2, rename the LEVEL2.OUT file to something else if you want to save the current results, or print the file to hardcopy. (Note: Even if you're done, reenter Lotus 1-2-3, and then exit with the menu option so as to clear Lotus 1-2-3 from random access memory.)

Complete source code listings of LEVEL1.BAS and LEVEL2.BAS are provided in Appendix D.

APPENDIX D: PROGRAM STRUCTURE CHARTS AND LISTINGS



STRUCTURE CHART OF SKETCH ANALYSIS PROGRAM (LEVEL1.BAS)



STRUCTURE CHART OF DETAILED ANALYSIS PROGRAM (LEVEL2.BAS)

```
'*************************************************************************
'*************************************************************************
'**                                                                     **
'** TITLE:        SKETCH ANALYSIS FOR EXCLUSIVE VEHICLE FACILITIES       **
'**                                                                     **
'** DESCRIPTION:  THE SKETCH ANALYSIS FORMAT READS A FEW INPUT DATA VALUES**
'**              AND ESTIMATES THE FOLLOWING:                           **
'**              1. Net Benefits                                        **
'**              2. Net Costs                                           **
'**              3. Net Present Value                                   **
  =>      **
'**              4. Benefit/Cost Ratio                                  **
'**              FOR EACH ONE OF THE FOLLOWING CASES:                   **
'**              CASE 0 - DO NOTHING                                    **
'**              CASE 1 - DESIGNATE EXISTING LANES FOR MIXED, LIGHT AND **
'**                       HEAVY VEHICLES.                               **
'**              CASE 2 - ADD MIXED-VEHICLE LANES (NO RESTRICTIONS).    **
'**              CASE 3 - ADD NONBARRIER SEPARATED LANES AND DESIGNATE  **
'**                       NEW AND EXISTING LANES FOR MIXED, LIGHT AND   **
'**                       HEAVY LANES.                                  **
'**              CASE 4 - ADD BARRIER SEPARATED LANES AND DESIGNATE NEW **
  =>
'**                       AND EXISTING LANES FOR MIXED, LIGHT AND HEAVY **
'**                       LANES.                                        **
'**                                                                     **
'** DEVELOPED BY: ANJU RATHI                                             **
'**              BRUCE N. JANSON       DEC. 1989                        **
'**                                                                     **
'*************************************************************************
'*************************************************************************


'************************************************
'**   SUBROUTINE DECLARATION SECTION          **
'************************************************
DECLARE SUB CASE0 ()
DECLARE SUB CASE1 ()
DECLARE SUB CASE2 ()
DECLARE SUB CASE3N4 (M4RFreq!, L4RFreq!, H4RFreq!, FourRFreq!)
DECLARE SUB ReadSetInput (ErrorCode%)
DECLARE SUB ErrorRoutine (ErrorCode%)
DECLARE SUB ComputeVehpct (yr%)
DECLARE SUB BenefitCost (NB!, NC!, NCw!, NP!, BC!, NPw!, BCw!)
DECLARE SUB DelayArea (Volume!, RemainLanes%, ClrDur!, Spct!, Cpct!, DelayTime!)
DECLARE SUB Accidents (VMT AS DOUBLE, LVpct!, SUpct!, CVpct!, MV!, HV!, LV!, Lca
  => p AS DOUBLE, Mcap AS DOUBLE)
DECLARE SUB TravelTime (Volume AS DOUBLE, Capac AS DOUBLE, TrvTime!, ActualMPH%,
  =>  PkS, CFS, LHS)
DECLARE SUB OperatingCost (PkMPH%, OfPkMPH%, SUpct!, CVpct!, PkVMT AS DOUBLE, Of
  => PkVMT AS DOUBLE, OperCost AS DOUBLE, LHS)
DECLARE SUB TimeValueRatio (CLVRatio!, FLVRatio!, CSURatio!, FSURatio!, CCVRatio
  => !, FCVRatio!)
DECLARE SUB OutScreen ()

'************************************************
'**  FUNCTION DECLARATION SECTION             **
'************************************************
DECLARE FUNCTION FreqByPCR! (TotEsal!)
DECLARE FUNCTION TruckAdjustFactor! (TrafficPerHour AS DOUBLE, VType$, VehPct!)

'************************************************
'**  VARIABLE TYPES SECTION                   **
'************************************************


TYPE CostType
     LV          AS SINGLE
     SU          AS SINGLE
     CV          AS SINGLE
END TYPE

DEFINT A-Z           'Default variable type is integer
CONST true = -1
      false = 0

OPEN "LEVEL1.PRN" FOR INPUT AS #1        'User Input
OPEN "LRUNCOST.DAT" FOR INPUT AS #2      'Operating cost for LVs
OPEN "SRUNCOST.DAT" FOR INPUT AS #3      'Operating cost for SUs
OPEN "CRUNCOST.DAT" FOR INPUT AS #4      'Operating cost for CVs
OPEN "LCRVCOST.DAT" FOR INPUT AS #5      'Excess operating cost for LVs due to cu
  => rvature
OPEN "SCRVCOST.DAT" FOR INPUT AS #6      'Excess operating cost for SUs due to cu
  => rvature
OPEN "CCRVCOST.DAT" FOR INPUT AS #7      'Excess operating cost for CVs due to cu
  => rvature

'************************************************************************
'**  INPUT ARRAYS AND VARIABLES SECTION                                 *
'************************************************************************
DIM SHARED RunCost(5 TO 80, -8 TO 8)          AS CostType
DIM SHARED CurveCost(5 TO 80, 1 TO 30)        AS CostType

'          ****************************************
'          *      LEVEL1.PRN (INPUT DATA)         *
'          ****************************************
DIM SHARED LocationType$            ' Location Type (Rural, Suburban, Urban)
DIM SHARED SectionLength!           ' Length of the section
DIM SHARED NumIntersection%         ' Number of Intersections in section
DIM SHARED CML%                     ' Num. of Current Mixed Lanes
DIM SHARED NL%                      ' Num. of newly added Lanes
DIM SHARED RWLanes%                 ' Num. of new lanes of right-of-way to acquire
DIM SHARED Yrs        AS INTEGER    ' Num. of years for analysis
DIM SHARED DRate      AS SINGLE     ' Discount rate

'**********************************************************************
'* THE FOLLOWING DATA VALUES ARE ESTIMATED USING INPUT DATA VALUES *
'**********************************************************************
'          ****************************************
'          *           SITE RELATED DATA          *
'          ****************************************
DIM SHARED FML%                         ' Num. of Future Mixed Lanes
DIM SHARED FLL%                         ' Num. of Future Light Use Lanes
DIM SHARED FHL%                         ' Num. of Future Heavy Use Lanes
DIM SHARED TL%                          ' Num. of total Future Lanes
DIM SHARED BarrierSeparated$            ' Barrier Seperation Flag (Y, N)
DIM SHARED Grade%                       ' Road Gradient level
DIM SHARED Curvature%                   ' Road Curvature
DIM SHARED YrsConstruc AS INTEGER       ' Number of years for constrution

'          ****************************************
'          *       TRAFFIC RELATED DATA           *
'          ****************************************
DIM SHARED CADT     AS LONG        ' Current Average Daily Traffic
DIM SHARED FPkIV    AS DOUBLE      ' Future Average annual increase in Peak hour
  => ADT/hr
DIM SHARED FOfPkIV AS DOUBLE       ' Future Average annual increase in OfPeak hou
  => r ADT/hr
DIM SHARED CPkV     AS DOUBLE      ' Current Peak volume per hour
DIM SHARED FPkV     AS DOUBLE      ' Future Peak volume per hour
DIM SHARED COfPkV   AS DOUBLE      ' Current Off-Peak volume per hour
DIM SHARED FOfPkV   AS DOUBLE      ' Future Off-Peak volume per hour
DIM SHARED LVmph    AS INTEGER     ' Speed limit for Light vehicles
DIM SHARED HVmph    AS INTEGER     ' Speed limit for heavy vehicles
DIM SHARED CLVpct   AS SINGLE      ' Light vehicle percentage for current volume
```

```
DIM SHARED FLVpct  AS SINGLE      ' Light vehicle percentage for future volume
DIM SHARED CSUpct  AS SINGLE      ' Single-unit vehicle percentage for current v
  => olume
DIM SHARED FSUpct  AS SINGLE      ' Single-unit vehicle percentage for future vo
  => lume
DIM SHARED CCVpct  AS SINGLE      ' Combination vehicle percentage for current v
  => olume
DIM SHARED FCVpct  AS SINGLE      ' Combination vehicle percentage for future vo
  => lume
DIM SHARED LVincr  AS SINGLE      ' Yearly increase/decrease in Light Vehicles
DIM SHARED SUincr  AS SINGLE      ' Yearly increase/decrease in Single Unit Vehi
  => cles
DIM SHARED CVincr  AS SINGLE      ' Yearly increase/decrease in Combination Vehi
  => cles

'         ***************************************
'         *    FACILITY COSTS RELATED DATA     *
'         ***************************************
DIM SHARED ConstrucCostPM       AS LONG     ' Construction cost per mile
DIM SHARED ConstrucCostPIntg    AS LONG     ' Construction cost per interchange
DIM SHARED RightOfWayPM         AS LONG     ' Right of Way cost per mile
DIM SHARED bConstrucCostPM      AS LONG     ' Construction cost per mile with barr
  => ier
DIM SHARED bConstrucCostPIntg AS LONG     ' Construction cost per interchange wi
  => th barrier
DIM SHARED bRightOfWayPM        AS LONG     ' Right of Way cost per mile with barr
  => ier
DIM SHARED MajorResurfcPM       AS LONG     ' Major Resurfacing per mile
DIM SHARED PSIdelta             AS SINGLE   ' PSI parameter delta in millions of 1
  => 8-kip ESALs
DIM SHARED PSIbeta              AS SINGLE   ' PSI parameter beta used as the power
  =>  exponent
DIM SHARED PSIMin               AS SINGLE   ' Minimum allowable PSI (0-5 decimals
  => included)
DIM SHARED PSIResurf            AS SINGLE   ' PSI at which resurfacing is desired
  => (0-5 decimals included)
DIM SHARED AvgLEsal             AS SINGLE   ' Average ESALs per Light vehicle
DIM SHARED AvgSEsal             AS SINGLE   ' Average ESALs per Single unit vehicl
  => e
DIM SHARED AvgCEsal             AS SINGLE   ' Average ESALs per Combination vehicl
  => e

'         ***************************************
'         *     USER COSTS RELATED DATA        *
'         ***************************************
DIM SHARED LVTimeValuePH      AS SINGLE   ' Time-value/hr. for LV
DIM SHARED SUtimeValuePH      AS SINGLE   ' Time-value/hr. for SU
DIM SHARED CVtimeValuePH      AS SINGLE   ' Time-value/hr. for CV
DIM SHARED LVaccPLVmvm        AS SINGLE   ' Accident rate per LV million vehicle
  => miles for light vehicles
DIM SHARED SUaccPSUmvm        AS SINGLE   ' Accident rate per SU million vehicle
  => miles for single-unit vehiles
DIM SHARED CVaccPCVmvm        AS SINGLE   ' Accident rate per CV million vehicle
  => miles for combination vehicles
DIM SHARED AccCostPFatal      AS LONG     ' Accident cost per fatal accident
DIM SHARED AccCostPInjury     AS LONG     ' Accident cost per injury accident
DIM SHARED AccCostPPDO        AS LONG     ' Accident cost per Property damage onl
  => y accident
DIM SHARED Block0Lanes        AS SINGLE   ' Percent of total accidents blocking n
  => o lanes.
DIM SHARED Block1Lanes        AS SINGLE   ' Percent of total accidents blocking 1
  =>  lanes.
DIM SHARED Block2Lanes        AS SINGLE   ' Percent of total accidents blocking 2
  =>  lanes.
DIM SHARED LClrDur            AS SINGLE   ' Avg. clearing duration for non-truck
  => involvements.
DIM SHARED HClrDur            AS SINGLE   ' Avg. clearing duration for truck invo
  => lvements.
DIM SHARED MaxQlen            AS SINGLE   ' Maximum queue length before traffic d
  => iversion.

'***************************************************************************
'**  OUTPUT VARIABLES SECTION                                             **
'***************************************************************************
DIM SHARED CPkCapacity    AS DOUBLE
DIM SHARED COfPkCapacity  AS DOUBLE
DIM SHARED FPkCapacity    AS DOUBLE
DIM SHARED FOfPkCapacity  AS DOUBLE
DIM SHARED FPkVolume      AS DOUBLE
DIM SHARED FOfPkVolume    AS DOUBLE
DIM SHARED COCTrvTime     AS DOUBLE
DIM SHARED COC4RCost      AS DOUBLE
DIM SHARED COCRunCost     AS DOUBLE
DIM SHARED COCAccCost     AS DOUBLE
DIM SHARED COCDelayCost   AS DOUBLE
DIM SHARED COCTotVMT!
DIM SHARED COCAccidents!
DIM SHARED COCAvgAccCost!
DIM SHARED COCAvgDelayCost!
DIM SHARED COCAvgTrvSpeed!
DIM SHARED COFAccCost     AS DOUBLE
DIM SHARED COFRunCost     AS DOUBLE
DIM SHARED COF4RCost      AS DOUBLE
DIM SHARED COFTrvTime     AS DOUBLE
DIM SHARED COFDelayCost   AS DOUBLE
DIM SHARED COFTotVMT!
DIM SHARED COFAccidents!
DIM SHARED COFAvgAccCost!
DIM SHARED COFAvgDelayCost!
DIM SHARED COFAvgTrvSpeed!
DIM SHARED FTrvTime       AS DOUBLE
DIM SHARED F4RCost        AS DOUBLE
DIM SHARED FRunCost       AS DOUBLE
DIM SHARED FDelayCost     AS DOUBLE
DIM SHARED FTotVMT!
DIM SHARED FAccidents!
DIM SHARED FAvgAccCost!
DIM SHARED FAvgDelayCost!
DIM SHARED FAvgTrvSpeed!
DIM SHARED ConstrucCost   AS DOUBLE
DIM SHARED RightOfWayCost AS DOUBLE
DIM SHARED LVaccCost      AS DOUBLE
DIM SHARED HVaccCost      AS DOUBLE
DIM SHARED MVaccCost      AS DOUBLE
DIM SHARED FAccCost       AS DOUBLE
DIM SHARED LVDCost        AS DOUBLE
DIM SHARED HVDCost        AS DOUBLE
DIM SHARED MVDCost        AS DOUBLE
DIM SHARED MNumAcc!
DIM SHARED LNumAcc!
DIM SHARED HNumAcc!
DIM SHARED NPw1!
DIM SHARED BCw1!
DIM SHARED NPw2!
DIM SHARED BCw2!
DIM SHARED NPw3!
DIM SHARED BCw3!
DIM SHARED NPw4!
DIM SHARED BCw4!
DIM SHARED NP1!
DIM SHARED BC1!
DIM SHARED NP2!
```

```
DIM SHARED BC2!
DIM SHARED NP3!
DIM SHARED BC3!
DIM SHARED NP4!
DIM SHARED BC4!
DIM SHARED NB0!
DIM SHARED NC0!
DIM SHARED NCw0!
DIM SHARED NB1!
DIM SHARED NC1!
DIM SHARED NCw1!
DIM SHARED NB2!
DIM SHARED NC2!
DIM SHARED NCw2!
DIM SHARED NB3!
DIM SHARED NC3!
DIM SHARED NCw3!
DIM SHARED NB4!
DIM SHARED NC4!
DIM SHARED NCw4!

'*************************************************************************
'**                                                                     **
'** CODE BEGINS HERE !!                                                 **
'**                                                                     **
'*************************************************************************
       CLS
       SCREEN 12
       ErrorCode% = 0
       CALL ReadSetInput(ErrorCode%)
       IF (ErrorCode% <> 0) THEN
          CALL ErrorRoutine(ErrorCode%)
          GOTO Done
       END IF

       IF (CML% = 0) AND (FML% = 0) AND (FLL% = 0) AND (FHL% = 0) THEN
          PRINT "Analyzation can not be performed, since all lanes = 0"
          GOTO Done
       END IF
'CASE 0
       FML% = CML%
       FLL% = 0
       FHL% = 0
       CALL CASE0
       NB0! = COFTrvTime + COFAccCost + COFDelayCost
       NCw0! = COF4RCost + COFRunCost + ConstrucCost + RightOfWayCost
       NC0! = COF4RCost + ConstrucCost + RightOfWayCost

'CASE 1
       FLL% = INT(CML% / 2)
       REMAINDER% = CML% MOD 2
       FML% = FLL% + REMAINDER%
       FHL% = 0
       CALL CASE0
       CALL CASE1
       CALL BenefitCost(NB1!, NC1!, NCw1!, NP1!, BC1!, NPw1!, BCw1!)

'CASE 2
       FML% = TL%
       FLL% = 0
       FHL% = 0
       CALL CASE0
       CALL CASE2
       CALL BenefitCost(NB2!, NC2!, NCw2!, NP2!, BC2!, NPw2!, BCw2!)

'CASE 3
       FLL% = INT(TL% / 2)
       REMAINDER% = TL% MOD 2
       FML% = FLL% + REMAINDER%
       FHL% = 0
       CALL CASE0
       CALL CASE1
       CALL BenefitCost(NB3!, NC3!, NCw3!, NP3!, BC3!, NPw3!, BCw3!)

'CASE 4
       BarrierSeparated$ = "Y"
       CALL CASE0
       CALL CASE1
       CALL BenefitCost(NB4!, NC4!, NCw4!, NP4!, BC4!, NPw4!, BCw4!)

       CALL OutScreen

Done:  CLOSE #1
       CLOSE #2
       CLOSE #3
       CLOSE #4
       CLOSE #5
       CLOSE #6
       CLOSE #7

END

'*************************************************************************
'*                         SUB PROCEDURE Accidents                       *
'*                                                                       *
'* Operation:    Computes number of accidents as well as accident        *
'*               costs for light, heavy and mixed vehicles.              *
'*                                                                       *
'* Parameter(s): VMT - Vehicle miles travelled for the current year.     *
'*               LVpct! - Percentage of light vehicles.                  *
'*               HVpct! - Percentage of single unit vehicles.            *
'*               CVpct! - Percentage of combination vehicles.            *
'*               MV!    - Mixed vehicle volume.                          *
'*               HV!    - Heavy vehicle volume.                          *
'*               LV!    - Light vehicle volume.                          *
'*               Lcap   - Light vehicle lane(s) capacity.                *
'*               Mcap   - Heavy or Mixed vehicle lane(s) capacity        *
'*                        where applicable.                              *
'*                                                                       *
'*************************************************************************
SUB Accidents (VMT AS DOUBLE, LVpct!, SUpct!, CVpct!, MV!, HV!, LV!, Lcap AS DOU
  => BLE, Mcap AS DOUBLE)

CONST lvClnRep = 1000
      suClnRep = 5000
      cvClnRep = 10000

DIM LVCost     AS DOUBLE
DIM SUCost     AS DOUBLE
DIM SUaccCost  AS DOUBLE
DIM CVCost     AS DOUBLE
DIM CVaccCost  AS DOUBLE
DIM SUCVCost   AS DOUBLE
DIM LVSUCost   AS DOUBLE
DIM LVCVCost   AS DOUBLE
DIM SUDCost    AS DOUBLE
DIM CVDCost    AS DOUBLE
```

```
DIM LVSUDCost   AS DOUBLE
DIM LVCVDCost   AS DOUBLE
DIM SUCVDCost   AS DOUBLE

'Compute millions of miles travelled by each vehicle type.
      Vlv! = VMT * LVpct! / 1000000
      Vsu! = VMT * SUpct! / 1000000
      Vcv! = VMT * CVpct! / 1000000

'Look for the definations of the following variables in the report.
      Rlv1! = LVaccPLVmvm * .199 / .959
      Rlv2! = LVaccPLVmvm * .671 / .959
      Rlv3! = LVaccPLVmvm * .02 / .959
      Rlv4! = LVaccPLVmvm * .069 / .959

      Rsu1! = SUaccPSUmvm * .061 / .69
      Rsu2! = SUaccPSUmvm * .019 / .69
      Rsu3! = SUaccPSUmvm * .566 / .69
      Rsu4! = SUaccPSUmvm * .044 / .69

      Rcv1! = CVaccPCVmvm * .099 / 1.002
      Rcv2! = CVaccPCVmvm * .035 / 1.002
      Rcv3! = CVaccPCVmvm * .849 / 1.002
      Rcv4! = CVaccPCVmvm * .019 / 1.002

      RLVsu! = (1 / (1 / Rlv3! + 1 / Rsu3!))
      RLVcv! = (1 / (1 / Rlv3! + 1 / Rcv3!))
      RSuCv! = (1 / (1 / Rsu3! + 1 / Rcv3!))


      SUacc! = Vsu! * Rsu1! + Vsu! * Rsu2!
      SUCost = AccCostPFatal * (.032 / 1.951) + AccCostPInjury * (.579 / 1.951)
 =>  + AccCostPPDO * (1.34 / 1.951)
      SUaccCost = SUacc! * (SUCost + suClnRep)

      CVacc! = Vcv! * Rcv1! + Vcv! * Rcv2!
      CVCost = AccCostPFatal * (.028 / 1.787) + AccCostPInjury * (.51 / 1.787)
 => + AccCostPPDO * (1.249 / 1.787)
      CVaccCost = CVacc! * (CVCost + cvClnRep)

      SUCVacc! = (2 * Vsu! * Rsu4! * Vcv! * Rcv4!) / ((Vsu! + Vcv!) * RSuCv!)
      SUCVCost = SUCVacc! * ((SUCost + CVCost + suClnRep + cvClnRep) / 2)

      HVaccCost = SUaccCost + CVaccCost + SUCVCost
      HNumAcc! = SUacc! + CVacc! + SUCVacc!

      IF (FML% <> 0) AND (FLL% <> 0) THEN

'Compute millions of miles travelled by Light vehicles on Light-Vehicle lanes.
         Vlvlv! = ((VMT / 1000000) * Lcap / Mcap) / (1 + Lcap / Mcap)
         Vlvmv! = Vlv! - Vlvlv!

         LVacc! = Vlv! * Rlv1! + Vlv! * Rlv2!
         LVCost = AccCostPFatal * (.013 / 1.134) + AccCostPInjury * (.373 / 1.1
 => 34) + AccCostPPDO * (.748 / 1.134)
         LVaccCost = LVacc! * (LVCost + lvClnRep)

         LVSUacc! = (2 * Vlvmv! * Rlv3! * Vsu! * Rsu3!) / ((Vlvmv! + Vsu!) * RL
 => Vsu!)
         LVSUCost = LVSUacc! * ((LVCost + SUCost + lvClnRep + suClnRep) / 2)

         LVCVacc! = (2 * Vlvmv! * Rlv4! * Vcv! * Rcv3!) / ((Vlvmv! + Vcv!) * RL
 => Vcv!)
         LVCVCost = LVCVacc! * ((LVCost + CVCost + lvClnRep + cvClnRep) / 2)

      ELSE  '(FHL AND FLL) OR (FML) OR (CML)
```



```
         LVacc! = Vlv! * Rlv1! + Vlv! * Rlv2!
         LVCost = AccCostPFatal * (.013 / 1.134) + AccCostPInjury * (.373 / 1.1
 => 34) + AccCostPPDO * (.748 / 1.134)
         LVaccCost = LVacc! * (LVCost + lvClnRep)

         LVSUacc! = (2 * Vlv! * Rlv3! * Vsu! * Rsu3!) / ((Vlv! + Vsu!) * RLVsu!
 => )
         LVSUCost = LVSUacc! * ((LVCost + SUCost + lvClnRep + suClnRep) / 2)

         LVCVacc! = (2 * Vlv! * Rlv4! * Vcv! * Rcv3!) / ((Vlv! + Vcv!) * RLVcv!
 => )
         LVCVCost = LVCVacc! * (LVCost + CVCost + lvClnRep + cvClnRep) / 2
      END IF

      MVaccCost = LVaccCost + HVaccCost + LVSUCost + LVCVCost
      MNumAcc! = LVacc! + HNumAcc! + LVSUacc! + LVCVacc!
      LNumAcc! = LVacc!

'Compute Delay Costs
      TimeRatio! = LVpct! * LVTimeValuePH + SUpct! * SUtimeValuePH + CVpct! * C
 => VtimeValuePH
      VehVolume! = MV! + HV! + LV!

      RemainLanes% = FML% + FHL% + FLL%
      CALL DelayArea(VehVolume!, RemainLanes%, LClrDur, SUpct!, CVpct!, DelayTi
 => me!)
      LVDCost = LVacc! * Block0Lanes * DelayTime! * TimeRatio!

      RemainLanes% = FML% + FHL% + FLL% - 1
      CALL DelayArea(VehVolume!, RemainLanes%, LClrDur, SUpct!, CVpct!, DelayTi
 => me!)
      LVDCost = LVDCost + (LVacc! * Block1Lanes * DelayTime! * TimeRatio!)

      RemainLanes% = FML% + FHL% + FLL% - 2
      CALL DelayArea(VehVolume!, RemainLanes%, LClrDur, SUpct!, CVpct!, DelayTi
 => me!)
      LVDCost = LVDCost + (LVacc! * Block2Lanes * DelayTime! * TimeRatio!)

      RemainLanes% = FML% + FHL% + FLL%
      CALL DelayArea(VehVolume!, RemainLanes%, HClrDur, SUpct!, CVpct!, DelayTi
 => me!)
      HVDCost = (SUacc! + CVacc! + LVSUacc! + LVCVacc! + SUCVacc!) * Block0Lane
 => s * DelayTime! * TimeRatio!

      RemainLanes% = FML% + FHL% + FLL% - 1
      CALL DelayArea(VehVolume!, RemainLanes%, HClrDur, SUpct!, CVpct!, DelayTi
 => me!)
      HVDCost = HVDCost + ((SUacc! + CVacc! + LVSUacc! + LVCVacc! + SUCVacc!) *
 =>  Block1Lanes * DelayTime! * TimeRatio!)

      RemainLanes% = FML% + FHL% + FLL% - 2
      CALL DelayArea(VehVolume!, RemainLanes%, HClrDur, SUpct!, CVpct!, DelayTi
 => me!)
      HVDCost = HVDCost + ((SUacc! + CVacc! + LVSUacc! + LVCVacc! + SUCVacc!) *
 =>  Block2Lanes * DelayTime! * TimeRatio!)

      MVDCost = LVDCost + HVDCost
END SUB

'*************************************************************************
'*                       SUB PROCEDURE BenefitCost                        *
'*                                                                        *
'* Operation:    Computes the following specified as parameters.          *
'*                                                                        *
'* Parameter(s):  NB!  - Net Benefits.                                    *
'*                NC!  - Net Costs.                                       *
```

```
'*              NCw! - Net Costs without the operating costs.         *
'*              NP!  - Net Present Value.                             *
'*              BC!  - Benefit/Cost Ratio.                            *
  =>
'*              NPw! - Net Present Value without the operating costs.*
'*              BCw! - Benefit/Cost Ratio without the operating costs*
'**********************************************************************
SUB BenefitCost (NB!, NC!, NCw!, NP!, BC!, NPw!, BCw!)

NB! = -FTrvTime + COFTrvTime - FAccCost + COFAccCost - FDelayCost + COFDelayCost
NCw! = F4RCost - COF4RCost + FRunCost - COFRunCost + ConstrucCost + RightOfWayCo
  => st
NPw! = NB! - NCw!
IF NCw! > 0 THEN
   BCw! = NB! / NCw!
END IF
   NC! = F4RCost - COF4RCost + ConstrucCost + RightOfWayCost
   NP! = NB! - NC!
   IF NC! > 0 THEN
      BC! = NB! / NC!
   END IF

END SUB

'**********************************************************************
'*                      SUB PROCEDURE CASE0                           *
'*                                                                    *
'* Operation:     Computes all the costs and benefits for case 0 for  *
'*                current and future traffic conditions. All global   *
'*                output varibles for current traffic conditions have *
'*                prefix "COC".  All global output variables for future*
'*                traffic conditions have prefix "COF".               *
'*                                                                    *
'* Parameter(s):  none.                                               *
'**********************************************************************
SUB CASE0

CONST W! = 1          'Lane width clearence assumed to be equal to 1.

DIM VMT       AS DOUBLE
DIM PkVMT     AS DOUBLE
DIM OfPkVMT   AS DOUBLE
DIM Volume    AS DOUBLE
DIM OperCost  AS DOUBLE


       SaveFML% = FML%
       SaveFHL% = FHL%
       SaveFLL% = FLL%

       FML% = CML%
       FHL% = 0
       FLL% = 0

'COMPUTE CURRENT COSTS AND BENEFITS
'Compute CAPACITY for current Mixed traffic
       TSU! = TruckAdjustFactor((CPkV / FML%), "SU", CSUpct)
       TCV! = TruckAdjustFactor((CPkV / FML%), "CV", CCVpct)
       CPkCapacity = 2000 * W! * TSU! * TCV! * FML%

       TSU! = TruckAdjustFactor((COfPkV / FML%), "SU", CSUpct)
       TCV! = TruckAdjustFactor((COfPkV / FML%), "CV", CCVpct)
       COfPkCapacity = 2000 * W! * TSU! * TCV! * FML%

'Compute TRAVEL TIME required for current Light vehicles
       CALL TravelTime((CPkV * CLVpct), (CPkCapacity * CLVpct), CPkTrvTime!, CPk
 => MPH%, "PK", "C", "L")
       CALL TravelTime((COfPkV * CLVpct), (COfPkCapacity * CLVpct), COfPkTrvTime
 => !, COfPkMPH%, "OFPK", "C", "L")
       COCTrvTime = (CPkTrvTime! + COfPkTrvTime!) * (((1 + DRate) ^ Yrs - 1) / (
 => DRate * ((1 + DRate) ^ Yrs)))

'Compute Vehicle Operating Cost for current light vehicles
       PkVMT = SectionLength! * CPkV * 3 * 365 * CLVpct
       OfPkVMT = SectionLength! * COfPkV * 15 * 365 * CLVpct
       VMT = PkVMT + OfPkVMT

       CALL OperatingCost(CPkMPH%, COfPkMPH%, CSUpct, CCVpct, PkVMT, OfPkVMT, Op
 => erCost, "L")
       COCRunCost = OperCost / 1000 * (((1 + DRate) ^ Yrs - 1) / (DRate * ((1 +
 => DRate) ^ Yrs)))
       COCAvgTrvSpeed! = (CPkMPH% * 3 + COfPkMPH% * 15) / 18 * CLVpct

'Compute TRAVEL TIME required for current Heavy vehicles
       CALL TravelTime((CPkV * (1 - CLVpct)), (CPkCapacity * (1 - CLVpct)), CPkT
 => rvTime!, CPkMPH%, "PK", "C", "H")
       CALL TravelTime((COfPkV * (1 - CLVpct)), (COfPkCapacity * (1 - CLVpct)),
 => COfPkTrvTime!, COfPkMPH%, "OFPK", "C", "H")
       COCTrvTime = COCTrvTime + (CPkTrvTime! + COfPkTrvTime!) * (((1 + DRate) ^
 =>  Yrs - 1) / (DRate * ((1 + DRate) ^ Yrs)))
       COCTrvTime = COCTrvTime / 1000

'Compute Vehicle Operating Cost for current Heavy vehicles
       PkVMT = SectionLength! * CPkV * 3 * 365 * (1 - CLVpct)
       OfPkVMT = SectionLength! * COfPkV * 15 * 365 * (1 - CLVpct)
       VMT = VMT + PkVMT + OfPkVMT

       CALL OperatingCost(CPkMPH%, COfPkMPH%, CSUpct, CCVpct, PkVMT, OfPkVMT, Op
 => erCost, "H")
       COCRunCost = COCRunCost + (OperCost / 1000 * (((1 + DRate) ^ Yrs - 1) / (
 => DRate * ((1 + DRate) ^ Yrs))))
       COCAvgTrvSpeed! = COCAvgTrvSpeed! + (CPkMPH% * 3 + COfPkMPH% * 15) / 18 *
 =>  (1 - CLVpct)

'Compute the Lane-Resurfacing cost during the analysis period
       TotEsal! = ((CADT * 365 * Yrs) * ((CLVpct! * AvgLEsal) + (CSUpct! * AvgSE
 => sal) + (CCVpct! * AvgCEsal))) / CML% / 1000000
       FourRFreq! = FreqByPCR!(TotEsal!)
       COC4RCost = FourRFreq! * CML% * MajorResurfcPM * SectionLength! / 1000

       Vol! = CADT / 18
       CALL Accidents(VMT, CLVpct, CSUpct, CCVpct, Vol!, 0, 0, 0, ((CPkCapacity
 => * 3 + COfPkCapacity * 15) / 18))
       COCAccCost = MVaccCost / 1000 * (((1 + DRate) ^ Yrs - 1) / (DRate * ((1 +
 =>  DRate) ^ Yrs)))
       COCDelayCost = MVDCost / 1000 * (((1 + DRate) ^ Yrs - 1) / (DRate * ((1 +
 =>  DRate) ^ Yrs)))

'COMPUTE SUMMARY STATISTICS
       COCTotVMT! = VMT * Yrs
       COCAccidents! = MNumAcc! * Yrs
       COCAvgAccCost! = MVaccCost / MNumAcc!
       COCAvgDelayCost! = MVDCost / MNumAcc!


'COMPUTE FUTURE COSTS AND BENEFITS
       COFTrvTime = 0
       COFRunCost = 0
       COFAccCost = 0
       COFDelayCost = 0
       COFTotVMT! = 0
       COFAccidents! = 0
```

```
        COFAvgAccCost! = 0
        COFAvgDelayCost! = 0
        COFAvgTrvSpeed! = 0
        FourRFreq! = 0
        TotEsal! = 0

        FOR i% = 1 TO Yrs
           CALL ComputeVehpct(i%)
           FPkVolume = (CPkV + (FPkIV * i%))
           FOfPkVolume = (COfPkV + (FOfPkIV * i%))
           Volume = (FPkVolume * 3 + FOfPkVolume * 15) * 365
           TotEsal! = TotEsal! + (Volume * ((FLVpct! * AvgLEsal) + (FSUpct! * Avg
  => SEsal) + (FCVpct! * AvgCEsal))) / FML% / 1000000
           HrVolume! = (FPkVolume * 3 + FOfPkVolume * 15) / 18

'Compute CAPACITY for future Mixed traffic
           TSU! = TruckAdjustFactor((FPkVolume / FML%), "SU", FSUpct)
           TCV! = TruckAdjustFactor((FPkVolume / FML%), "CV", FCVpct)
           FPkCapacity = 2000 * W! * TSU! * TCV! * FML%

           TSU! = TruckAdjustFactor((FOfPkVolume / FML%), "SU", FSUpct)
           TCV! = TruckAdjustFactor((FOfPkVolume / FML%), "CV", FCVpct)
           FOfPkCapacity = 2000 * W! * TSU! * TCV! * FML%

'Compute TRAVEL TIME required for future Light vehicles
           CALL TravelTime((FPkVolume * FLVpct), (FPkCapacity * FLVpct), PkTrvTim
  => e!, FPkMPH%, "PK", "F", "L")
           CALL TravelTime((FOfPkVolume * FLVpct), (FOfPkCapacity * FLVpct), OfPk
  => TrvTime!, FOfPkMPH%, "OFPK", "F", "L")
           COFTrvTime = COFTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate)
  => ^ i%))

'Compute Vehicle Operating Cost for future Light vehicles
           PkVMT = SectionLength! * FPkVolume * FLVpct * 3 * 365
           OfPkVMT = SectionLength! * FOfPkVolume * FLVpct * 15 * 365
           VMT = PkVMT + OfPkVMT

           CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkVMT,
  =>  OperCost, "L")
           COFRunCost = COFRunCost + (OperCost / ((1 + DRate) ^ i%))
           COFAvgTrvSpeed! = COFAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 1
  => 8 * FLVpct

'Compute TRAVEL TIME required for future Heavy vehicles
           CALL TravelTime((FPkVolume * (1 - FLVpct)), (FPkCapacity * (1 - FLVpct
  => )), PkTrvTime!, FPkMPH%, "PK", "F", "H")
           CALL TravelTime((FOfPkVolume * (1 - FLVpct)), (FOfPkCapacity * (1 - FL
  => Vpct)), OfPkTrvTime!, FOfPkMPH%, "OFPK", "F", "H")
           COFTrvTime = COFTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate)
  => ^ i%))

'Compute Vehicle Operating Cost for future Heavy vehicles
           PkVMT = SectionLength! * FPkVolume * (1 - FLVpct) * 3 * 365
           OfPkVMT = SectionLength! * FOfPkVolume * (1 - FLVpct) * 15 * 365
           VMT = VMT + PkVMT + OfPkVMT

           CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkVMT,
  =>  OperCost, "H")
           COFRunCost = COFRunCost + (OperCost / ((1 + DRate) ^ i%))
           COFAvgTrvSpeed! = COFAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 1
  => 8 * (1 - FLVpct)

'Compute Accidents and Accidents-delay Costs
           CALL Accidents(VMT, FLVpct, FSUpct, FCVpct, HrVolume!, 0, 0, 0, ((FPkC
  => apacity * 3 + FOfPkCapacity * 15) / 18))
           COFAccCost = COFAccCost + (MVaccCost / ((1 + DRate) ^ i%))
           COFDelayCost = COFDelayCost + (MVDCost / ((1 + DRate) ^ i%))

'Compute Lane-Resurfacing frequency
           FourRFreq! = FourRFreq! + FreqByPCR!(TotEsal!)

           COFTotVMT! = COFTotVMT! + VMT
           COFAccidents! = COFAccidents! + MNumAcc!
           COFAvgAccCost! = COFAvgAccCost! + MVaccCost
           COFAvgDelayCost! = COFAvgDelayCost! + MVDCost
        NEXT i%

        COFTrvTime = COFTrvTime / 1000
        COFRunCost = COFRunCost / 1000
        COFAccCost = COFAccCost / 1000
        COFDelayCost = COFDelayCost / 1000
'Compute the Lane-Resurfacing cost
        COF4RCost = FourRFreq! * FML% * MajorResurfcPM * SectionLength! / 1000

'COMPUTE SUMMARY STATISTICS
        COFAvgAccCost! = COFAvgAccCost! / COFAccidents!
        COFAvgDelayCost! = COFAvgDelayCost! / COFAccidents!
        COFAvgTrvSpeed! = COFAvgTrvSpeed! / Yrs

        F4RCost = COF4RCost
        FTrvTime = COFTrvTime
        FRunCost = COFRunCost
        FAccCost = COFAccCost
        FDelayCost = COFDelayCost
        FTotVMT! = COFTotVMT!
        FAccidents! = COFAccidents!
        FAvgAccCost! = COFAvgAccCost!
        FAvgDelayCost! = COFAvgDelayCost!
        FAvgTrvSpeed! = COFAvgTrvSpeed!

        FML% = SaveFML%
        FHL% = SaveFHL%
        FLL% = SaveFLL%

END SUB

'*************************************************************************
'*                         SUB PROCEDURE CASE1                           *
'*                                                                       *
'* Operation:     Computes all the costs and benefits for case 1 for     *
'*                future traffic conditions. All global output           *
'*                variables have prefix "F".                             *
'*                                                                       *
'* Parameter(s):  none.                                                  *
'*************************************************************************
SUB CASE1

CONST W! = 1          'Lane width clearence assumed to be equal to 1.

DIM VMT          AS DOUBLE
DIM PkVMT        AS DOUBLE
DIM OfPkVMT      AS DOUBLE
DIM LVolume      AS DOUBLE
DIM HVolume      AS DOUBLE
DIM MVolume      AS DOUBLE
DIM OperCost     AS DOUBLE
DIM AccCost      AS DOUBLE
DIM PkVol        AS DOUBLE
DIM OfPkVol      AS DOUBLE
DIM LPkvol       AS DOUBLE
DIM LOfPkvol     AS DOUBLE
DIM LtPkvol      AS DOUBLE
```

```
DIM LtOfPkvol     AS DOUBLE
DIM EPkVol        AS DOUBLE
DIM EOfPkVol      AS DOUBLE
DIM HPkVol        AS DOUBLE
DIM HOfPkVol      AS DOUBLE
DIM MPkCapacity   AS DOUBLE
DIM MOfPkCapacity AS DOUBLE
DIM HPkCapacity   AS DOUBLE
DIM HOfPkCapacity AS DOUBLE
DIM LCapacity     AS DOUBLE


       L4RFreq! = 0
       H4RFreq! = 0
       M4RFreq! = 0
       LTotEsal! = 0
       HTotEsal! = 0
       MTotEsal! = 0
       FTrvTime = 0
       FRunCost = 0
       FAccCost = 0
       FDelayCost = 0

       FTotVMT! = 0
       FAccidents! = 0
       FAvgAccCost! = 0
       FAvgDelayCost! = 0
       FAvgTrvSpeed! = 0

       FOR i% = 1 TO Yrs
          CALL ComputeVehpct(i%)
          FPkVolume = CPkV + (FPkIV * i%)
          FOfPkVolume = COfPkV + (FOfPkIV * i%)
          HPkVol = FPkVolume * (FSUpct + FCVpct)
          HOfPkVol = FOfPkVolume * (FSUpct + FCVpct)

          IF (FML% <> 0) AND (FLL% <> 0) THEN

'Compute CAPACITY for future Mixed vehicle lanes
             TSU! = TruckAdjustFactor((HPkVol / FML%), "SU", FSUpct)
             TCV! = TruckAdjustFactor((HPkVol / FML%), "CV", FCVpct)
             MPkCapacity = 2000 * W! * TSU! * TCV! * FML%

             TSU! = TruckAdjustFactor((HOfPkVol / FML%), "SU", FSUpct)
             TCV! = TruckAdjustFactor((HOfPkVol / FML%), "CV", FCVpct)
             MOfPkCapacity = 2000 * W! * TSU! * TCV! * FML%

'Compute CAPACITY for future Light vehicle Lanes
             LCapacity = 2000 * W! * FLL%
             LtPkvol = FPkVolume * FLVpct
             LtOfPkvol = FOfPkVolume * FLVpct

'Estimated the number of Light vehicles that will take Light-Vehicle lanes
ReEst:       EPkVol = (FPkVolume * (LCapacity / MPkCapacity)) / (1 + LCapacity /
  =>  MPkCapacity)
             EOfPkVol = (FOfPkVolume * (LCapacity / MOfPkCapacity)) / (1 + LCapa
  => city / MOfPkCapacity)

             IF LtPkvol > EPkVol THEN
                LPkvol = EPkVol
                PkVol = LtPkvol - LPkvol
             ELSE
                LPkvol = LtPkvol
                PkVol = 0
             END IF
             IF LtOfPkvol > EOfPkVol THEN
                LOfPkvol = EOfPkVol
                OfPkVol = LtOfPkvol - LOfPkvol
             ELSE
                LOfPkvol = LtOfPkvol
                OfPkVol = 0
             END IF

'Compute TRAVEL TIME required for future Light vehicles
             CALL TravelTime(LPkvol, LCapacity, PkTrvTime!, FPkMPH%, "PK", "F",
  => "L")
             CALL TravelTime(LOfPkvol, LCapacity, OfPkTrvTime!, FOfPkMPH%, "OFPK
  => ", "F", "L")
             FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^
  =>  i%))

'Compute Vehicle Operating Cost for the light vehicles on light vehicle lanes
             PkVMT = SectionLength! * LPkvol * 3 * 365
             OfPkVMT = SectionLength! * LOfPkvol * 15 * 365
             VMT = PkVMT + OfPkVMT
             HrLVolume! = (LPkvol * 3 + LOfPkvol * 15) / 18
             LVolume = (LPkvol * 3 + LOfPkvol * 15) * 365

             CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkV
  => MT, OperCost, "L")
             FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))

             pct! = (LPkvol + LOfPkvol) / (FPkVolume + FOfPkVolume)
             FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18
  =>  * pct!

             SMPkCap = MPkCapacity
             SMOfPkCap = MOfPkCapacity

             PkSUpct! = (FPkVolume * FSUpct) / (HPkVol + PkVol)
             PkCVpct! = (FPkVolume * FCVpct) / (HPkVol + PkVol)
             OfPkSUpct! = (FOfPkVolume * FSUpct) / (HOfPkVol + OfPkVol)
             OfPkCVpct! = (FOfPkVolume * FCVpct) / (HOfPkVol + OfPkVol)
             PkLVpct! = 1 - (PkSUpct! + PkCVpct!)
             OfPkLVpct! = 1 - (OfPkSUpct! + OfPkCVpct!)

'ReCompute CAPACITY for future mixed vehicle Lanes
             TSU! = TruckAdjustFactor(((HPkVol + PkVol) / FML%), "SU", PkSUpct!)
             TCV! = TruckAdjustFactor(((HPkVol + PkVol) / FML%), "CV", PkCVpct!)
             MPkCapacity = 2000 * W! * TSU! * TCV! * FML%

             TSU! = TruckAdjustFactor(((HOfPkVol + OfPkVol) / FML%), "SU", OfPkS
  => Upct!)
             TCV! = TruckAdjustFactor(((HOfPkVol + OfPkVol) / FML%), "CV", OfPkC
  => Vpct!)
             MOfPkCapacity = 2000 * W! * TSU! * TCV! * FML%

             IF ((SMPkCap - MPkCapacity) > 1) THEN
             'OR ((SMOfPkCap - MOfPkCapacity) > 1) THEN
                FTrvTime = FTrvTime - (((PkTrvTime! + OfPkTrvTime!) / ((1 + DRat
  => e) ^ i%)))
                VMT = 0
                FRunCost = FRunCost - ((OperCost / ((1 + DRate) ^ i%)))
                FAvgTrvSpeed! = FAvgTrvSpeed! - (FPkMPH% * 3 + FOfPkMPH% * 15) /
  =>  18 * pct!
                GOTO ReEst
             END IF

'Compute TRAVEL TIME required for future Heavy vehicles
             CALL TravelTime(HPkVol, (MPkCapacity * (1 - PkLVpct!)), PkTrvTime!,
  =>  FPkMPH%, "PK", "F", "H")
```

```
            CALL TravelTime(HOfPkVol, (MOfPkCapacity * (1 - OfPkLVpct!)), OfPkT
  => rvTime!, FOfPkMPH%, "OFPK", "F", "H")
            FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^
  =>  i%))

'Compute Vehicle Operating Cost for the Heavy vehicles on the mixed lanes
            PkVMT = SectionLength! * HPkVol * 3 * 365
            OfPkVMT = SectionLength! * HOfPkVol * 15 * 365
            VMT = VMT + PkVMT + OfPkVMT
            HrHVolume! = (HPkVol * 3 + HOfPkVol * 15) / 18
            HVolume = (HPkVol * 3 + HOfPkVol * 15) * 365
            HrMVolume! = ((HPkVol + PkVol) * 3 + (HOfPkVol + OfPkVol) * 15) / 1
  => 8
            MVolume = ((HPkVol + PkVol) * 3 + (HOfPkVol + OfPkVol) * 15) * 365

            CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkV
  => MT, OperCost, "H")
            FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))
            pct! = (HPkVol + HOfPkVol) / (FPkVolume + FOfPkVolume)
            FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18
  =>  * pct!

'Compute TRAVEL TIME required for future Light vehicles on mixed lanes
  =>
            CALL TravelTime(PkVol, (MPkCapacity * PkLVpct!), PkTrvTime!, FPkMPH
  => %, "PK", "F", "L")
            CALL TravelTime(OfPkVol, (MOfPkCapacity * OfPkLVpct!), OfPkTrvTime!
  => , FOfPkMPH%, "OFPK", "F", "L")
            FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^
  =>  i%))

'Compute Vehicle Operating Cost for the light vehicles on mixed lanes
            PkVMT = SectionLength! * PkVol * 3 * 365
            OfPkVMT = SectionLength! * OfPkVol * 15 * 365
            VMT = VMT + PkVMT + OfPkVMT

            CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkV
  => MT, OperCost, "L")
            FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))
            pct! = (PkVol + OfPkVol) / (FPkVolume + FOfPkVolume)
            FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18
  =>  * pct!

'Compute Accidents and Accidents-delay Costs
            CALL Accidents(VMT, FLVpct, FSUpct, FCVpct, HrMVolume!, 0, HrLVolum
  => e!, LCapacity, ((MPkCapacity * 3 + MOfPkCapacity * 15) / 18))
            FAccCost = FAccCost + (MVaccCost / ((1 + DRate) ^ i%))
            FDelayCost = FDelayCost + (MVDCost / ((1 + DRate) ^ i%))

'Compute vehicle-type percentages and compute ESAL and Resurfacing freq. for mix
  => ed and light lanes
            Lpct! = 1 - (HVolume / MVolume)
            Totpct! = FSUpct + FCVpct
            Spct! = (1 - Lpct!) * (FSUpct / Totpct!)
            Cpct! = (1 - Lpct!) * (FCVpct / Totpct!)
            MTotEsal! = MTotEsal! + (MVolume * ((Lpct! * AvgLEsal) + (Spct! * A
  => vgSEsal) + (Cpct! * AvgCEsal))) / FML% / 1000000
            M4RFreq! = M4RFreq! + FreqByPCR!(MTotEsal!)
            LTotEsal! = LTotEsal! + (LVolume * AvgLEsal) / FLL% / 1000000
            L4RFreq! = L4RFreq! + FreqByPCR!(LTotEsal!)

'COMPUTE SUMMARY STATISTICS
            FTotVMT! = FTotVMT! + VMT
            FAccidents! = FAccidents! + MNumAcc!
            FAvgAccCost! = FAvgAccCost! + MVaccCost
            FAvgDelayCost! = FAvgDelayCost! + MVDCost

        ELSEIF (FLL% <> 0) AND (FHL% <> 0) THEN

'Compute CAPACITY for future Light vehicle lanes
            LCapacity = 2000 * W! * FLL%
            LPkvol = FPkVolume * FLVpct
            LOfPkvol = FOfPkVolume * FLVpct

'Compute TRAVEL TIME required for future Light vehicles
            CALL TravelTime(LPkvol, LCapacity, PkTrvTime!, FPkMPH%, "PK", "F",
  => "L")
            CALL TravelTime(LOfPkvol, LCapacity, OfPkTrvTime!, FOfPkMPH%, "OFPK
  => ", "F", "L")
            FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^
  =>  i%))

'Compute Vehicle Operating Cost for the Light vehicles on Light-Vehicle lanes
            PkVMT = SectionLength! * LPkvol * 3 * 365
            OfPkVMT = SectionLength! * LOfPkvol * 15 * 365
            VMT = PkVMT + OfPkVMT
            HrLVolume! = (LPkvol * 3 + LOfPkvol * 15) / 18
            LVolume = (LPkvol * 3 + LOfPkvol * 15) * 365

            CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkV
  => MT, OperCost, "L")
            FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))
            FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18
  =>  * FLVpct

'Compute CAPACITY for future Heavy vehicle lanes
            TSU! = TruckAdjustFactor((HPkVol / FHL%), "SU", (FSUpct / (1 - FLVp
  => ct)))
            TCV! = TruckAdjustFactor((HPkVol / FHL%), "CV", (FCVpct / (1 - FLVp
  => ct)))
            HPkCapacity = 2000 * W! * TSU! * TCV! * FHL%

            TSU! = TruckAdjustFactor((HOfPkVol / FHL%), "SU", (FSUpct / (1 - FL
  => Vpct)))
            TCV! = TruckAdjustFactor((HOfPkVol / FHL%), "CV", (FCVpct / (1 - FL
  => Vpct)))
            HOfPkCapacity = 2000 * W! * TSU! * TCV! * FHL%

'Compute TRAVEL TIME required for future Heavy vehicles
            CALL TravelTime(HPkVol, HPkCapacity, PkTrvTime!, FPkMPH%, "PK", "F"
  => , "H")
            CALL TravelTime(HOfPkVol, HOfPkCapacity, OfPkTrvTime!, FOfPkMPH%, "
  => OFPK", "F", "H")
            FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^
  =>  i%))

'Compute Vehicle Operating Cost for the Heavy vehicles on Heavy-Vehicle lanes
            PkVMT = SectionLength! * HPkVol * 3 * 365
            OfPkVMT = SectionLength! * HOfPkVol * 15 * 365
            VMT = VMT + PkVMT + OfPkVMT
            HrHVolume! = (HPkVol * 3 + HOfPkVol * 15) / 18
            HVolume = (HPkVol * 3 + HOfPkVol * 15) * 365

            CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkV
  => MT, OperCost, "H")
            FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))
            FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18
  =>  * (1 - FLVpct)

'Compute Accidents and Accidents-delay Costs
            CALL Accidents(VMT, FLVpct, FSUpct, FCVpct, 0, HrHVolume!, HrLVolum
  => e!, LCapacity, ((HPkCapacity * 3 + HOfPkCapacity * 15) / 18))
```

```
            AccCost = LVaccCost + HVaccCost
            FAccCost = FAccCost + (AccCost / ((1 + DRate) ^ i%))
            AccCost = LVDCost + HVDCost
            FDelayCost = FDelayCost + (AccCost / ((1 + DRate) ^ i%))

'Compute vehicle-type percentages and compute ESAL & Resurfacing freq. for heavy
 =>  and light lanes
            Spct! = FSUpct / (FSUpct + FCVpct)
            Cpct! = FCVpct / (FSUpct + FCVpct)
            HTotEsal! = HTotEsal! + (HVolume * ((Spct! * AvgSEsal) + (Cpct! * A
 => vgCEsal))) / FHL% / 1000000
            H4RFreq! = H4RFreq! + FreqByPCR!(HTotEsal!)
            LTotEsal! = LTotEsal! + (LVolume * AvgLEsal) / FLL% / 1000000
            L4RFreq! = L4RFreq! + FreqByPCR!(LTotEsal!)

'COMPUTE SUMMARY STATISTICS
            FTotVMT! = FTotVMT! + VMT
            FAccidents! = FAccidents! + LNumAcc! + HNumAcc!
            FAvgAccCost! = FAvgAccCost! + LVaccCost + HVaccCost
            FAvgDelayCost! = FAvgDelayCost! + LVDCost + HVDCost

         ELSE
            PRINT "Only feasible options are (ML and LL) or (HL and LL) "
         END IF
   NEXT i%

   FTrvTime = FTrvTime / 1000
   FRunCost = FRunCost / 1000
   FAccCost = FAccCost / 1000
   FDelayCost = FDelayCost / 1000

'Compute Lane-Resurfacing cost
      IF FML% <> 0 THEN
         FourRFreq! = M4RFreq!
      ELSE
         FourRFreq! = 0
      END IF
      IF (FHL% <> 0) AND (H4RFreq! > FourRFreq!) THEN
            FourRFreq! = H4RFreq!
      END IF
      IF (FLL% <> 0) AND (L4RFreq! > FourRFreq!) THEN
            FourRFreq! = L4RFreq!
      END IF
      F4RCost = FourRFreq! * (FML% + FHL% + FLL%) * MajorResurfcPM * SectionLen
 => gth! / 1000

      FAvgAccCost! = FAvgAccCost! / FAccidents!
      FAvgDelayCost! = FAvgDelayCost! / FAccidents!
      FAvgTrvSpeed! = FAvgTrvSpeed! / Yrs

      IF CML% < (FML% + FLL% + FHL%) THEN
         CALL CASE3N4(M4RFreq!, L4RFreq!, H4RFreq!, FourRFreq!)
      END IF

END SUB

'*************************************************************************
'*                         SUB PROCEDURE CASE2                            *
'*                                                                        *
'* Operation:     Computes all the costs and benefits for case 2 for      *
'*                future traffic conditions. All global output            *
'*                variables have prefix "F".                              *
'*                                                                        *
'* Parameter(s):  none.                                                   *
'*************************************************************************
SUB CASE2

CONST W! = 1          'Lane width clearence assumed to be equal to 1.

DIM VMT        AS DOUBLE
DIM PkVMT      AS DOUBLE
DIM OfPkVMT    AS DOUBLE
DIM Volume     AS DOUBLE
DIM OperCost   AS DOUBLE
DIM ConsperYr  AS DOUBLE

'COMPUTE FUTURE COSTS AND BENEFITS
      FTrvTime = 0
      FRunCost = 0
      FAccCost = 0
      FDelayCost = 0
      FTotVMT! = 0
      FAccidents! = 0
      FAvgAccCost! = 0
      FAvgDelayCost! = 0
      FAvgTrvSpeed! = 0
      FourRFreq! = 0
      TotEsal! = 0

      FOR i% = 1 TO Yrs
         CALL ComputeVehpct(i%)
         FPkVolume = CPkV + (FPkIV * i%)
         FOfPkVolume = COfPkV + (FOfPkIV * i%)
         HrVolume! = (FPkVolume * 3 + FOfPkVolume * 15) / 18
         Volume = (FPkVolume * 3 + FOfPkVolume * 15) * 365
         TotEsal! = TotEsal! + (Volume * ((FLVpct! * AvgLEsal) + (FSUpct! * Avg
 => SEsal) + (FCVpct! * AvgCEsal))) / FML% / 1000000

'Compute CAPACITY for future Mixed traffic
         TSU! = TruckAdjustFactor((FPkVolume / FML%), "SU", FSUpct)
         TCV! = TruckAdjustFactor((FPkVolume / FML%), "CV", FCVpct)
         FPkCapacity = 2000 * W! * TSU! * TCV! * FML%

         TSU! = TruckAdjustFactor((FOfPkVolume / FML%), "SU", FSUpct)
         TCV! = TruckAdjustFactor((FOfPkVolume / FML%), "CV", FCVpct)
         FOfPkCapacity = 2000 * W! * TSU! * TCV! * FML%

'Compute TRAVEL TIME required for future Light vehicles
         CALL TravelTime((FPkVolume * FLVpct), (FPkCapacity * FLVpct), PkTrvTim
 => e!, FPkMPH%, "PK", "F", "L")
         CALL TravelTime((FOfPkVolume * FLVpct), (FOfPkCapacity * FLVpct), OfPk
 => TrvTime!, FOfPkMPH%, "OFPK", "F", "L")
         FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^ i%
 => ))

'Compute Vehicle Operating Cost for future Light vehicles
         PkVMT = SectionLength! * FPkVolume * FLVpct * 3 * 365
         OfPkVMT = SectionLength! * FOfPkVolume * FLVpct * 15 * 365
         VMT = PkVMT + OfPkVMT

         CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkVMT,
 =>  OperCost, "L")
         FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))
         FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18 *
 => FLVpct

'Compute TRAVEL TIME required for future Heavy vehicles
         CALL TravelTime((FPkVolume * (1 - FLVpct)), (FPkCapacity * (1 - FLVpct
 => )), PkTrvTime!, FPkMPH%, "PK", "F", "H")
         CALL TravelTime((FOfPkVolume * (1 - FLVpct)), (FOfPkCapacity * (1 - FL
 => Vpct)), OfPkTrvTime!, FOfPkMPH%, "OFPK", "F", "H")
         FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^ i%
```

```
=> ))

'Compute Vehicle Operating Cost for future Heavy vehicles
          PkVMT = SectionLength! * FPkVolume * (1 - FLVpct) * 3 * 365
          OfPkVMT = SectionLength! * FOfPkVolume * (1 - FLVpct) * 15 * 365
          VMT = VMT + PkVMT + OfPkVMT

          CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkVMT,
 =>  OperCost, "H")
          FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))
          FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18 *
 => (1 - FLVpct)

'Compute Accidents and Accidents-delay Costs
          CALL Accidents(VMT, FLVpct, FSUpct, FCVpct, HrVolume!, 0, 0, 0, ((FPkC
 => apacity * 3 + FOfPkCapacity * 15) / 18))
          FAccCost = FAccCost + (MVaccCost / ((1 + DRate) ^ i%))
          FDelayCost = FDelayCost + (MVDCost / ((1 + DRate) ^ i%))

'Compute Lane-Resurfacing frequency
          FourRFreq! = FourRFreq! + FreqByPCR!(TotEsal!)

          FTotVMT! = FTotVMT! + VMT
          FAccidents! = FAccidents! + MNumAcc!
          FAvgAccCost! = FAvgAccCost! + MVaccCost
          FAvgDelayCost! = FAvgDelayCost! + MVDCost

       NEXT i%

       FTrvTime = FTrvTime / 1000
       FRunCost = FRunCost / 1000
       FAccCost = FAccCost / 1000
       FDelayCost = FDelayCost / 1000
'Compute the Lane-Resurfacing cost
       F4RCost = FourRFreq! * FML% * MajorResurfcPM * SectionLength! / 1000

'COMPUTE SUMMARY STATISTICS
       FAvgAccCost! = FAvgAccCost! / FAccidents!
       FAvgDelayCost! = FAvgDelayCost! / FAccidents!
       FAvgTrvSpeed! = FAvgTrvSpeed! / Yrs

'Compute the Lane-Resurfacing cost during the analysis period
       F4RCost = FourRFreq! * FML% * MajorResurfcPM * SectionLength! / 1000

'Compute the Construction & Right-of-way cost
       ConstrucCost = (ConstrucCostPM) * SectionLength! * (FML% - CML%) + NumInt
 => ersection% * ConstrucCostPIntg
       ConstrucCost = ConstrucCost + CML% * MajorResurfcPM * SectionLength!
       ConsperYr = ConstrucCost / YrsConstruc
       ConstrucCost = 0
       FOR i% = 1 TO YrsConstruc
          ConstrucCost = ConstrucCost + ConsperYr / ((1 + DRate) ^ i%)
       NEXT i%
       ConstrucCost = ConstrucCost / 1000
       RightOfWayCost = RightOfWayPM * SectionLength! * (FML% - CML%) / 1000
END SUB

'*********************************************************************
'*                    SUB PROCEDURE CASE3N4                          *
'*                                                                   *
'* Operation:    Computes all the costs and benefits for case 3 and  *
'*               case 4 for future traffic conditions. This sub-     *
'*               procedure is called from another sub procedure      *
'*               "CASE1", since new construction cost and the        *
'*               resurfacing cost (due to barrier) are the only      *
'*               diffrences between these cases.  All global output  *
'*               variables have prefix "F".                          *
'*                                                                   *
'* Parameter(s):  none.                                              *
'*********************************************************************
SUB CASE3N4 (M4Freq!, L4Freq!, H4Freq!, FourRFrq!)

CONST W! = 1               'Lane width clearence assumed to be equal to 1.
DIM ConsperYr AS DOUBLE

'Compute the Construction & Right-of-way cost
       IF BarrierSeparated$ = "Y" THEN
          F4RCost = (M4Freq! * FML% + H4Freq! * FHL% + L4Freq! * FLL%) * MajorRe
 => surfcPM * SectionLength! / 1000
       ELSE
          F4RCost = FourRFrq! * (FML% + FHL% + FLL%) * MajorResurfcPM * SectionL
 => ength! / 1000
       END IF

       IF BarrierSeparated$ = "Y" THEN
          ConstrucCost = bConstrucCostPM * SectionLength! * (FML% + FLL% + FHL%
 => - CML%) + NumIntersection% * bConstrucCostPIntg
          RightOfWayCost = bRightOfWayPM * SectionLength! * (FML% + FLL% + FHL%
 => - CML%) / 1000
       ELSE
          ConstrucCost = ConstrucCostPM * SectionLength! * (FML% + FLL% + FHL% -
 =>  CML%) + NumIntersection% * ConstrucCostPIntg
          RightOfWayCost = RightOfWayPM * SectionLength! * (FML% + FLL% + FHL% -
 =>  CML%) / 1000
       END IF
       ConstrucCost = ConstrucCost + CML% * MajorResurfcPM * SectionLength!
       ConsperYr = ConstrucCost / YrsConstruc
       ConstrucCost = 0
       FOR i% = 1 TO YrsConstruc
          ConstrucCost = ConstrucCost + ConsperYr / ((1 + DRate) ^ i%)
       NEXT i%
       ConstrucCost = ConstrucCost / 1000

END SUB

'*********************************************************************
'*                 SUB PROCEDURE ComputeVehpct                       *
'*                                                                   *
'* Operation:    Computes the vehicle type percentage for the given  *
'*               year.                                               *
'*                                                                   *
'* Parameter(s):  yr% - Analysis year.                               *
'*********************************************************************
'
SUB ComputeVehpct (yr%)

       IF LVincr < 0 THEN
          FLVpct = (CLVpct - (-LVincr * yr%))
       ELSE
          FLVpct = (CLVpct + (LVincr * yr%))
       END IF
       IF SUincr < 0 THEN
          FSUpct = (CSUpct - (-SUincr * yr%))
       ELSE
          FSUpct = (CSUpct + (SUincr * yr%))
       END IF
       IF CVincr < 0 THEN
          FCVpct = (CCVpct - (-CVincr * yr%))
       ELSE
          FCVpct = (CCVpct + (CVincr * yr%))
       END IF
```

```
END SUB

'**********************************************************************
'*                    SUB PROCEDURE DelayArea                          *
'*                                                                     *
'* Operation:     Computes the delay time by computing the area of a   *
'*                polygon described in model qdelay2.wk1. The output   *
'*                parameter "DelayTime!" contains this delay time.     *
'*                                                                     *
'* Parameter(s):  Volume!       - Vehicle volume for the analysis year. *
'*                RemainLanes% - Number of open lanes.                 *
'*                ClrDur!      - Minutes required to clear the accident*
'*                Spct!        - Single unit vehicle percentage.       *
'*                Cpct!        - Combination unit vehicle percentage.  *
'*                DelayTime!   - Time delay caused by an accident.     *
'**********************************************************************
SUB DelayArea (Volume!, RemainLanes%, ClrDur!, Spct!, Cpct!, DelayTime!)

CONST W! = 1                     'assumed lane width clearence to be 1.

       V1! = Volume!
       T2! = ClrDur!

       IF (RemainLanes% < 0) THEN
          DelayTime! = 0
          GOTO INFEASIBLE
       ELSEIF (RemainLanes% = 0) THEN
          C1! = 0

          TSU! = TruckAdjustFactor((VehVolume! / (FML% + FHL% + FLL%)), "SU", Sp
  => ct!)
          TCV! = TruckAdjustFactor((VehVolume! / (FML% + FHL% + FLL%)), "CV", Cp
  => ct!)
          C2! = 2000 * W! * TSU! * TCV! * (FML% + FHL% + FLL%)

          IF (FLL% > 0) THEN  ' ONLY FOR EXCLUSIVE VEHICLE LANES A SHIFT IS POSS
  => IBLE.
             V1! = 1600
          END IF
       ELSEIF (Spct! = 0) AND (Cpct! = 0) THEN
          C1! = 2000 * W! * RemainLanes% * .8
          C2! = 2000 * W! * (FML% + FHL% + FLL%)
       ELSE
          TSU! = TruckAdjustFactor((VehVolume! / RemainLanes%), "SU", Spct!)
          TCV! = TruckAdjustFactor((VehVolume! / RemainLanes%), "CV", Cpct!)
          C1! = 2000 * W! * TSU! * TCV! * RemainLanes% * .8

          TSU! = TruckAdjustFactor((VehVolume! / (FML% + FHL% + FLL%)), "SU", Sp
  => ct!)
          TCV! = TruckAdjustFactor((VehVolume! / (FML% + FHL% + FLL%)), "CV", Cp
  => ct!)
          C2! = 2000 * W! * TSU! * TCV! * (FML% + FHL% + FLL%)
       END IF
       IF (V1! < C1!) THEN
          DelayTime! = 0
       ELSE
          IF (BarrierSeparated$ = "N") OR ((FML% > 0) AND (FLL% = 0) AND (FHL% =
  =>  0)) THEN
             V2! = V1! - .35 * (V1! - C1!)
          ELSE
             V2! = V1! - .7 * (V1! - C1!)
          END IF
          IF (V2! >= (.9 * C2!)) THEN
             V2! = .9 * C2!
          END IF
          Qlength! = (FML% + FLL% + FHL%) * 105.6 * MaxQlen
          T1! = Qlength! / (V1! - C1!)
          T2! = T2! / 60
          IF (T1! > T2!) THEN
             T1! = T2!
          END IF
          T3! = T1! + (T1! * (V1! - C1!) + (T2! - T1!) * (C2! - C1!)) / (C2! - V
  => 2!)
          Delay1! = .5 * (T1! ^ 2 * (V1! - C1!) - (T2! - T1!) ^ 2 * (C2! - C1!))
          Delay2! = .5 * (T3! - T1!) * (T1! * (V1! - C1!) + (T2! - T1!) * (C2! -
  =>  C1!))
          DelayTime! = Delay1! + Delay2!
       END IF
INFEASIBLE:          'END OF THE SUBROUTINE
END SUB

DEFSNG A-Z
'**********************************************************************
'*                    SUB PROCEDURE ErrorRoutine                       *
'*                                                                     *
'* Operation:     Displays an output screen with an error message.     *
'*                                                                     *
'* Parameter(s):  ErrorCode%   - Error type number.                    *
'**********************************************************************
'
SUB ErrorRoutine (ErrorCode%)
       SCREEN 12
       COLOR 15
       LINE (2, 2)-(637, 2)
       LINE (637, 2)-(637, 100)
       LINE (637, 100)-(2, 100)
       LINE (2, 100)-(2, 2)
       COLOR 5
       LOCATE 3, 3
       SELECT CASE ErrorCode%
          CASE 1
             PRINT "Area Type must be either R, S, or U"
             LOCATE 5, 3
             PRINT "R = Rural, S = Suburban, U = Urban"
          CASE 2
             PRINT "Years for Analysis must be greater than 0"
          CASE 3
             PRINT "Discount rate must be greater than 0"
          END SELECT
          LOCATE 6, 53
          PRINT "Press any key to exit"
          DO
          LOOP WHILE INKEY$ = ""

   END SUB

DEFINT A-Z
'**********************************************************************
'*                    SUB PROCEDURE FreqByPCR!                         *
'*                                                                     *
'* Operation:     Computes frequency for resurfacing the lanes if it is*
'*                required during the current year?                    *
'*                                                                     *
'* Parameter(s):  TotEsal!  - Total ESALs since last resurfacing.      *
'**********************************************************************
FUNCTION FreqByPCR! (TotEsal!)

CONST InitPSI! = 5!

       a! = LOG(-LOG(PSIResurf / (InitPSI! - PSIMin)))
       EsalMin! = EXP((-a! / PSIbeta) + LOG(PSIdelta))
```

```
      IF TotEsal! > EsalMin! THEN
         FreqByPCR! = TotEsal! / EsalMin!
         TotEsal! = 0
      ELSE
         FreqByPCR! = 0
      END IF

END FUNCTION

'**********************************************************************
'*                  SUB PROCEDURE OperatingCost                       *
'*                                                                    *
'* Operation:     Computes operating cost for given MPH, vehicle      *
'*                combination type and the vehicle miles travelled.   *
'*                                                                    *
'* Parameter(s):  PkMPH%   - MPH during peak hours.                   *
'*                OfPkMPH% - MPH during off-peak hours.               *
'*                SUpct!   - Single unit vehicle percntages.          *
'*                CVpct!   - Combination vehicle percentages.         *
'*                PkVMT    - VMT during peak hours.                   *
'*                OfPkVMT  - VMT during off-peak hours.               *
'*                OperCost - Operating cost for the given input values.*
'*                LH$      - Vehicle type (Light or Heavy).           *
'**********************************************************************
SUB OperatingCost (PkMPH%, OfPkMPH%, SUpct!, CVpct!, PkVMT AS DOUBLE, OfPkVMT AS
 =>  DOUBLE, OperCost AS DOUBLE, LH$)

DIM PkRunCost       AS DOUBLE
DIM OfPkRunCost     AS DOUBLE
DIM PkCurvCost      AS DOUBLE
DIM OfPkCurvCost    AS DOUBLE

      Totpct! = SUpct! + CVpct!
      Spct! = SUpct! / Totpct!
      Cpct! = CVpct! / Totpct!


      IF PkMPH% < 5 THEN
         PkMPH% = 5
      END IF
      IF OfPkMPH% < 5 THEN
         OfPkMPH% = 5
      END IF
      IF PkMPH% > 80 THEN
         PkMPH% = 80
      END IF
      IF OfPkMPH% > 80 THEN
         OfPkMPH% = 80
      END IF

      IF LH$ = "L" THEN
         PkRunCost = (PkVMT / 1000) * (RunCost(PkMPH%, Grade%).LV + CurveCost(P
 => kMPH%, Curvature%).LV)
         OfPkRunCost = (OfPkVMT / 1000) * (RunCost(OfPkMPH%, Grade%).LV + Curve
 => Cost(OfPkMPH%, Curvature%).LV)
      ELSEIF LH$ = "H" THEN
         PkRunCost = (PkVMT / 1000) * (RunCost(PkMPH%, Grade%).SU * Spct! + Run
 => Cost(PkMPH%, Grade%).CV * Cpct!)
         PkCurvCost = (PkVMT / 1000) * (CurveCost(PkMPH%, Curvature%).SU * Spct
 => ! + CurveCost(PkMPH%, Curvature%).CV * Cpct!)
         PkRunCost = PkRunCost + PkCurvCost

         OfPkRunCost = (OfPkVMT / 1000) * (RunCost(OfPkMPH%, Grade%).SU * Spct!
 =>  + RunCost(OfPkMPH%, Grade%).CV * Cpct!)
         OfPkCurvCost = (OfPkVMT / 1000) * (CurveCost(OfPkMPH%, Curvature%).SU
 => * Spct! + CurveCost(OfPkMPH%, Curvature%).CV * Cpct!)
```

```
         OfPkRunCost = OfPkRunCost + OfPkCurvCost
      END IF

      OperCost = PkRunCost + OfPkRunCost

END SUB

'**********************************************************************
'*                  SUB PROCEDURE OutScreen                           *
'*                                                                    *
'* Operation:     Displays an output screen.                          *
'*                                                                    *
'* Parameter(s):  none.                                               *
'**********************************************************************
SUB OutScreen
      SCREEN 12
'********************** Print CASE 0 *********************************
      CLS
      COLOR 15
      LINE (2, 10)-(637, 10)
      LINE (637, 10)-(637, 419)
      LINE (637, 419)-(2, 419)
      LINE (2, 419)-(2, 10)
      COLOR 15
      LOCATE 2, 2
      PRINT "  With Vehicle Operating Costs (1000's)"
      LOCATE 2, 43
      PRINT "  Without Vehicle Operating Costs"
      COLOR 5
      LOCATE 4, 2
      PRINT "CASE 0      MVL = "
      LOCATE 4, 26
      PRINT "LVL = 0     HVL = 0"
      LOCATE 4, 20
      PRINT CML%
      COLOR 3
      LOCATE 5, 2
      PRINT "Benefits (user costs)   ="
      LOCATE 6, 2
      PRINT "Veh. & Facility Costs   = "
      LOCATE 5, 28
      PRINT USING "$$#########"; NB0!
      LOCATE 6, 28
      PRINT USING "$$#########"; NCw0!
      LOCATE 5, 43
      PRINT "Benefits (user costs)   ="
      LOCATE 6, 43
      PRINT "Veh. & Facility Costs   = "
      LOCATE 5, 68
      PRINT USING "$$#########"; NB0!
      LOCATE 6, 68
      PRINT USING "$$#########"; NC0!
'********************** Print CASE 1 *********************************
      FLL% = INT(CML% / 2)
      REMAINDER% = CML% MOD 2
      FML% = FLL% + REMAINDER%
      COLOR 5
      LOCATE 7, 2
      PRINT "CASE 1      MVL =       LVL =       HVL = 0 "
      LOCATE 7, 20
      PRINT FML%
      LOCATE 7, 32
      PRINT FLL%
      COLOR 3
      LOCATE 8, 2
      PRINT "Net Benefits            ="
```

```
        LOCATE 9, 2
        PRINT "Net Costs                  = "
        LOCATE 8, 28
        PRINT USING "$$#########"; NB1!
        LOCATE 9, 28
        PRINT USING "$$#########"; NCw1!
        LOCATE 8, 43
        PRINT "Net Benefits               = "
        LOCATE 9, 43
        PRINT "Net Costs                  = "
        LOCATE 8, 69
        PRINT USING "$$########"; NB1!
        LOCATE 9, 69
        PRINT USING "$$########"; NC1!
        LOCATE 10, 2
        PRINT "Net Present Value         ="
        LOCATE 11, 2
        PRINT "Benefit/Cost Ratio        = "
        LOCATE 10, 28
        PRINT USING "$$#########"; NPw1!
        LOCATE 11, 28
        PRINT USING "#######.###"; BCw1!
        LOCATE 10, 43
        PRINT "Net Present Value         = "
        LOCATE 11, 43
        PRINT "Benefit/Cost Ratio        = "
        LOCATE 10, 69
        PRINT USING "$$########"; NP1!
        LOCATE 11, 68
        PRINT USING "#######.###"; BC1!

'*********************** Print CASE 2 ********************************
        FML% = TL%
        COLOR 5
        LOCATE 12, 2
        PRINT "CASE 2     MVL =       LVL =       HVL = 0 "
        LOCATE 12, 20
        PRINT FML%
        LOCATE 12, 32
        PRINT 0
        COLOR 3
        LOCATE 13, 2
        PRINT "Net Benefits               ="
        LOCATE 14, 2
        PRINT "Net Costs                  = "
        LOCATE 13, 28
        PRINT USING "$$#########"; NB2!
        LOCATE 14, 28
        PRINT USING "$$#########"; NCw2!
        LOCATE 13, 43
        PRINT "Net Benefits               = "
        LOCATE 14, 43
        PRINT "Net Costs                  = "
        LOCATE 13, 69
        PRINT USING "$$########"; NB2!
        LOCATE 14, 69
        PRINT USING "$$########"; NC2!
        LOCATE 15, 2
        PRINT "Net Present Value         ="
        LOCATE 16, 2
        PRINT "Benefit/Cost Ratio        = "
        LOCATE 15, 28
        PRINT USING "$$#########"; NPw2!
        LOCATE 16, 28
        PRINT USING "#######.###"; BCw2!
        LOCATE 15, 43
        PRINT "Net Present Value         = "
        LOCATE 16, 43
        PRINT "Benefit/Cost Ratio        = "
        LOCATE 15, 69
        PRINT USING "$$########"; NP2!
        LOCATE 16, 68
        PRINT USING "#######.###"; BC2!

'*********************** Print CASE 3 ********************************
        FLL% = INT(TL% / 2)
        REMAINDER% = TL% MOD 2
        FML% = FLL% + REMAINDER%
        COLOR 5
        LOCATE 17, 2
        PRINT "CASE 3     MVL =       LVL =       HVL = 0 "
        LOCATE 17, 20
        PRINT FML%
        LOCATE 17, 32
        PRINT FLL%
        COLOR 3
        LOCATE 18, 2
        PRINT "Net Benefits               ="
        LOCATE 19, 2
        PRINT "Net Costs                  = "
        LOCATE 18, 28
        PRINT USING "$$#########"; NB3!
        LOCATE 19, 28
        PRINT USING "$$#########"; NCw3!
        LOCATE 18, 43
        PRINT "Net Benefits               = "
        LOCATE 19, 43
        PRINT "Net Costs                  = "
        LOCATE 18, 69
        PRINT USING "$$########"; NB3!
        LOCATE 19, 69
        PRINT USING "$$########"; NC3!
        LOCATE 20, 2
        PRINT "Net Present Value         ="
        LOCATE 21, 2
        PRINT "Benefit/Cost Ratio        = "
        LOCATE 20, 28
        PRINT USING "$$#########"; NPw3!
        LOCATE 21, 28
        PRINT USING "#######.###"; BCw3!
        LOCATE 20, 43
        PRINT "Net Present Value         = "
        LOCATE 21, 43
        PRINT "Benefit/Cost Ratio        = "
        LOCATE 20, 69
        PRINT USING "$$########"; NP3!
        LOCATE 21, 68
        PRINT USING "#######.###"; BC3!

'*********************** Print CASE 4 ********************************
        FLL% = INT(TL% / 2)
        REMAINDER% = TL% MOD 2
        FML% = FLL% + REMAINDER%
        COLOR 5
        LOCATE 22, 2
        PRINT "CASE 4     MVL =       LVL =       HVL = 0 "
        LOCATE 22, 20
        PRINT FML%
        LOCATE 22, 32
        PRINT FLL%
        COLOR 3
        LOCATE 23, 2
```

```
      PRINT "Net Benefits             ="
      LOCATE 24, 2
      PRINT "Net Costs                = "
      LOCATE 23, 28
      PRINT USING "$$#########"; NB4!
      LOCATE 24, 28
      PRINT USING "$$#########"; NCw4!
      LOCATE 23, 43
      PRINT "Net Benefits             = "
      LOCATE 24, 43
      PRINT "Net Costs                = "
      LOCATE 23, 69
      PRINT USING "$$########"; NB4!
      LOCATE 24, 69
      PRINT USING "$$########"; NC4!
      LOCATE 25, 2
      PRINT "Net Present Value        ="
      LOCATE 26, 2
      PRINT "Benefit/Cost Ratio       = "
      LOCATE 25, 28
      PRINT USING "$$#########"; NPw4!
      LOCATE 26, 28
      PRINT USING "#######.###"; BCw4!
      LOCATE 25, 43
      PRINT "Net Present Value        = "
      LOCATE 26, 43
      PRINT "Benefit/Cost Ratio       = "
      LOCATE 25, 69
      PRINT USING "$$########"; NP4!
      LOCATE 26, 68
      PRINT USING "#######.###"; BC4!
      COLOR 15
      LOCATE 27, 59
      PRINT "Press any key to exit"
      COLOR 3
      LOCATE 28, 2
      PRINT "MVL = Mixed Vehicle Lanes  LVL = Light Vehicle Lanes  HVL = Heavy
 => Vehicle Lanes"
      DO
      LOOP WHILE INKEY$ = ""

END SUB

'**************************************************************************
'*                       SUB PROCEDURE ReadSetInput                       *
'*                                                                        *
'* Operation:     Reads all of the input files and initializes rest of    *
'*                data values.                                            *
'*                                                                        *
'* Parameter(s):  ErrorCode%                                              *
'*                                                                        *
'**************************************************************************
SUB ReadSetInput (ErrorCode%)

      LINE INPUT #1, LocationType$
      LocationType$ = LTRIM$(RTRIM$(UCASE$(LocationType$)))
      IF (LTRIM$(RTRIM$(UCASE$(LocationType$))) <> "R") AND (LTRIM$(RTRIM$(UCAS
 => E$(LocationType$))) <> "S") AND (LTRIM$(RTRIM$(UCASE$(LocationType$))) <> "
 => U") THEN
         ErrorCode% = 1
         GOTO ERRORYES
      END IF
      INPUT #1, SectionLength!
      INPUT #1, NumIntersection%
      INPUT #1, CML%
      INPUT #1, NL%
      TL% = CML% + NL%
      INPUT #1, RWLanes%

      INPUT #1, CADT
      COfPkV = CADT * .05
      CPkV = (CADT - COfPkV * 15) / 3

      INPUT #1, FAIDT!
      FOfPkV = (CADT + FAIDT! * 10) * .05
      FPkV = ((CADT + FAIDT! * 10) - (FOfPkV * 15)) / 3

      INPUT #1, CHVehPct!
      CSUpct = CHVehPct! * .783           '.783 IS CORRECT FOR SUBURBAN.
      CCVpct = CHVehPct! - CSUpct
      CLVpct = 1 - CSUpct - CCVpct

      INPUT #1, FHVehPct!
      FSUpct = FHVehPct! * .783
      FCVpct = FHVehPct! - FSUpct
      FLVpct = 1 - FSUpct - FCVpct

      INPUT #1, Yrs
      IF (Yrs <= 0) THEN
         ErrorCode% = 2
         GOTO ERRORYES
      END IF

      INPUT #1, DRate
      IF (DRate <= 0) THEN
         ErrorCode% = 3
         GOTO ERRORYES
      END IF

      YrsConstruc = 3
      Grade% = 0
      Curvature% = 3

      LVmph = 65
      HVmph = 55
      BarrierSeparated$ = "N"

'Compute yearly increments
      FPkIV = (FPkV - CPkV) / 10
      FOfPkIV = (FOfPkV - COfPkV) / 10
      LVincr = (FLVpct - CLVpct) / 10
      SUincr = (FSUpct - CSUpct) / 10
      CVincr = (FCVpct - CCVpct) / 10

      IF LocationType$ = "R" THEN
         IF (CML% = 0) AND ((FML% + FHL% + FLL%) <= 2) THEN
            ConstrucCostPM = 1110000
         ELSEIF (CML% = 0) AND ((FML% + FHL% + FLL%) > 2) THEN
            ConstrucCostPM = 1220000
         ELSE
            ConstrucCostPM = 1500000
         END IF
         ConstrucCostPIntg = 400000
         RightOfWayPM = 390000 * RWLanes%
         bConstrucCostPM = ConstrucCostPM * 1.4
         bConstrucCostPIntg = ConstrucCostPIntg * 1.4
         bRightOfWayPM = RightOfWayPM * 1.4

         LVaccPLVmvm = 1.134 * .79 / 1.23
         SUaccPSUmvm = 1.951 * .79 / 1.23
         CVaccPCVmvm = 1.787 * .79 / 1.23
```


LC14PRINT

```
      ELSEIF LocationType$ = "S" THEN
         IF (CML% = 0) AND ((FML% + FHL% + FLL%) <= 2) THEN
            ConstrucCostPM = 1500000
         ELSEIF (CML% = 0) AND ((FML% + FHL% + FLL%) > 2) THEN
            ConstrucCostPM = 1730000
         ELSE
            ConstrucCostPM = 1900000
         END IF
         ConstrucCostPIntg = 500000
         RightOfWayPM = 405000 * RWLanes%
         bConstrucCostPM = ConstrucCostPM * 1.4
         bConstrucCostPIntg = ConstrucCostPIntg * 1.4
         bRightOfWayPM = RightOfWayPM * 1.4

         LVaccPLVmvm = 1.134 * 1.07 / 1.23
         SUaccPSUmvm = 1.951 * 1.07 / 1.23
         CVaccPCVmvm = 1.787 * 1.07 / 1.23

      ELSE
         IF (CML% = 0) AND ((FML% + FHL% + FLL%) <= 2) THEN
            ConstrucCostPM = 1880000
         ELSEIF (CML% = 0) AND ((FML% + FHL% + FLL%) > 2) THEN
            ConstrucCostPM = 2240000
         ELSE
            ConstrucCostPM = 2300000
         END IF
         ConstrucCostPIntg = 600000
         RightOfWayPM = 420000 * RWLanes%
         bConstrucCostPM = ConstrucCostPM * 1.4
         bConstrucCostPIntg = ConstrucCostPIntg * 1.4
         bRightOfWayPM = RightOfWayPM * 1.4

         LVaccPLVmvm = 1.134 * 1.43 / 1.23
         SUaccPSUmvm = 1.951 * 1.43 / 1.23
         CVaccPCVmvm = 1.787 * 1.43 / 1.23
      END IF
      MajorResurfcPM = 108000
      PSIdelta = 2!
      PSIbeta = 1.2
      PSIMin = 1.5
      PSIResurf = 2.5
      AvgLEsal = .0003
      AvgSEsal = .06
      AvgCEsal = 1.5

      LVTimeValuePH = 5
      SUtimeValuePH = 10
      CVtimeValuePH = 15
      AccCostPFatal = 226800
      AccCostPInjury = 9288
      AccCostPPDO = 1242
      Block0Lanes = .59
      Block1Lanes = .28
      Block2Lanes = .13
      LClrDur = 39
      HClrDur = 63
      MaxQlen = SectionLength! / NumIntersection% / 2

'*****************************************************
'* Read Operating Cost related Data                  *
'*****************************************************
      FOR s% = 5 TO 80 STEP 5
         FOR g% = -8 TO 8
         INPUT #2, RunCost(s%, g%).LV
         NEXT g%
      NEXT s%

      FOR s% = 5 TO 80 STEP 5
         FOR g% = -8 TO 8
            INPUT #3, RunCost(s%, g%).SU
         NEXT g%
      NEXT s%

      FOR s% = 5 TO 80 STEP 5
         FOR g% = -8 TO 8
            INPUT #4, RunCost(s%, g%).CV
         NEXT g%
      NEXT s%

      FOR s% = 5 TO 80 STEP 5
         FOR c% = 1 TO 30
            INPUT #5, CurveCost(s%, c%).LV
         NEXT c%
      NEXT s%

      FOR s% = 5 TO 80 STEP 5
         FOR c% = 1 TO 30
            INPUT #6, CurveCost(s%, c%).SU
         NEXT c%
      NEXT s%

      FOR s% = 5 TO 80 STEP 5
         FOR c% = 1 TO 30
            INPUT #7, CurveCost(s%, c%).CV
         NEXT c%
      NEXT s%

'* Interpolate the costs in between                  *

      FOR s% = 5 TO 75 STEP 5
         FOR g% = -8 TO 8
            Lincrement! = (RunCost(s% + 5, g%).LV - RunCost(s%, g%).LV) / 5
            Sincrement! = (RunCost(s% + 5, g%).SU - RunCost(s%, g%).SU) / 5
            Cincrement! = (RunCost(s% + 5, g%).CV - RunCost(s%, g%).CV) / 5
            J% = 1
            FOR i% = (s% + 1) TO (s% + 4)
               RunCost(i%, g%).LV = RunCost(s%, g%).LV + Lincrement! * J%
               RunCost(i%, g%).SU = RunCost(s%, g%).SU + Sincrement! * J%
               RunCost(i%, g%).CV = RunCost(s%, g%).CV + Cincrement! * J%
               J% = J% + 1
            NEXT i%
         NEXT g%
      NEXT s%

      FOR s% = 5 TO 75 STEP 5
         FOR c% = 1 TO 30

            Lincrement! = (CurveCost(s% + 5, c%).LV - CurveCost(s%, c%).LV) / 5
            Sincrement! = (CurveCost(s% + 5, c%).SU - CurveCost(s%, c%).SU) / 5
            Cincrement! = (CurveCost(s% + 5, c%).CV - CurveCost(s%, c%).CV) / 5
            J% = 1
            FOR i% = (s% + 1) TO (s% + 4)
               CurveCost(i%, c%).LV = CurveCost(s%, c%).LV + Lincrement! * J%
               CurveCost(i%, c%).SU = CurveCost(s%, c%).SU + Sincrement! * J%
               CurveCost(i%, c%).CV = CurveCost(s%, c%).CV + Cincrement! * J%
               J% = J% + 1
            NEXT i%
         NEXT c%
      NEXT s%
ERRORYES: i% = 1
END SUB
```

```
'*************************************************************************
'*                    SUB PROCEDURE TimeValueRatio                        *
'*                                                                        *
'* Operation:     Computes time value for each vehicle type in dollars.*
'*                                                                        *
'* Parameter(s):  CLVRatio! - Current time value ratio for light vehs. *
  =>
'*                FLVRatio! - Future time value ratio for light vehs.  *
'*                CSURatio! - Current time value ratio for SU vehicles.*
'*                FSURatio! - Future time value ratio for SU vehicles. *
'*                CCVRatio! - Current time value ratio for Comb-vehs.  *
'*                FCVRatio! - Future time value ratio for Comb-vehs.   *
'*************************************************************************
SUB TimeValueRatio (CLVRatio!, FLVRatio!, CSURatio!, FSURatio!, CCVRatio!, FCVRa
  => tio!)

       Totpct! = CSUpct + CCVpct
       CLVRatio! = LVTimeValuePH
       CSURatio! = CSUpct / Totpct! * SUtimeValuePH
       CCVRatio! = CCVpct / Totpct! * CVtimeValuePH

       Totpct! = FSUpct + FCVpct
       FLVRatio! = LVTimeValuePH
       FSURatio! = FSUpct / Totpct! * SUtimeValuePH
       FCVRatio! = FCVpct / Totpct! * CVtimeValuePH

END SUB

'*************************************************************************
'*                    SUB PROCEDURE TravelTime                            *
'*                                                                        *
'* Operation:     Computes travel time for given volume and capacity     *
'*                during peak or off-peak hours for current or future    *
'*                traffic conditions and for light or heavy traffic.     *
'*                It also computes actual mph under given traffic        *
'*                conditions.                                             *
'*                                                                        *
'* Parameter(s):  Volume      - Vehicle volume for the analysis year.    *
  =>
'*                Capac       - Lane capacity for the analysis year.     *
'*                TrvTime!    - Travel time computed by this procedure.  *
'*                ActualMPH%  - Actual MPH for given traffic conditions.*
'*                Pk$         - Peak or Off-peak hours.                  *
'*                CF$         - Current or Future traffic conditions.    *
'*                LH$         - Light or heavy traffic.                  *
'*************************************************************************
SUB TravelTime (Volume AS DOUBLE, Capac AS DOUBLE, TrvTime!, ActualMPH%, Pk$, CF
  => $, LH$)
       IF LH$ = "L" THEN
          MPH! = LVmph%
       ELSE
          MPH! = HVmph%
       END IF

       Tbase! = SectionLength! / MPH!

       TTime! = Tbase! * (1! + .15 * ((Volume / Capac) ^ 4))
       IF Pk$ = "PK" THEN
          TrvTime! = TTime! * 3 * 365
       ELSEIF Pk$ = "OFPK" THEN
          TrvTime! = TTime! * 15 * 365
       ELSE
          PRINT "VALID PARAMETERS ARE ONLY PK OR OFPK"
       END IF

       CALL TimeValueRatio(CLVRatio!, FLVRatio!, CSURatio!, FSURatio!, CCVRatio!
  => , FCVRatio!)
       IF CF$ = "C" THEN
          IF LH$ = "L" THEN
             TrvTime! = TrvTime! * CLVRatio!
          ELSE
             TrvTime! = TrvTime! * (CSURatio! + CCVRatio!)
          END IF
       ELSEIF CF$ = "F" THEN
          IF LH$ = "L" THEN
             TrvTime! = TrvTime! * FLVRatio!
          ELSE
             TrvTime! = TrvTime! * (FSURatio! + FCVRatio!)
          END IF
       ELSE
          PRINT "ERROR IN SUB TRAVELTIME"
       END IF

TrvTime! = TrvTime! * Volume
ActualMPH% = SectionLength! / TTime!

END SUB

DEFSNG A-Z
'*************************************************************************
'*                    FUNCTION TruckAdjustFactor                          *
'*                                                                        *
'* Operation:     Computes truck adjustment factor for given traffic     *
'*                volume and vehicle combination type to be used in      *
'*                computing lane capacities.                              *
'*                                                                        *
'* Parameter(s):  TrafficPerHour -  Vehicle volume per hour.             *
'*                VType$         -  Vehicle type (SU or CV).             *
'*                VehPct!        -  Percentages for VType$.              *
'*************************************************************************
FUNCTION TruckAdjustFactor! (TrafficPerHour AS DOUBLE, VType$, VehPct!)

       SELECT CASE VType$
          CASE "SU"
             IF TrafficPerHour < 600 THEN
                Equiv! = 1.1
             ELSEIF TrafficPerHour < 1000 THEN
                Equiv! = 1.2
             ELSEIF TrafficPerHour < 1500 THEN
                Equiv! = 1.3
             ELSEIF TrafficPerHour < 1800 THEN
                Equiv! = 1.4
             ELSE
                Equiv! = 1.6
             END IF
             IF Grade% >= 0 THEN
                Equiv! = Equiv! + (Equiv! / 1.6) * (Grade% - .03)
             END IF

          CASE ELSE
             IF TrafficPerHour < 600 THEN
                Equiv! = 1.1
             ELSEIF TrafficPerHour < 1000 THEN
                Equiv! = 1.2
             ELSEIF TrafficPerHour < 1500 THEN
                Equiv! = 1.4
             ELSEIF TrafficPerHour < 1800 THEN
                Equiv! = 1.8
             ELSE
                Equiv! = 2!
             END IF
             IF Grade% >= 0 THEN
```

```
            Equiv! = Equiv! + (Equiv! / 2!) * (Grade% - .01)
         END IF
      END SELECT

      TruckAdjustFactor! = 100 / (100 + (Equiv! - 1) * VehPct!)

END FUNCTION
```

```
'***************************************************************************
'***************************************************************************
'**                                                                       **
'** TITLE:        DETAILED ANALYSIS FOR EXCLUSIVE VEHICLE FACILITIES      **
'**                                                                       **
'** DESCRIPTION:  THE DETAILED ANALYSIS FORMAT READS THE FOLLOWING        **
'**               INPUT *.PRN FILES CREATED BY THE USER VIA A LOTUS-123   **
'**               USER INTERFACE,                                         **
'**               1. SITEINFO.PRN                                         **
'**               2. TRAFFIC.PRN                                          **
'**               3. FACILITY.PRN                                         **
  =>     **
'**               4. USERCOST.PRN                                         **
'**               5. OTHER.PRN                                            **
'**               AND DISPLAYS A TWO SCREEN OUTPUT, THE BENEFITS AND      **
'**               COSTS ARE DISPLAYED ON THE FIRST OUTPUT SCREEN, AND THE **
'**               SUMMARY STATISTICS AS WELL AS THE CONTAINTS OF THE      **
'**               INPUT FILE SITEINFO.PRN ARE DISPLAYED ON THE SECOND     **
'**               OUTPUT SCREEN.  DATA FROM THE SITEINFO.PRN IS ANALYZED  **
'**               TO DETERMINE THE DESIRED CASE TYPE WHICH ARE AS FOLLOWS:**
'**               CASE 0 - DO NOTHING                                     **
'**               CASE 1 - DESIGNATE EXISTING LANES FOR MIXED, LIGHT AND  **
'**                        HEAVY VEHICLES.                                **
'**               CASE 2 - ADD MIXED-VEHICLE LANES (NO RESTRICTIONS).     **
'**               CASE 3 - ADD NONBARRIER SEPARATED LANES AND DESIGNATE   **
'**                        NEW AND EXISTING LANES FOR MIXED, LIGHT AND    **
'**                        HEAVY LANES.                                   **
'**               CASE 4 - ADD BARRIER SEPARATED LANES AND DESIGNATE NEW  **
  =>
'**                        AND EXISTING LANES FOR MIXED, LIGHT AND HEAVY  **
'**                        LANES.                                         **
'**                                                                       **
'** DEVELOPED BY: ANJU RATHI                                              **
'**               BRUCE N. JANSON      DEC. 1989                          **
'**                                                                       **
'***************************************************************************
'***************************************************************************

'*************************************************
'**   SUBROUTINE DECLARATION SECTION           **
'*************************************************
DECLARE SUB CASE0 ()
DECLARE SUB CASE1 ()
DECLARE SUB CASE2 ()
DECLARE SUB CASE3N4 (M4RFreq!, L4RFreq!, H4RFreq!, FourRFreq!)
DECLARE SUB ReadInput (ErrorCode%)
DECLARE SUB ErrorRoutine (ErrorCode%)
DECLARE SUB ComputeVehpct (yr%)
DECLARE SUB DelayArea (Volume!, RemainLanes%, ClrDur!, Spct!, Cpct!, DelayTime!)
DECLARE SUB Accidents (VMT AS DOUBLE, LVpct!, SUpct!, CVpct!, MV!, HV!, LV!, Lca
  => p AS DOUBLE, Mcap AS DOUBLE)
DECLARE SUB TravelTime (Volume AS DOUBLE, Capac AS DOUBLE, TrvTime!, ActualMPH%,
  => Pk$, CF$, LH$)
DECLARE SUB OperatingCost (PkMPH%, OfPkMPH%, SUpct!, CVpct!, PkVMT AS DOUBLE, Of
  => PkVMT AS DOUBLE, OperCost AS DOUBLE, LH$)
DECLARE SUB TimeValueRatio (CLVRatio!, FLVRatio!, CSURatio!, FSURatio!, CCVRatio
  => !, FCVRatio!)
DECLARE SUB OutputFile ()
DECLARE SUB OutputScreen1 ()
DECLARE SUB OutputScreen2 ()

'*************************************************
'**  FUNCTION DECLARATION SECTION             **
'*************************************************
DECLARE FUNCTION TruckAdjustFactor! (TrafficPerHour AS DOUBLE, VType$, VehPct!)
DECLARE FUNCTION FreqByPCR! (TotEsal!)
```

```
'*******************************************
'**  VARIABLE TYPES SECTION              **
'*******************************************
TYPE CostType
     LV        AS SINGLE
     SU        AS SINGLE
     CV        AS SINGLE
END TYPE

DEFINT A-Z          'Default variable type is integer
CONST true = -1
      false = 0

OPEN "SITEINFO.PRN" FOR INPUT AS #1            'Site Characteristics
OPEN "TRAFFIC.PRN" FOR INPUT AS #2             'Traffic Characteristics
OPEN "FACILITY.PRN" FOR INPUT AS #3            'Facility related cost figures
OPEN "USERCOST.PRN" FOR INPUT AS #4            'User related cost figures
OPEN "OTHER.PRN" FOR INPUT AS #5               'Other data
OPEN "LRUNCOST.DAT" FOR INPUT AS #6            'Operating cost for LVs
OPEN "SRUNCOST.DAT" FOR INPUT AS #7            'Operating cost for SUs
OPEN "CRUNCOST.DAT" FOR INPUT AS #8            'Operating cost for CVs
OPEN "LCRVCOST.DAT" FOR INPUT AS #9            'Excess operating cost for LVs d
  => ue to curvature
OPEN "SCRVCOST.DAT" FOR INPUT AS #10           'Excess operating cost for SUs d
  => ue to curvature
OPEN "CCRVCOST.DAT" FOR INPUT AS #11           'Excess operating cost for CVs d
  => ue to curvature
OPEN "LEVEL2.OUT" FOR OUTPUT AS #12            'File with the output results

'*************************************************************************
'**  INPUT ARRAYS AND VARIABLES SECTION                                  *
'*************************************************************************
DIM SHARED RunCost(5 TO 80, -8 TO 8)       AS CostType
DIM SHARED CurveCost(5 TO 80, 1 TO 30)     AS CostType

'         ***********************************
'         *        SITEINFO.PRN  DATA       *
'         ***********************************

DIM SHARED LocationType$            ' Location Type (Rural, Suburban, Urban)
DIM SHARED CML%                     ' Num. of Current Mixed Lanes
DIM SHARED FML%                     ' Num. of Future Mixed Lanes
DIM SHARED FLL%                     ' Num. of Future Light Use Lanes
DIM SHARED FHL%                     ' Num. of Future Heavy Use Lanes
DIM SHARED BarrierSeparated$        ' Barrier Seperation Flag (Y, N)
DIM SHARED SectionLength!           ' Length of the section
DIM SHARED NumIntersection%         ' Number of Intersections in section
DIM SHARED Grade%                   ' Road Gradient level
DIM SHARED Curvature%               ' Road Curvature

'         ***********************************
'         *        TRAFFIC.PRN  DATA        *
'         ***********************************
DIM SHARED CADT    AS LONG          ' Current Average Daily Traffic
DIM SHARED FPkIV   AS DOUBLE        ' Future Average annual increase in Peak hour
  => ADT/hr
DIM SHARED FOfPkIV AS DOUBLE        ' Future Average annual increase in OfPeak hou
  => r ADT/hr
DIM SHARED CPkV    AS DOUBLE        ' Current Peak volume per hour
DIM SHARED FPkV    AS DOUBLE        ' Future Peak volume per hour
DIM SHARED COfPkV  AS DOUBLE        ' Current Off-Peak volume per hour
DIM SHARED FOfPkV  AS DOUBLE        ' Future Off-Peak volume per hour
DIM SHARED LVmph   AS INTEGER       ' Speed limit for Light vehicles
DIM SHARED HVmph   AS INTEGER       ' Speed limit for heavy vehicles
DIM SHARED CLVpct  AS SINGLE        ' Light vehicle percentage for current volume
DIM SHARED FLVpct  AS SINGLE        ' Light vehicle percentage for future volume
```

```
DIM SHARED CSUpct  AS SINGLE      ' Single-unit vehicle percentage for current v
  => olume
DIM SHARED FSUpct  AS SINGLE      ' Single-unit vehicle percentage for future vo
  => lume
DIM SHARED CCVpct  AS SINGLE      ' Combination vehicle percentage for current v
  => olume
DIM SHARED FCVpct  AS SINGLE      ' Combination vehicle percentage for future vo
  => lume
DIM SHARED LVincr  AS SINGLE      ' Yearly increase/decrease in Light Vehicles
DIM SHARED SUincr  AS SINGLE      ' Yearly increase/decrease in Single Unit Vehi
  => cles
DIM SHARED CVincr  AS SINGLE      ' Yearly increase/decrease in Combination Vehi
  => cles

'        ***************************************
'        *        FACILITY.PRN  DATA           *
'        ***************************************
DIM SHARED ConstrucCostPM      AS LONG     ' Construction cost per mile
DIM SHARED ConstrucCostPIntg   AS LONG     ' Construction cost per interchange
DIM SHARED RightOfWayPM        AS LONG     ' Right of Way cost per mile
DIM SHARED bConstrucCostPM     AS LONG     ' Construction cost per mile with barr
  => ier
DIM SHARED bConstrucCostPIntg  AS LONG     ' Construction cost per interchange wi
  => th barrier
DIM SHARED bRightOfWayPM       AS LONG     ' Right of Way cost per mile with barr
  => ier
DIM SHARED MajorResurfcPM      AS LONG     ' Major Resurfacing per mile
DIM SHARED PSIdelta            AS SINGLE   ' PSI parameter delta in millions of 1
  => 8-kip ESALs
DIM SHARED PSIbeta             AS SINGLE   ' PSI parameter beta used as the power
  =>  exponent
DIM SHARED PSIMin              AS SINGLE   ' Minimum allowable PSI (0-5 decimals
  => included)
DIM SHARED PSIResurf           AS SINGLE   ' PSI at which resurfacing is desired
  => (0-5 decimals included)
DIM SHARED AvgLEsal            AS SINGLE   ' Average ESALs per Light vehicle
DIM SHARED AvgSEsal            AS SINGLE   ' Average ESALs per Single unit vehicl
  => e
DIM SHARED AvgCEsal            AS SINGLE   ' Average ESALs per Combination vehicl
  => e

'        ***************************************
'        *        USERCOST.PRN  DATA           *
'        ***************************************
DIM SHARED LVTimeValuePH     AS SINGLE   ' Time-value/hr. for LV
DIM SHARED SUtimeValuePH     AS SINGLE   ' Time-value/hr. for SU
DIM SHARED CVtimeValuePH     AS SINGLE   ' Time-value/hr. for CV
DIM SHARED LVaccPLVmvm       AS SINGLE   ' Accident rate per LV million vehicle
  => miles for light vehicles
DIM SHARED SUaccPSUmvm       AS SINGLE   ' Accident rate per SU million vehicle
  => miles for single-unit vehiles
DIM SHARED CVaccPCVmvm       AS SINGLE   ' Accident rate per CV million vehicle
  => miles for combination vehicles
DIM SHARED AccCostPFatal     AS LONG     ' Accident cost per fatal accident
DIM SHARED AccCostPInjury    AS LONG     ' Accident cost per injury accident
DIM SHARED AccCostPPDO       AS LONG     ' Accident cost per Property damage onl
  => y accident
DIM SHARED Block0Lanes       AS SINGLE   ' Percent of total accidents blocking n
  => o lanes.
DIM SHARED Block1Lanes       AS SINGLE   ' Percent of total accidents blocking 1
  =>  lanes.
DIM SHARED Block2Lanes       AS SINGLE   ' Percent of total accidents blocking 2
  =>  lanes.
DIM SHARED LClrDur           AS SINGLE   ' Avg. clearing duration for non-truck
  => involvements.
DIM SHARED HClrDur           AS SINGLE   ' Avg. clearing duration for truck invo
  => lvements.
DIM SHARED MaxQlen              AS SINGLE   ' Maximum queue length before traffic d
  => iversion.

'        ***************************************
'        *        OTHER.PRN  DATA              *
'        ***************************************
DIM SHARED Yrs                  AS INTEGER  ' Number of years for analysis
DIM SHARED YrsConstruc          AS INTEGER  ' Number of years for constrution
DIM SHARED DRate                AS SINGLE   ' Discount rate

'*************************************************************************
'**  OUTPUT VARIABLES SECTION                                           **
'*************************************************************************
DIM SHARED CPkCapacity    AS DOUBLE
DIM SHARED COfPkCapacity  AS DOUBLE
DIM SHARED FPkCapacity    AS DOUBLE
DIM SHARED FOfPkCapacity  AS DOUBLE
DIM SHARED FPkVolume      AS DOUBLE
DIM SHARED FOfPkVolume    AS DOUBLE
DIM SHARED COCTrvTime     AS DOUBLE
DIM SHARED COC4RCost      AS DOUBLE
DIM SHARED COCRunCost     AS DOUBLE
DIM SHARED COCAccCost     AS DOUBLE
DIM SHARED COCDelayCost   AS DOUBLE
DIM SHARED COCTotVMT!
DIM SHARED COCAccidents!
DIM SHARED COCAvgAccCost!
DIM SHARED COCAvgDelayCost!
DIM SHARED COCAvgTrvSpeed!
DIM SHARED COFAccCost     AS DOUBLE
DIM SHARED COFRunCost     AS DOUBLE
DIM SHARED COF4RCost      AS DOUBLE
DIM SHARED COFTrvTime     AS DOUBLE
DIM SHARED COFDelayCost   AS DOUBLE
DIM SHARED COFTotVMT!
DIM SHARED COFAccidents!
DIM SHARED COFAvgAccCost!
DIM SHARED COFAvgDelayCost!
DIM SHARED COFAvgTrvSpeed!
DIM SHARED FTrvTime       AS DOUBLE
DIM SHARED F4RCost        AS DOUBLE
DIM SHARED FRunCost       AS DOUBLE
DIM SHARED FDelayCost     AS DOUBLE
DIM SHARED FTotVMT!
DIM SHARED FAccidents!
DIM SHARED FAvgAccCost!
DIM SHARED FAvgDelayCost!
DIM SHARED FAvgTrvSpeed!
DIM SHARED ConstrucCost   AS DOUBLE
DIM SHARED RightOfWayCost AS DOUBLE
DIM SHARED LVaccCost      AS DOUBLE
DIM SHARED HVaccCost      AS DOUBLE
DIM SHARED MVaccCost      AS DOUBLE
DIM SHARED FAccCost       AS DOUBLE
DIM SHARED LVDCost        AS DOUBLE
DIM SHARED HVDCost        AS DOUBLE
DIM SHARED MVDCost        AS DOUBLE
DIM SHARED MNumAcc!
DIM SHARED LNumAcc!
DIM SHARED HNumAcc!

'*************************************************************************
'**                                                                     **
'** CODE BEGINS HERE !!                                                 **
```

```
'**                                                                        **
'***************************************************************************
      CLS
      SCREEN 12
      ErrorCode% = 0
      CALL ReadInput(ErrorCode%)
      IF (ErrorCode% <> 0) THEN
         CALL ErrorRoutine(ErrorCode%)
         GOTO Done
      END IF

      IF (CML% = 0) AND (FML% = 0) AND (FLL% = 0) AND (FHL% = 0) THEN
         PRINT "Analyzation can not be performed, since all lanes = 0"
         GOTO Done
      ELSEIF (CML% = FML%) AND (FLL% = 0) AND (FHL% = 0) THEN
         CALL CASE0

      ELSEIF CML% = (FLL% + FHL% + FML%) THEN
         CALL CASE0
         CALL CASE1

      ELSEIF (CML% < FML%) AND (FLL% = 0) AND (FHL% = 0) THEN
         CALL CASE0
         CALL CASE2

      ELSEIF CML% < (FML% + FLL% + FHL%) THEN
         CALL CASE0
         CALL CASE1

      ELSE
         LOCATE 4, 3
         PRINT "THE SPECIFIED CASE IS AN INFEASIBLE ONE."
         GOTO Done
      END IF
      CALL OutputFile
      CALL OutputScreen1
      BEEP
      LOCATE 30, 2
      PRINT "1 = Benefit/Cost Summary   2 = Statistics Summary   Press any othe
 => r key to exit."
Views: DO
      LOOP WHILE INKEY$ = ""
      INPUT "Enter your selection:  "; key$
      IF LTRIM$(RTRIM$(UCASE$(MID$(key$, 1, 1)))) = "1" THEN
         CALL OutputScreen1
         LOCATE 30, 2
         PRINT "1 = Benefit/Cost Summary   2 = Statistics Summary   Press any o
 => ther key to exit."
         GOTO Views
      ELSEIF LTRIM$(RTRIM$(UCASE$(MID$(key$, 1, 1)))) = "2" THEN
         CALL OutputScreen2
         LOCATE 30, 2
         PRINT "1 = Benefit/Cost Summary   2 = Statistics Summary   Press any o
 => ther key to exit."
         GOTO Views
      END IF
Done:  CLOSE #1
      CLOSE #2
      CLOSE #3
      CLOSE #4
      CLOSE #5
      CLOSE #6
      CLOSE #7
      CLOSE #8
      CLOSE #9
      CLOSE #10
      CLOSE #11
      CLOSE #12

END


'***************************************************************************
'*                        SUB PROCEDURE Accidents                         *
'*                                                                         *
'* Operation:     Computes number of accidents as well as accident        *
'*                costs for light, heavy and mixed vehicles.               *
'*                                                                         *
'* Parameter(s):  VMT - Vehicle miles travelled for the current year.     *
'*                LVpct! - Percentage of light vehicles.                   *
'*                HVpct! - Percentage of single unit vehicles.             *
'*                CVpct! - Percentage of combination vehicles.             *
'*                MV!    - Mixed vehicle volume.                           *
'*                HV!    - Heavy vehicle volume.                           *
'*                LV!    - Light vehicle volume.                           *
'*                Lcap   - Light vehicle lane(s) capacity.                 *
'*                Mcap   - Heavy or Mixed vehicle lane(s) capacity         *
'*                         where applicable.                               *
'*                                                                         *
'***************************************************************************
SUB Accidents (VMT AS DOUBLE, LVpct!, SUpct!, CVpct!, MV!, HV!, LV!, Lcap AS DOU
 => BLE, Mcap AS DOUBLE)

CONST lvClnRep = 1000
      suClnRep = 5000
      cvClnRep = 10000

DIM LVCost      AS DOUBLE
DIM SUCost      AS DOUBLE
DIM SUaccCost   AS DOUBLE
DIM CVCost      AS DOUBLE
DIM CVaccCost   AS DOUBLE
DIM SUCVCost    AS DOUBLE
DIM LVSUCost    AS DOUBLE
DIM LVCVCost    AS DOUBLE
DIM SUDCost     AS DOUBLE
DIM CVDCost     AS DOUBLE
DIM LVSUDCost   AS DOUBLE
DIM LVCVDCost   AS DOUBLE
DIM SUCVDCost   AS DOUBLE

'Compute millions of miles travelled by each vehicle type.
      Vlv! = VMT * LVpct! / 1000000
      Vsu! = VMT * SUpct! / 1000000
      Vcv! = VMT * CVpct! / 1000000

'Look for the definations of the following variables in the report.
      Rlv1! = LVaccPLVmvm * .199 / .959
      Rlv2! = LVaccPLVmvm * .671 / .959
      Rlv3! = LVaccPLVmvm * .02 / .959
      Rlv4! = LVaccPLVmvm * .069 / .959

      Rsu1! = SUaccPSUmvm * .061 / .69
      Rsu2! = SUaccPSUmvm * .019 / .69
      Rsu3! = SUaccPSUmvm * .566 / .69
      Rsu4! = SUaccPSUmvm * .044 / .69

      Rcv1! = CVaccPCVmvm * .099 / 1.002
      Rcv2! = CVaccPCVmvm * .035 / 1.002
      Rcv3! = CVaccPCVmvm * .849 / 1.002
      Rcv4! = CVaccPCVmvm * .019 / 1.002
```

```
      RLVsu! = (1 / (1 / Rlv3! + 1 / Rsu3!))
      RLVcv! = (1 / (1 / Rlv3! + 1 / Rcv3!))
      RSuCv! = (1 / (1 / Rsu3! + 1 / Rcv3!))


      SUacc! = Vsu! * Rsu1! + Vsu! * Rsu2!
      SUCost = AccCostPFatal * (.032 / 1.951) + AccCostPInjury * (.579 / 1.951)
 =>  + AccCostPPDO * (1.34 / 1.951)
      SUaccCost = SUacc! * (SUCost + suClnRep)

      CVacc! = Vcv! * Rcv1! + Vcv! * Rcv2!
      CVCost = AccCostPFatal * (.028 / 1.787) + AccCostPInjury * (.51 / 1.787)
 => + AccCostPPDO * (1.249 / 1.787)
      CVaccCost = CVacc! * (CVCost + cvClnRep)

      SUCVacc! = (2 * Vsu! * Rsu4! * Vcv! * Rcv4!) / ((Vsu! + Vcv!) * RSuCv!)
      SUCVCost = SUCVacc! * ((SUCost + CVCost + suClnRep + cvClnRep) / 2)

      HVaccCost = SUaccCost + CVaccCost + SUCVCost
      HNumAcc! = SUacc! + CVacc! + SUCVacc!

      IF (FML% <> 0) AND (FLL% <> 0) THEN

'Compute millions of miles travelled by Light vehicles on Light-Vehicle lanes.
         Vlvlv! = ((VMT / 1000000) * Lcap / Mcap) / (1 + Lcap / Mcap)
         Vlvmv! = Vlv! - Vlvlv!

         LVacc! = Vlv! * Rlv1! + Vlv! * Rlv2!
         LVCost = AccCostPFatal * (.013 / 1.134) + AccCostPInjury * (.373 / 1.1
 => 34) + AccCostPPDO * (.748 / 1.134)
         LVaccCost = LVacc! * (LVCost + lvClnRep)

         LVSUacc! = (2 * Vlvmv! * Rlv3! * Vsu! * Rsu3!) / ((Vlvmv! + Vsu!) * RL
 => Vsu!)
         LVSUCost = LVSUacc! * ((LVCost + SUCost + lvClnRep + suClnRep) / 2)

         LVCVacc! = (2 * Vlvmv! * Rlv4! * Vcv! * Rcv3!) / ((Vlvmv! + Vcv!) * RL
 => Vcv!)
         LVCVCost = LVCVacc! * ((LVCost + CVCost + lvClnRep + cvClnRep) / 2)

      ELSE  '(FHL AND FLL) OR (FML) OR (CML)
         LVacc! = Vlv! * Rlv1! + Vlv! * Rlv2!
         LVCost = AccCostPFatal * (.013 / 1.134) + AccCostPInjury * (.373 / 1.1
 => 34) + AccCostPPDO * (.748 / 1.134)
         LVaccCost = LVacc! * (LVCost + lvClnRep)

         LVSUacc! = (2 * Vlv! * Rlv3! * Vsu! * Rsu3!) / ((Vlv! + Vsu!) * RLVsu!
 => )
         LVSUCost = LVSUacc! * ((LVCost + SUCost + lvClnRep + suClnRep) / 2)

         LVCVacc! = (2 * Vlv! * Rlv4! * Vcv! * Rcv3!) / ((Vlv! + Vcv!) * RLVcv!
 => )
         LVCVCost = LVCVacc! * (LVCost + CVCost + lvClnRep + cvClnRep) / 2
      END IF

      MVaccCost = LVaccCost + HVaccCost + LVSUCost + LVCVCost
      MNumAcc! = LVacc! + HNumAcc! + LVSUacc! + LVCVacc!
      LNumAcc! = LVacc!

'Compute Delay Costs
      TimeRatio! = LVpct! * LVTimeValuePH + SUpct! * SUtimeValuePH + CVpct! * C
 => VtimeValuePH
      VehVolume! = MV! + HV! + LV!

      RemainLanes% = FML% + FHL% + FLL%
      CALL DelayArea(VehVolume!, RemainLanes%, LClrDur, SUpct!, CVpct!, DelayTi
 => me!)
      LVDCost = LVacc! * Block0Lanes * DelayTime! * TimeRatio!

      RemainLanes% = FML% + FHL% + FLL% - 1
      CALL DelayArea(VehVolume!, RemainLanes%, LClrDur, SUpct!, CVpct!, DelayTi
 => me!)
      LVDCost = LVDCost + (LVacc! * Block1Lanes * DelayTime! * TimeRatio!)

      RemainLanes% = FML% + FHL% + FLL% - 2
      CALL DelayArea(VehVolume!, RemainLanes%, LClrDur, SUpct!, CVpct!, DelayTi
 => me!)
      LVDCost = LVDCost + (LVacc! * Block2Lanes * DelayTime! * TimeRatio!)

      RemainLanes% = FML% + FHL% + FLL%
      CALL DelayArea(VehVolume!, RemainLanes%, HClrDur, SUpct!, CVpct!, DelayTi
 => me!)
      HVDCost = (SUacc! + CVacc! + LVSUacc! + LVCVacc! + SUCVacc!) * Block0Lane
 => s * DelayTime! * TimeRatio!

      RemainLanes% = FML% + FHL% + FLL% - 1
      CALL DelayArea(VehVolume!, RemainLanes%, HClrDur, SUpct!, CVpct!, DelayTi
 => me!)
      HVDCost = HVDCost + ((SUacc! + CVacc! + LVSUacc! + LVCVacc! + SUCVacc!) *
 =>  Block1Lanes * DelayTime! * TimeRatio!)

      RemainLanes% = FML% + FHL% + FLL% - 2
      CALL DelayArea(VehVolume!, RemainLanes%, HClrDur, SUpct!, CVpct!, DelayTi
 => me!)
      HVDCost = HVDCost + ((SUacc! + CVacc! + LVSUacc! + LVCVacc! + SUCVacc!) *
 =>  Block2Lanes * DelayTime! * TimeRatio!)

      MVDCost = LVDCost + HVDCost
END SUB

'**************************************************************************
'*                        SUB PROCEDURE CASE0                            *
'*                                                                        *
'* Operation:    Computes all the costs and benefits for case 0 for      *
'*               current and future traffic conditions. All global       *
'*               output varibles for current traffic conditions have     *
'*               prefix "COC".  All global output variables for future*
'*               traffic conditions have prefix "COF".                   *
'*                                                                        *
'* Parameter(s):  none.                                                  *
'**************************************************************************
SUB CASE0

CONST W! = 1           'Lane width clearence assumed to be equal to 1.

DIM VMT        AS DOUBLE
DIM PkVMT      AS DOUBLE
DIM OfPkVMT    AS DOUBLE
DIM Volume     AS DOUBLE
DIM OperCost   AS DOUBLE


      SaveFML% = FML%
      SaveFHL% = FHL%
      SaveFLL% = FLL%

      FML% = CML%
      FHL% = 0
      FLL% = 0

'COMPUTE CURRENT COSTS AND BENEFITS
'Compute CAPACITY for current Mixed traffic
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92

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        TSU! = TruckAdjustFactor((CPkV / FML%), "SU", CSUpct)
        TCV! = TruckAdjustFactor((CPkV / FML%), "CV", CCVpct)
        CPkCapacity = 2000 * W! * TSU! * TCV! * FML%

        TSU! = TruckAdjustFactor((COfPkV / FML%), "SU", CSUpct)
        TCV! = TruckAdjustFactor((COfPkV / FML%), "CV", CCVpct)
        COfPkCapacity = 2000 * W! * TSU! * TCV! * FML%

'Compute TRAVEL TIME required for current Light vehicles
        CALL TravelTime((CPkV * CLVpct), (CPkCapacity * CLVpct), CPkTrvTime!, CPk
  => MPH%, "PK", "C", "L")
        CALL TravelTime((COfPkV * CLVpct), (COfPkCapacity * CLVpct), COfPkTrvTime
  => !, COfPkMPH%, "OFPK", "C", "L")
        COCTrvTime = (CPkTrvTime! + COfPkTrvTime!) * (((1 + DRate) ^ Yrs - 1) / (
  => DRate * ((1 + DRate) ^ Yrs)))

'Compute Vehicle Operating Cost for current light vehicles
        PkVMT = SectionLength! * CPkV * 3 * 365 * CLVpct
        OfPkVMT = SectionLength! * COfPkV * 15 * 365 * CLVpct
        VMT = PkVMT + OfPkVMT

        CALL OperatingCost(CPkMPH%, COfPkMPH%, CSUpct, CCVpct, PkVMT, OfPkVMT, Op
  => erCost, "L")
        COCRunCost = OperCost / 1000 * (((1 + DRate) ^ Yrs - 1) / (DRate * ((1 +
  => DRate) ^ Yrs)))
        COCAvgTrvSpeed! = (CPkMPH% * 3 + COfPkMPH% * 15) / 18 * CLVpct

'Compute TRAVEL TIME required for current Heavy vehicles
        CALL TravelTime((CPkV * (1 - CLVpct)), (CPkCapacity * (1 - CLVpct)), CPkT
  => rvTime!, CPkMPH%, "PK", "C", "H")
        CALL TravelTime((COfPkV * (1 - CLVpct)), (COfPkCapacity * (1 - CLVpct)),
  => COfPkTrvTime!, COfPkMPH%, "OFPK", "C", "H")
        COCTrvTime = COCTrvTime + (CPkTrvTime! + COfPkTrvTime!) * (((1 + DRate) ^
  =>  Yrs - 1) / (DRate * ((1 + DRate) ^ Yrs)))
        COCTrvTime = COCTrvTime / 1000

'Compute Vehicle Operating Cost for current Heavy vehicles
        PkVMT = SectionLength! * CPkV * 3 * 365 * (1 - CLVpct)
        OfPkVMT = SectionLength! * COfPkV * 15 * 365 * (1 - CLVpct)
        VMT = VMT + PkVMT + OfPkVMT

        CALL OperatingCost(CPkMPH%, COfPkMPH%, CSUpct, CCVpct, PkVMT, OfPkVMT, Op
  => erCost, "H")
        COCRunCost = COCRunCost + (OperCost / 1000 * (((1 + DRate) ^ Yrs - 1) / (
  => DRate * ((1 + DRate) ^ Yrs))))
        COCAvgTrvSpeed! = COCAvgTrvSpeed! + (CPkMPH% * 3 + COfPkMPH% * 15) / 18 *
  =>  (1 - CLVpct)

'Compute the Lane-Resurfacing cost during the analysis period
        TotEsal! = ((CADT * 365 * Yrs) * ((CLVpct! * AvgLEsal) + (CSUpct! * AvgSE
  => sal) + (CCVpct! * AvgCEsal))) / CML% / 1000000
        FourRFreq! = FreqByPCR!(TotEsal!)
        COC4RCost = FourRFreq! * CML% * MajorResurfcPM * SectionLength! / 1000

        Vol! = CADT / 18
        CALL Accidents(VMT, CLVpct, CSUpct, CCVpct, Vol!, 0, 0, 0, ((CPkCapacity
  => * 3 + COfPkCapacity * 15) / 18))
        COCAccCost = MVaccCost / 1000 * (((1 + DRate) ^ Yrs - 1) / (DRate * ((1 +
  =>  DRate) ^ Yrs)))
        COCDelayCost = MVDCost / 1000 * (((1 + DRate) ^ Yrs - 1) / (DRate * ((1 +
  =>  DRate) ^ Yrs)))

'COMPUTE SUMMARY STATISTICS
        COCTotVMT! = VMT * Yrs
        COCAccidents! = MNumAcc! * Yrs
        COCAvgAccCost! = MVaccCost / MNumAcc!
        COCAvgDelayCost! = MVDCost / MNumAcc!

'COMPUTE FUTURE COSTS AND BENEFITS
        COFTrvTime = 0
        COFRunCost = 0
        COFAccCost = 0
        COFDelayCost = 0
        COFTotVMT! = 0
        COFAccidents! = 0
        COFAvgAccCost! = 0
        COFAvgDelayCost! = 0
        COFAvgTrvSpeed! = 0
        FourRFreq! = 0
        TotEsal! = 0

        FOR i% = 1 TO Yrs
           CALL ComputeVehpct(i%)
           FPkVolume = (CPkV + (FPkIV * i%))
           FOfPkVolume = (COfPkV + (FOfPkIV * i%))
           Volume = (FPkVolume * 3 + FOfPkVolume * 15) * 365
           TotEsal! = TotEsal! + (Volume * ((FLVpct! * AvgLEsal) + (FSUpct! * Avg
  => SEsal) + (FCVpct! * AvgCEsal))) / FML% / 1000000
           HrVolume! = (FPkVolume * 3 + FOfPkVolume * 15) / 18

'Compute CAPACITY for future Mixed traffic
           TSU! = TruckAdjustFactor((FPkVolume / FML%), "SU", FSUpct)
           TCV! = TruckAdjustFactor((FPkVolume / FML%), "CV", FCVpct)
           FPkCapacity = 2000 * W! * TSU! * TCV! * FML%

           TSU! = TruckAdjustFactor((FOfPkVolume / FML%), "SU", FSUpct)
           TCV! = TruckAdjustFactor((FOfPkVolume / FML%), "CV", FCVpct)
           FOfPkCapacity = 2000 * W! * TSU! * TCV! * FML%

'Compute TRAVEL TIME required for future Light vehicles
           CALL TravelTime((FPkVolume * FLVpct), (FPkCapacity * FLVpct), PkTrvTim
  => e!, FPkMPH%, "PK", "F", "L")
           CALL TravelTime((FOfPkVolume * FLVpct), (FOfPkCapacity * FLVpct), OfPk
  => TrvTime!, FOfPkMPH%, "OFPK", "F", "L")
           COFTrvTime = COFTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate)
  => ^ i%))

'Compute Vehicle Operating Cost for future Light vehicles
           PkVMT = SectionLength! * FPkVolume * FLVpct * 3 * 365
           OfPkVMT = SectionLength! * FOfPkVolume * FLVpct * 15 * 365
           VMT = PkVMT + OfPkVMT

           CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkVMT,
  =>  OperCost, "L")
           COFRunCost = COFRunCost + (OperCost / ((1 + DRate) ^ i%))
           COFAvgTrvSpeed! = COFAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 1
  => 8 * FLVpct

'Compute TRAVEL TIME required for future Heavy vehicles
           CALL TravelTime((FPkVolume * (1 - FLVpct)), (FPkCapacity * (1 - FLVpct
  => )), PkTrvTime!, FPkMPH%, "PK", "F", "H")
           CALL TravelTime((FOfPkVolume * (1 - FLVpct)), (FOfPkCapacity * (1 - FL
  => Vpct)), OfPkTrvTime!, FOfPkMPH%, "OFPK", "F", "H")
           COFTrvTime = COFTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate)
  => ^ i%))

'Compute Vehicle Operating Cost for future Heavy vehicles
           PkVMT = SectionLength! * FPkVolume * (1 - FLVpct) * 3 * 365
           OfPkVMT = SectionLength! * FOfPkVolume * (1 - FLVpct) * 15 * 365
           VMT = VMT + PkVMT + OfPkVMT
```

```
        CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkVMT,
  =>  OperCost, "H")
        COFRunCost = COFRunCost + (OperCost / ((1 + DRate) ^ i%))
        COFAvgTrvSpeed! = COFAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 1
  => 8 * (1 - FLVpct)

'Compute Accidents and Accidents-delay Costs
        CALL Accidents(VMT, FLVpct, FSUpct, FCVpct, HrVolume!, 0, 0, 0, ((FPkC
  => apacity * 3 + FOfPkCapacity * 15) / 18))
        COFAccCost = COFAccCost + (MVaccCost / ((1 + DRate) ^ i%))
        COFDelayCost = COFDelayCost + (MVDCost / ((1 + DRate) ^ i%))

'Compute Lane-Resurfacing frequency
        FourRFreq! = FourRFreq! + FreqByPCR!(TotEsal!)

        COFTotVMT! = COFTotVMT! + VMT
        COFAccidents! = COFAccidents! + MNumAcc!
        COFAvgAccCost! = COFAvgAccCost! + MVaccCost
        COFAvgDelayCost! = COFAvgDelayCost! + MVDCost
     NEXT i%

     COFTrvTime = COFTrvTime / 1000
     COFRunCost = COFRunCost / 1000
     COFAccCost = COFAccCost / 1000
     COFDelayCost = COFDelayCost / 1000
'Compute the Lane-Resurfacing cost
     COF4RCost = FourRFreq! * FML% * MajorResurfcPM * SectionLength! / 1000

'COMPUTE SUMMARY STATISTICS
     COFAvgAccCost! = COFAvgAccCost! / COFAccidents!
     COFAvgDelayCost! = COFAvgDelayCost! / COFAccidents!
     COFAvgTrvSpeed! = COFAvgTrvSpeed! / Yrs

     F4RCost = COF4RCost
     FTrvTime = COFTrvTime
     FRunCost = COFRunCost
     FAccCost = COFAccCost
     FDelayCost = COFDelayCost
     FTotVMT! = COFTotVMT!
     FAccidents! = COFAccidents!
     FAvgAccCost! = COFAvgAccCost!
     FAvgDelayCost! = COFAvgDelayCost!
     FAvgTrvSpeed! = COFAvgTrvSpeed!

     FML% = SaveFML%
     FHL% = SaveFHL%
     FLL% = SaveFLL%

END SUB

'************************************************************************
'*                       SUB PROCEDURE CASE1                            *
'*                                                                      *
'* Operation:     Computes all the costs and benefits for case 1 for    *
'*                future traffic conditions. All global output          *
'*                variables have prefix "F".                            *
'*                                                                      *
'* Parameter(s):  none.                                                 *
'************************************************************************
SUB CASE1

CONST W! = 1          'Lane width clearence assumed to be equal to 1.

DIM VMT          AS DOUBLE
DIM PkVMT        AS DOUBLE
DIM OfPkVMT      AS DOUBLE
DIM LVolume      AS DOUBLE
DIM HVolume      AS DOUBLE
DIM MVolume      AS DOUBLE
DIM OperCost     AS DOUBLE
DIM AccCost      AS DOUBLE
DIM PkVol        AS DOUBLE
DIM OfPkVol      AS DOUBLE
DIM LPkvol       AS DOUBLE
DIM LOfPkvol     AS DOUBLE
DIM LtPkvol      AS DOUBLE
DIM LtOfPkvol    AS DOUBLE
DIM EPkVol       AS DOUBLE
DIM EOfPkVol     AS DOUBLE
DIM HPkVol       AS DOUBLE
DIM HOfPkVol     AS DOUBLE
DIM MPkCapacity  AS DOUBLE
DIM MOfPkCapacity AS DOUBLE
DIM HPkCapacity  AS DOUBLE
DIM HOfPkCapacity AS DOUBLE
DIM LCapacity    AS DOUBLE


       L4RFreq! = 0
       H4RFreq! = 0
       M4RFreq! = 0
       LTotEsal! = 0
       HTotEsal! = 0
       MTotEsal! = 0
       FTrvTime = 0
       FRunCost = 0
       FAccCost = 0
       FDelayCost = 0

       FTotVMT! = 0
       FAccidents! = 0
       FAvgAccCost! = 0
       FAvgDelayCost! = 0
       FAvgTrvSpeed! = 0

       FOR i% = 1 TO Yrs
          CALL ComputeVehpct(i%)
          FPkVolume = CPkV + (FPkIV * i%)
          FOfPkVolume = COfPkV + (FOfPkIV * i%)
          HPkVol = FPkVolume * (FSUpct + FCVpct)
          HOfPkVol = FOfPkVolume * (FSUpct + FCVpct)

          IF (FML% <> 0) AND (FLL% <> 0) THEN

'Compute CAPACITY for future Mixed vehicle lanes
             TSU! = TruckAdjustFactor((HPkVol / FML%), "SU", FSUpct)
             TCV! = TruckAdjustFactor((HPkVol / FML%), "CV", FCVpct)
             MPkCapacity = 2000 * W! * TSU! * TCV! * FML%

             TSU! = TruckAdjustFactor((HOfPkVol / FML%), "SU", FSUpct)
             TCV! = TruckAdjustFactor((HOfPkVol / FML%), "CV", FCVpct)
             MOfPkCapacity = 2000 * W! * TSU! * TCV! * FML%

'Compute CAPACITY for future Light vehicle Lanes
             LCapacity = 2000 * W! * FLL%
             LtPkvol = FPkVolume * FLVpct
             LtOfPkvol = FOfPkVolume * FLVpct

'Estimated the number of Light vehicles that will take Light-Vehicle lanes
ReEst:       EPkVol = (FPkVolume * (LCapacity / MPkCapacity)) / (1 + LCapacity /
  =>  MPkCapacity)
             EOfPkVol = (FOfPkVolume * (LCapacity / MOfPkCapacity)) / (1 + LCapa
```

```
 => city / MOfPkCapacity)

            IF LtPkvol > EPkVol THEN
               LPkvol = EPkVol
               PkVol = LtPkvol - LPkvol
            ELSE
               LPkvol = LtPkvol
               PkVol = 0
            END IF

            IF LtOfPkvol > EOfPkVol THEN
               LOfPkvol = EOfPkVol
               OfPkVol = LtOfPkvol - LOfPkvol
            ELSE
               LOfPkvol = LtOfPkvol
               OfPkVol = 0
            END IF

'Compute TRAVEL TIME required for future Light vehicles
            CALL TravelTime(LPkvol, LCapacity, PkTrvTime!, FPkMPH%, "PK", "F",
 => "L")
            CALL TravelTime(LOfPkvol, LCapacity, OfPkTrvTime!, FOfPkMPH%, "OFPK
 => ", "F", "L")
            FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^
 =>  i%))

'Compute Vehicle Operating Cost for the light vehicles on light vehicle lanes
            PkVMT = SectionLength! * LPkvol * 3 * 365
            OfPkVMT = SectionLength! * LOfPkvol * 15 * 365
            VMT = PkVMT + OfPkVMT
            HrLVolume! = (LPkvol * 3 + LOfPkvol * 15) / 18
            LVolume = (LPkvol * 3 + LOfPkvol * 15) * 365

            CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkV
 => MT, OperCost, "L")
            FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))

            pct! = (LPkvol + LOfPkvol) / (FPkVolume + FOfPkVolume)
            FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18
 =>  * pct!

            SMPkCap = MPkCapacity
            SMOfPkCap = MOfPkCapacity

            PkSUpct! = (FPkVolume * FSUpct) / (HPkVol + PkVol)
            PkCVpct! = (FPkVolume * FCVpct) / (HPkVol + PkVol)
            OfPkSUpct! = (FOfPkVolume * FSUpct) / (HOfPkVol + OfPkVol)
            OfPkCVpct! = (FOfPkVolume * FCVpct) / (HOfPkVol + OfPkVol)
            PkLVpct! = 1 - (PkSUpct! + PkCVpct!)
            OfPkLVpct! = 1 - (OfPkSUpct! + OfPkCVpct!)

'ReCompute CAPACITY for future mixed vehicle Lanes
            TSU! = TruckAdjustFactor(((HPkVol + PkVol) / FML%), "SU", PkSUpct!)
            TCV! = TruckAdjustFactor(((HPkVol + PkVol) / FML%), "CV", PkCVpct!)
            MPkCapacity = 2000 * W! * TSU! * TCV! * FML%

            TSU! = TruckAdjustFactor(((HOfPkVol + OfPkVol) / FML%), "SU", OfPkS
 => Upct!)
            TCV! = TruckAdjustFactor(((HOfPkVol + OfPkVol) / FML%), "CV", OfPkC
 => Vpct!)
            MOfPkCapacity = 2000 * W! * TSU! * TCV! * FML%

            IF ((SMPkCap - MPkCapacity) > 1) THEN
            'OR ((SMOfPkCap - MOfPkCapacity) > 1) THEN
               FTrvTime = FTrvTime - (((PkTrvTime! + OfPkTrvTime!) / ((1 + DRat
 => e) ^ i%)))
               VMT = 0
               FRunCost = FRunCost - ((OperCost / ((1 + DRate) ^ i%)))
               FAvgTrvSpeed! = FAvgTrvSpeed! - (FPkMPH% * 3 + FOfPkMPH% * 15) /
 =>  18 * pct!
               GOTO ReEst
            END IF

'Compute TRAVEL TIME required for future Heavy vehicles
            CALL TravelTime(HPkVol, (MPkCapacity * (1 - PkLVpct!)), PkTrvTime!,
 =>  FPkMPH%, "PK", "F", "H")
            CALL TravelTime(HOfPkVol, (MOfPkCapacity * (1 - OfPkLVpct!)), OfPkT
 => rvTime!, FOfPkMPH%, "OFPK", "F", "H")
            FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^
 =>  i%))

'Compute Vehicle Operating Cost for the Heavy vehicles on the mixed lanes
            PkVMT = SectionLength! * HPkVol * 3 * 365
            OfPkVMT = SectionLength! * HOfPkVol * 15 * 365
            VMT = VMT + PkVMT + OfPkVMT
            HrHVolume! = (HPkVol * 3 + HOfPkVol * 15) / 18
            HVolume = (HPkVol * 3 + HOfPkVol * 15) * 365
            HrMVolume! = ((HPkVol + PkVol) * 3 + (HOfPkVol + OfPkVol) * 15) / 1
 => 8
            MVolume = ((HPkVol + PkVol) * 3 + (HOfPkVol + OfPkVol) * 15) * 365

            CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkV
 => MT, OperCost, "H")
            FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))
            pct! = (HPkVol + HOfPkVol) / (FPkVolume + FOfPkVolume)
            FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18
 =>  * pct!

'Compute TRAVEL TIME required for future Light vehicles on mixed lanes
 =>
            CALL TravelTime(PkVol, (MPkCapacity * PkLVpct!), PkTrvTime!, FPkMPH
 => %, "PK", "F", "L")
            CALL TravelTime(OfPkVol, (MOfPkCapacity * OfPkLVpct!), OfPkTrvTime!
 => , FOfPkMPH%, "OFPK", "F", "L")
            FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^
 =>  i%))

'Compute Vehicle Operating Cost for the light vehicles on mixed lanes
            PkVMT = SectionLength! * PkVol * 3 * 365
            OfPkVMT = SectionLength! * OfPkVol * 15 * 365
            VMT = VMT + PkVMT + OfPkVMT

            CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkV
 => MT, OperCost, "L")
            FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))
            pct! = (PkVol + OfPkVol) / (FPkVolume + FOfPkVolume)
            FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18
 =>  * pct!

'Compute Accidents and Accidents-delay Costs
            CALL Accidents(VMT, FLVpct, FSUpct, FCVpct, HrMVolume!, 0, HrLVolum
 => e!, LCapacity, ((MPkCapacity * 3 + MOfPkCapacity * 15) / 18))
            FAccCost = FAccCost + (MVaccCost / ((1 + DRate) ^ i%))
            FDelayCost = FDelayCost + (MVDCost / ((1 + DRate) ^ i%))

'Compute vehicle-type percentages and compute ESAL and Resurfacing freq. for mix
 => ed and light lanes
            Lpct! = 1 - (HVolume / MVolume)
            Totpct! = FSUpct + FCVpct
            Spct! = (1 - Lpct!) * (FSUpct / Totpct!)
            Cpct! = (1 - Lpct!) * (FCVpct / Totpct!)
            MTotEsal! = MTotEsal! + (MVolume * ((Lpct! * AvgLEsal) + (Spct! * A
```

```
=> vgSEsal) + (Cpct! * AvgCEsal))) / FML% / 1000000
            M4RFreq! = M4RFreq! + FreqByPCR!(MTotEsal!)
            LTotEsal! = LTotEsal! + (LVolume * AvgLEsal) / FLL% / 1000000
            L4RFreq! = L4RFreq! + FreqByPCR!(LTotEsal!)

'COMPUTE SUMMARY STATISTICS
            FTotVMT! = FTotVMT! + VMT
            FAccidents! = FAccidents! + MNumAcc!
            FAvgAccCost! = FAvgAccCost! + MVaccCost
            FAvgDelayCost! = FAvgDelayCost! + MVDCost

         ELSEIF (FLL% <> 0) AND (FHL% <> 0) THEN

'Compute CAPACITY for future Light vehicle lanes
            LCapacity = 2000 * W! * FLL%
            LPkvol = FPkVolume * FLVpct
            LOfPkvol = FOfPkVolume * FLVpct

'Compute TRAVEL TIME required for future Light vehicles
            CALL TravelTime(LPkvol, LCapacity, PkTrvTime!, FPkMPH%, "PK", "F",
 => "L")
            CALL TravelTime(LOfPkvol, LCapacity, OfPkTrvTime!, FOfPkMPH%, "OFPK
 => ", "F", "L")
            FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^
 =>  i%))

'Compute Vehicle Operating Cost for the Light vehicles on Light-Vehicle lanes
            PkVMT = SectionLength! * LPkvol * 3 * 365
            OfPkVMT = SectionLength! * LOfPkvol * 15 * 365
            VMT = PkVMT + OfPkVMT
            HrLVolume! = (LPkvol * 3 + LOfPkvol * 15) / 18
            LVolume = (LPkvol * 3 + LOfPkvol * 15) * 365

            CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkV
 => MT, OperCost, "L")
            FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))
            FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18
 =>  * FLVpct

'Compute CAPACITY for future Heavy vehicle lanes
            TSU! = TruckAdjustFactor((HPkVol / FHL%), "SU", (FSUpct / (1 - FLVp
 => ct)))
            TCV! = TruckAdjustFactor((HPkVol / FHL%), "CV", (FCVpct / (1 - FLVp
 => ct)))
            HPkCapacity = 2000 * W! * TSU! * TCV! * FHL%

            TSU! = TruckAdjustFactor((HOfPkVol / FHL%), "SU", (FSUpct / (1 - FL
 => Vpct)))
            TCV! = TruckAdjustFactor((HOfPkVol / FHL%), "CV", (FCVpct / (1 - FL
 => Vpct)))
            HOfPkCapacity = 2000 * W! * TSU! * TCV! * FHL%

'Compute TRAVEL TIME required for future Heavy vehicles
            CALL TravelTime(HPkVol, HPkCapacity, PkTrvTime!, FPkMPH%, "PK", "F"
 => , "H")
            CALL TravelTime(HOfPkVol, HOfPkCapacity, OfPkTrvTime!, FOfPkMPH%, "
 => OFPK", "F", "H")
            FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^
 =>  i%))

'Compute Vehicle Operating Cost for the Heavy vehicles on Heavy-Vehicle lanes
            PkVMT = SectionLength! * HPkVol * 3 * 365
            OfPkVMT = SectionLength! * HOfPkVol * 15 * 365
            VMT = VMT + PkVMT + OfPkVMT
            HrHVolume! = (HPkVol * 3 + HOfPkVol * 15) / 18
            HVolume = (HPkVol * 3 + HOfPkVol * 15) * 365

            CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkV
 => MT, OperCost, "H")
            FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))
            FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18
 =>  * (1 - FLVpct)

'Compute Accidents and Accidents-delay Costs
            CALL Accidents(VMT, FLVpct, FSUpct, FCVpct, 0, HrHVolume!, HrLVolum
 => e!, LCapacity, ((HPkCapacity * 3 + HOfPkCapacity * 15) / 18))
            AccCost = LVaccCost + HVaccCost
            FAccCost = FAccCost + (AccCost / ((1 + DRate) ^ i%))
            AccCost = LVDCost + HVDCost
            FDelayCost = FDelayCost + (AccCost / ((1 + DRate) ^ i%))

'Compute vehicle-type percentages and compute ESAL & Resurfacing freq. for heavy
 =>  and light lanes
            Spct! = FSUpct / (FSUpct + FCVpct)
            Cpct! = FCVpct / (FSUpct + FCVpct)
            HTotEsal! = HTotEsal! + (HVolume * ((Spct! * AvgSEsal) + (Cpct! * A
 => vgCEsal))) / FHL% / 1000000
            H4RFreq! = H4RFreq! + FreqByPCR!(HTotEsal!)
            LTotEsal! = LTotEsal! + (LVolume * AvgLEsal) / FLL% / 1000000
            L4RFreq! = L4RFreq! + FreqByPCR!(LTotEsal!)

'COMPUTE SUMMARY STATISTICS
            FTotVMT! = FTotVMT! + VMT
            FAccidents! = FAccidents! + LNumAcc! + HNumAcc!
            FAvgAccCost! = FAvgAccCost! + LVaccCost + HVaccCost
            FAvgDelayCost! = FAvgDelayCost! + LVDCost + HVDCost

         ELSE
            PRINT "Only feasible options are (ML and LL) or (HL and LL) "
         END IF
      NEXT i%

      FTrvTime = FTrvTime / 1000
      FRunCost = FRunCost / 1000
      FAccCost = FAccCost / 1000
      FDelayCost = FDelayCost / 1000

'Compute Lane-Resurfacing cost
      IF FML% <> 0 THEN
         FourRFreq! = M4RFreq!
      ELSE
         FourRFreq! = 0
      END IF
      IF (FHL% <> 0) AND (H4RFreq! > FourRFreq!) THEN
            FourRFreq! = H4RFreq!
      END IF
      IF (FLL% <> 0) AND (L4RFreq! > FourRFreq!) THEN
            FourRFreq! = L4RFreq!
      END IF
      F4RCost = FourRFreq! * (FML% + FHL% + FLL%) * MajorResurfcPM * SectionLen
 => gth! / 1000

      FAvgAccCost! = FAvgAccCost! / FAccidents!
      FAvgDelayCost! = FAvgDelayCost! / FAccidents!
      FAvgTrvSpeed! = FAvgTrvSpeed! / Yrs

      IF CML% < (FML% + FLL% + FHL%) THEN
         CALL CASE3N4(M4RFreq!, L4RFreq!, H4RFreq!, FourRFreq!)
      END IF

END SUB
```

```
'***************************************************************************
'*                       SUB PROCEDURE CASE2                               *
'*                                                                         *
'* Operation:     Computes all the costs and benefits for case 2 for       *
'*                future traffic conditions. All global output             *
'*                variables have prefix "F".                               *
'*                                                                         *
'* Parameter(s):  none.                                                    *
'***************************************************************************
SUB CASE2

CONST W! = 1          'Lane width clearence assumed to be equal to 1.

DIM VMT       AS DOUBLE
DIM PkVMT     AS DOUBLE
DIM OfPkVMT   AS DOUBLE
DIM Volume    AS DOUBLE
DIM OperCost  AS DOUBLE
DIM ConsperYr AS DOUBLE

'COMPUTE FUTURE COSTS AND BENEFITS
       FTrvTime = 0
       FRunCost = 0
       FAccCost = 0
       FDelayCost = 0
       FTotVMT! = 0
       FAccidents! = 0
       FAvgAccCost! = 0
       FAvgDelayCost! = 0
       FAvgTrvSpeed! = 0
       FourRFreq! = 0
       TotEsal! = 0

       FOR i% = 1 TO Yrs
          CALL ComputeVehpct(i%)
          FPkVolume = CPkV + (FPkIV * i%)
          FOfPkVolume = COfPkV + (FOfPkIV * i%)
          HrVolume! = (FPkVolume * 3 + FOfPkVolume * 15) / 18
          Volume = (FPkVolume * 3 + FOfPkVolume * 15) * 365
          TotEsal! = TotEsal! + (Volume * ((FLVpct! * AvgLEsal) + (FSUpct! * Avg
  => SEsal) + (FCVpct! * AvgCEsal))) / FML% / 1000000

'Compute CAPACITY for future Mixed traffic
          TSU! = TruckAdjustFactor((FPkVolume / FML%), "SU", FSUpct)
          TCV! = TruckAdjustFactor((FPkVolume / FML%), "CV", FCVpct)
          FPkCapacity = 2000 * W! * TSU! * TCV! * FML%

          TSU! = TruckAdjustFactor((FOfPkVolume / FML%), "SU", FSUpct)
          TCV! = TruckAdjustFactor((FOfPkVolume / FML%), "CV", FCVpct)
          FOfPkCapacity = 2000 * W! * TSU! * TCV! * FML%

'Compute TRAVEL TIME required for future Light vehicles
          CALL TravelTime((FPkVolume * FLVpct), (FPkCapacity * FLVpct), PkTrvTim
  => e!, FPkMPH%, "PK", "F", "L")
          CALL TravelTime((FOfPkVolume * FLVpct), (FOfPkCapacity * FLVpct), OfPk
  => TrvTime!, FOfPkMPH%, "OFPK", "F", "L")
          FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^ i%
  => ))

'Compute Vehicle Operating Cost for future Light vehicles
          PkVMT = SectionLength! * FPkVolume * FLVpct * 3 * 365
          OfPkVMT = SectionLength! * FOfPkVolume * FLVpct * 15 * 365
          VMT = PkVMT + OfPkVMT

          CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkVMT,
  =>  OperCost, "L")
          FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))
          FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18 *
  => FLVpct

'Compute TRAVEL TIME required for future Heavy vehicles
          CALL TravelTime((FPkVolume * (1 - FLVpct)), (FPkCapacity * (1 - FLVpct
  => )), PkTrvTime!, FPkMPH%, "PK", "F", "H")
          CALL TravelTime((FOfPkVolume * (1 - FLVpct)), (FOfPkCapacity * (1 - FL
  => Vpct)), OfPkTrvTime!, FOfPkMPH%, "OFPK", "F", "H")
          FTrvTime = FTrvTime + ((PkTrvTime! + OfPkTrvTime!) / ((1 + DRate) ^ i%
  => ))

'Compute Vehicle Operating Cost for future Heavy vehicles
          PkVMT = SectionLength! * FPkVolume * (1 - FLVpct) * 3 * 365
          OfPkVMT = SectionLength! * FOfPkVolume * (1 - FLVpct) * 15 * 365
          VMT = VMT + PkVMT + OfPkVMT

          CALL OperatingCost(FPkMPH%, FOfPkMPH%, FSUpct, FCVpct, PkVMT, OfPkVMT,
  =>  OperCost, "H")
          FRunCost = FRunCost + (OperCost / ((1 + DRate) ^ i%))
          FAvgTrvSpeed! = FAvgTrvSpeed! + (FPkMPH% * 3 + FOfPkMPH% * 15) / 18 *
  => (1 - FLVpct)

'Compute Accidents and Accidents-delay Costs
          CALL Accidents(VMT, FLVpct, FSUpct, FCVpct, HrVolume!, 0, 0, 0, ((FPkC
  => apacity * 3 + FOfPkCapacity * 15) / 18))
          FAccCost = FAccCost + (MVaccCost / ((1 + DRate) ^ i%))
          FDelayCost = FDelayCost + (MVDCost / ((1 + DRate) ^ i%))

'Compute Lane-Resurfacing frequency
          FourRFreq! = FourRFreq! + FreqByPCR!(TotEsal!)

          FTotVMT! = FTotVMT! + VMT
          FAccidents! = FAccidents! + MNumAcc!
          FAvgAccCost! = FAvgAccCost! + MVaccCost
          FAvgDelayCost! = FAvgDelayCost! + MVDCost

       NEXT i%

       FTrvTime = FTrvTime / 1000
       FRunCost = FRunCost / 1000
       FAccCost = FAccCost / 1000
       FDelayCost = FDelayCost / 1000
'Compute the Lane-Resurfacing cost
       F4RCost = FourRFreq! * FML% * MajorResurfcPM * SectionLength! / 1000

'COMPUTE SUMMARY STATISTICS
       FAvgAccCost! = FAvgAccCost! / FAccidents!
       FAvgDelayCost! = FAvgDelayCost! / FAccidents!
       FAvgTrvSpeed! = FAvgTrvSpeed! / Yrs

'Compute the Lane-Resurfacing cost during the analysis period
       F4RCost = FourRFreq! * FML% * MajorResurfcPM * SectionLength! / 1000

'Compute the Construction & Right-of-way cost
       ConstrucCost = (ConstrucCostPM) * SectionLength! * (FML% - CML%) + NumInt
  => ersection% * ConstrucCostPIntg
       ConstrucCost = ConstrucCost + CML% * MajorResurfcPM * SectionLength!
       ConsperYr = ConstrucCost / YrsConstruc
       ConstrucCost = 0
       FOR i% = 1 TO YrsConstruc
          ConstrucCost = ConstrucCost + ConsperYr / ((1 + DRate) ^ i%)
       NEXT i%
       ConstrucCost = ConstrucCost / 1000
       RightOfWayCost = RightOfWayPM * SectionLength! * (FML% - CML%) / 1000
```

```
END SUB

'*************************************************************************
'*                    SUB PROCEDURE CASE3N4                              *
'*                                                                       *
'* Operation:     Computes all the costs and benefits for case 3 and     *
'*                case 4 for future traffic conditions. This sub-        *
'*                procedure is called from another sub procedure         *
'*                "CASE1", since new construction cost and the           *
'*                resurfacing cost (due to barrier) are the only         *
'*                diffrences between these cases.  All global output     *
'*                variables have prefix "F".                             *
'*                                                                       *
'* Parameter(s):  none.                                                  *
'*************************************************************************
SUB CASE3N4 (M4Freq!, L4Freq!, H4Freq!, FourRFrq!)

CONST W! = 1               'Lane width clearence assumed to be equal to 1.
DIM ConsperYr AS DOUBLE

'Compute the Construction & Right-of-way cost
       IF BarrierSeparated$ = "Y" THEN
          F4RCost = (M4Freq! * FML% + H4Freq! * FHL% + L4Freq! * FLL%) * MajorRe
  => surfcPM * SectionLength! / 1000
       ELSE
          F4RCost = FourRFrq! * (FML% + FHL% + FLL%) * MajorResurfcPM * SectionL
  => ength! / 1000
       END IF

       IF BarrierSeparated$ = "Y" THEN
          ConstrucCost = bConstrucCostPM * SectionLength! * (FML% + FLL% + FHL%
  => - CML%) + NumIntersection% * bConstrucCostPIntg
          RightOfWayCost = bRightOfWayPM * SectionLength! * (FML% + FLL% + FHL%
  => - CML%) / 1000
       ELSE
          ConstrucCost = ConstrucCostPM * SectionLength! * (FML% + FLL% + FHL% -
  =>  CML%) + NumIntersection% * ConstrucCostPIntg
          RightOfWayCost = RightOfWayPM * SectionLength! * (FML% + FLL% + FHL% -
  =>  CML%) / 1000
       END IF
       ConstrucCost = ConstrucCost + CML% * MajorResurfcPM * SectionLength!
       ConsperYr = ConstrucCost / YrsConstruc
       ConstrucCost = 0
       FOR i% = 1 TO YrsConstruc
          ConstrucCost = ConstrucCost + ConsperYr / ((1 + DRate) ^ i%)
       NEXT i%
       ConstrucCost = ConstrucCost / 1000

END SUB

'*************************************************************************
'*                 SUB PROCEDURE ComputeVehpct                           *
'*                                                                       *
'* Operation:     Computes the vehicle type percentage for the given     *
'*                year.                                                  *
'*                                                                       *
'* Parameter(s):  yr% - Analysis year.                                   *
'*************************************************************************
SUB ComputeVehpct (yr%)

       IF LVincr < 0 THEN
          FLVpct = (CLVpct - (-LVincr * yr%))
       ELSE
          FLVpct = (CLVpct + (LVincr * yr%))
       END IF
       IF SUincr < 0 THEN
          FSUpct = (CSUpct - (-SUincr * yr%))
       ELSE
          FSUpct = (CSUpct + (SUincr * yr%))
       END IF
       IF CVincr < 0 THEN
          FCVpct = (CCVpct - (-CVincr * yr%))
       ELSE
          FCVpct = (CCVpct + (CVincr * yr%))
       END IF

END SUB

'*************************************************************************
'*                     SUB PROCEDURE DelayArea                           *
'*                                                                       *
'* Operation:     Computes the delay time by computing the area of a     *
'*                polygon described in model qdelay2.wk1. The output     *
'*                parameter "DelayTime!" contains this delay time.       *
'*                                                                       *
'* Parameter(s):  Volume!       - Vehicle volume for the analysis year.  *
'*                RemainLanes%  - Number of open lanes.                  *
'*                ClrDur!       - Minutes required to clear the accident*
'*                Spct!         - Single unit vehicle percentage.        *
'*                Cpct!         - Combination unit vehicle percentage.   *
'*                DelayTime!    - Time delay caused by an accident.      *
'*************************************************************************
SUB DelayArea (Volume!, RemainLanes%, ClrDur!, Spct!, Cpct!, DelayTime!)

CONST W! = 1                    'assumed lane width clearence to be 1.

       V1! = Volume!
       T2! = ClrDur!

       IF (RemainLanes% < 0) THEN
          DelayTime! = 0
          GOTO INFEASIBLE
       ELSEIF (RemainLanes% = 0) THEN
          C1! = 0

          TSU! = TruckAdjustFactor((VehVolume! / (FML% + FHL% + FLL%)), "SU", Sp
 => ct!)
          TCV! = TruckAdjustFactor((VehVolume! / (FML% + FHL% + FLL%)), "CV", Cp
 => ct!)
          C2! = 2000 * W! * TSU! * TCV! * (FML% + FHL% + FLL%)

          IF (FLL% > 0) THEN  ' ONLY FOR EXCLUSIVE VEHICLE LANES A SHIFT IS POSS
 => IBLE.
             V1! = 1600
          END IF
       ELSEIF (Spct! = 0) AND (Cpct! = 0) THEN
          C1! = 2000 * W! * RemainLanes% * .8
          C2! = 2000 * W! * (FML% + FHL% + FLL%)
       ELSE
          TSU! = TruckAdjustFactor((VehVolume! / RemainLanes%), "SU", Spct!)
          TCV! = TruckAdjustFactor((VehVolume! / RemainLanes%), "CV", Cpct!)
          C1! = 2000 * W! * TSU! * TCV! * RemainLanes% * .8

          TSU! = TruckAdjustFactor((VehVolume! / (FML% + FHL% + FLL%)), "SU", Sp
 => ct!)
          TCV! = TruckAdjustFactor((VehVolume! / (FML% + FHL% + FLL%)), "CV", Cp
 => ct!)
          C2! = 2000 * W! * TSU! * TCV! * (FML% + FHL% + FLL%)
       END IF
       IF (V1! < C1!) THEN
          DelayTime! = 0
       ELSE
```

```
         IF (BarrierSeparated$ = "N") OR ((FML% > 0) AND (FLL% = 0) AND (FHL% =
  =>  0)) THEN
            V2! = V1! - .35 * (V1! - C1!)
         ELSE
            V2! = V1! - .7 * (V1! - C1!)
         END IF
         IF (V2! >= (.9 * C2!)) THEN
            V2! = .9 * C2!
         END IF

         Qlength! = (FML% + FLL% + FHL%) * 105.6 * MaxQlen
         T1! = Qlength! / (V1! - C1!)
         T2! = T2! / 60
         IF (T1! > T2!) THEN
            T1! = T2!
         END IF
         T3! = T1! + (T1! * (V1! - C1!) + (T2! - T1!) * (C2! - C1!)) / (C2! - V
  => 2!)
         Delay1! = .5 * (T1! ^ 2 * (V1! - C1!) - (T2! - T1!) ^ 2 * (C2! - C1!))
         Delay2! = .5 * (T3! - T1!) * (T1! * (V1! - C1!) + (T2! - T1!) * (C2! -
  =>  C1!))
         DelayTime! = Delay1! + Delay2!
      END IF
INFEASIBLE:         'END OF THE SUBROUTINE
END SUB

DEFSNG A-Z
'***************************************************************************
'*                     SUB PROCEDURE ErrorRoutine                          *
'*                                                                         *
'* Operation:     Displays an output screen with an error message.         *
'*                                                                         *
'* Parameter(s):  ErrorCode%   - Error type number.                        *
'***************************************************************************
SUB ErrorRoutine (ErrorCode%)
       SCREEN 12
       COLOR 15
       LINE (2, 2)-(637, 2)
       LINE (637, 2)-(637, 187)
       LINE (637, 187)-(2, 187)
       LINE (2, 187)-(2, 2)
       COLOR 5
       LOCATE 4, 3
       SELECT CASE ErrorCode%
          CASE 1
             PRINT "Area Type must be either R, S, or U"
             LOCATE 5, 3
             PRINT "R = Rural, S = Suburban, U = Urban"
          CASE 2
             PRINT "Either Y or N is expected for barrier seperation"
          CASE 3
             PRINT "Years for Analysis must be greater than 0"
          CASE 4
             PRINT "Construction years must be greater than 0"
          CASE 5
             PRINT "Discount rate must be greater than 0"
          CASE 6
             PRINT "Gradient Level must be between -8 and +8"
          CASE 7
             PRINT "Curvature must be between 1 and 30"
          CASE 8
             PRINT "Speed limit for Light Vehicles must be between 5 and 80"
          CASE 9
             PRINT "Speed limit for Heavy Vehicles must be between 5 and 80"
          CASE 10
             PRINT "Sum of CLVpct, CSUpct and CCVpct is not equal to 100%"
          CASE 11
             PRINT "Sum of FLVpct, FSUpct and FCVpct is not equal to 100%"
          CASE 12
             PRINT "Mixed vehicle lanes and Heavy vehicle lanes together is not
  => a valid option!"
             LOCATE 6, 3
             PRINT "Valid options are as following:"
             LOCATE 7, 3
             PRINT "   Mixed vehicle lanes alone"
             LOCATE 8, 3
             PRINT "   Light vehicle lanes and Mixed vehicle lanes"
             LOCATE 9, 3
             PRINT "   Light vehicle lanes and Heavy vehicle lanes"
       END SELECT
       LOCATE 12, 53
       PRINT "Press any key to exit"
       DO
       LOOP WHILE INKEY$ = ""

  END SUB

DEFINT A-Z
'***************************************************************************
'*                         SUB PROCEDURE FreqByPCR!                        *
'*                                                                         *
'* Operation:     Computes frequency for resurfacing the lanes if it is*
'*                required during the current year?                        *
'*                                                                         *
'* Parameter(s):  TotEsal!   - Total ESALs since last resurfacing.         *
'***************************************************************************
FUNCTION FreqByPCR! (TotEsal!)

CONST InitPSI! = 5!

      a! = LOG(-LOG(PSIResurf / (InitPSI! - PSIMin)))
      EsalMin! = EXP((-a! / PSIbeta) + LOG(PSIdelta))
      IF TotEsal! > EsalMin! THEN
         FreqByPCR! = TotEsal! / EsalMin!
         TotEsal! = 0
      ELSE
         FreqByPCR! = 0
      END IF

END FUNCTION

'***************************************************************************
'*                        SUB PROCEDURE OperatingCost                      *
'*                                                                         *
'* Operation:     Computes operating cost for given MPH, vehicle           *
'*                combination type and the vehicle miles travelled.        *
'*                                                                         *
'* Parameter(s):  PkMPH%    - MPH during peak hours.                       *
'*                OfPkMPH%  - MPH during off-peak hours.                   *
'*                SUpct!    - Single unit vehicle percntages.              *
'*                CVpct!    - Combination vehicle percentages.             *
'*                PkVMT     - VMT during peak hours.                       *
'*                OfPkVMT   - VMT during off-peak hours.                   *
'*                OperCost  - Operating cost for the given input values.*
'*                LHS       - Vehicle type (Light or Heavy).               *
'***************************************************************************
SUB OperatingCost (PkMPH%, OfPkMPH%, SUpct!, CVpct!, PkVMT AS DOUBLE, OfPkVMT AS
  =>  DOUBLE, OperCost AS DOUBLE, LH$)

DIM PkRunCost       AS DOUBLE
DIM OfPkRunCost     AS DOUBLE
DIM PkCurvCost      AS DOUBLE
```

```
DIM OfPkCurvCost   AS DOUBLE

       Totpct! = SUpct! + CVpct!
       Spct! = SUpct! / Totpct!
       Cpct! = CVpct! / Totpct!


       IF PkMPH% < 5 THEN
          PkMPH% = 5
       END IF
       IF OfPkMPH% < 5 THEN
          OfPkMPH% = 5
       END IF
       IF PkMPH% > 80 THEN
          PkMPH% = 80
       END IF
       IF OfPkMPH% > 80 THEN
          OfPkMPH% = 80
       END IF

       IF LH$ = "L" THEN
          PkRunCost = (PkVMT / 1000) * (RunCost(PkMPH%, Grade%).LV + CurveCost(P
=> kMPH%, Curvature%).LV)
          OfPkRunCost = (OfPkVMT / 1000) * (RunCost(OfPkMPH%, Grade%).LV + Curve
=> Cost(OfPkMPH%, Curvature%).LV)
       ELSEIF LH$ = "H" THEN
          PkRunCost = (PkVMT / 1000) * (RunCost(PkMPH%, Grade%).SU * Spct! + Run
=> Cost(PkMPH%, Grade%).CV * Cpct!)
          PkCurvCost = (PkVMT / 1000) * (CurveCost(PkMPH%, Curvature%).SU * Spct
=> ! + CurveCost(PkMPH%, Curvature%).CV * Cpct!)
          PkRunCost = PkRunCost + PkCurvCost

          OfPkRunCost = (OfPkVMT / 1000) * (RunCost(OfPkMPH%, Grade%).SU * Spct!
=>  + RunCost(OfPkMPH%, Grade%).CV * Cpct!)
          OfPkCurvCost = (OfPkVMT / 1000) * (CurveCost(OfPkMPH%, Curvature%).SU
=> * Spct! + CurveCost(OfPkMPH%, Curvature%).CV * Cpct!)
          OfPkRunCost = OfPkRunCost + OfPkCurvCost
       END IF

       OperCost = PkRunCost + OfPkRunCost

END SUB

SUB OutputFile
       PRINT #12, "COST SUMMARY (in $1000s)"
       PRINT #12, "                          Base Case                   Alternati
=> ve Case"
       PRINT #12, "             No Traffic incr.   Traffic incr.  Traffic incr.
=>  Net Costs"
       PRINT #12, "Resurfacing Lanes";
       PRINT #12, USING "$$###########"; COC4RCost; COF4RCost;
       PRINT #12, "      ";
       PRINT #12, USING "$$#########"; F4RCost; (F4RCost - COF4RCost)
       PRINT #12, "Vehicle Operation";
       PRINT #12, USING "$$###########"; COCRunCost; COFRunCost;
       PRINT #12, "      ";
       PRINT #12, USING "$$#########"; FRunCost; (FRunCost - COFRunCost)
       PRINT #12, "New Construction ";
       PRINT #12, USING "$$###########"; 0, 0;
       PRINT #12, "      ";
       PRINT #12, USING "$$#########"; ConstrucCost; ConstrucCost
       PRINT #12, "Right Of Way     ";
       PRINT #12, USING "$$###########"; 0, 0;
       PRINT #12, "      ";
       PRINT #12, USING "$$#########"; RightOfWayCost; RightOfWayCost
       NetCost! = F4RCost - COF4RCost + FRunCost - COFRunCost + ConstrucCost + R
=> ightOfWayCost
       PRINT #12, "Total            ";
       PRINT #12, USING "$$###########"; COC4RCost + COCRunCost; COF4RCost + COF
=> RunCost;
       PRINT #12, "      ";
       PRINT #12, USING "$$#########"; F4RCost + FRunCost + ConstrucCost + Right
=> OfWayCost; NetCost!

'*****************************************************************************
' Print Benefits Box

       PRINT #12, "  "
       PRINT #12, "BENEFIT SUMMARY (in $1000s)"
       PRINT #12, "                          Base Case                   Alternati
=> ve Case"
       PRINT #12, "             No Traffic incr.   Traffic incr.  Traffic incr.
=>  Net Benefits"
       PRINT #12, "Travel Time";
       PRINT #12, USING "$$##############"; COCTrvTime; COFTrvTime; FTrvTime;
       PRINT #12, USING "$$##########"; (-FTrvTime + COFTrvTime)
       PRINT #12, "Accident Costs";
       PRINT #12, USING "$$###########"; COCAccCost;
       PRINT #12, USING "$$##############"; COFAccCost; FAccCost;
       PRINT #12, USING "$$##########"; (-FAccCost + COFAccCost)
       PRINT #12, "Accident Delays";
       PRINT #12, USING "$$##########"; COCDelayCost;
       PRINT #12, USING "$$##############"; COFDelayCost; FDelayCost;
       PRINT #12, USING "$$##########"; (-FDelayCost + COFDelayCost)
       NetBenefit! = -FTrvTime + COFTrvTime - FAccCost + COFAccCost - FDelayCost
=>  + COFDelayCost
       PRINT #12, "Total      ";
       PRINT #12, USING "$$##############"; COCTrvTime + COCAccCost + COCDelayCo
=> st; COFTrvTime + COFAccCost + COFDelayCost; FTrvTime + FAccCost + FDelayCos
=> t;
       PRINT #12, USING "$$##########"; NetBenefit!

'*****************************************************************************
' Print Benefit/Cost Ratio Box

       PRINT #12, "  "
       PRINT #12, "BENEFIT/COST RATIOS"
       PRINT #12, "  With Vehicle Operating Costs";
       PRINT #12, "        Without Vehicle Operating Costs"
       PRINT #12, "Net Present Value   =";
       PRINT #12, USING "$$#########"; (NetBenefit! - NetCost!);
       PRINT #12, "    Net Present Value   = ";
       PRINT #12, USING "$$###########"; (NetBenefit! - (F4RCost - COF4RCost + C
=> onstrucCost + RightOfWayCost))
       PRINT #12, "Benefit/Cost Ratio  = ";
       PRINT #12, USING "######.###"; NetBenefit! / NetCost!;
       PRINT #12, "    Benefit/Cost Ratio  = ";
       PRINT #12, USING "#########.###"; NetBenefit! / (F4RCost - COF4RCost + Co
=> nstrucCost + RightOfWayCost)
'*****************************************************************************
'*Print Statistics Summary
       PRINT #12, "  "
       PRINT #12, "  "
       PRINT #12, "STATISTICS SUMMARY"
       PRINT #12, "Base Case                   Alternative Case"
       PRINT #12, "              No Traffic incr.   Traffic incr.   Traffic in
=> cr.  Net Diff."
       PRINT #12, "Total VMT (in 1000s)";
       PRINT #12, USING "###########"; COCTotVMT! / 1000;
       PRINT #12, USING "################"; COFTotVMT! / 1000; FTotVMT! / 1000;
       PRINT #12, USING "###########"; (FTotVMT! - COFTotVMT!) / 1000
       PRINT #12, "Total Accidents     ";
```

```
        PRINT #12, USING "###########"; COCAccidents!;
        PRINT #12, USING "################"; COFAccidents!; FAccidents!;
        PRINT #12, USING "############"; (FAccidents! - COFAccidents!)
        PRINT #12, "Avg. Accident Cost  ";
        PRINT #12, USING "$$#########"; COCAvgAccCost!;
        PRINT #12, USING "$$##############"; COFAvgAccCost!; FAvgAccCost!;
        PRINT #12, USING "$$##########"; (FAvgAccCost! - COFAvgAccCost!)
        PRINT #12, "Avg. Delay Cost     ";
        PRINT #12, USING "$$#########"; COCAvgDelayCost!;
        PRINT #12, USING "$$##############"; COFAvgDelayCost!; FAvgDelayCost!;
        PRINT #12, USING "$$##########"; (FAvgDelayCost! - COFAvgDelayCost!)
        PRINT #12, "Avg. Travel Speed   ";
        PRINT #12, USING "#######.##"; COCAvgTrvSpeed!;
        PRINT #12, USING "#############.##"; COFAvgTrvSpeed!; FAvgTrvSpeed!;
        PRINT #12, USING "########.##"; (FAvgTrvSpeed! - COFAvgTrvSpeed!)

        OPEN "CASE.PRN" FOR INPUT AS #13             'Info. related to the cas
  => e type
        linenum% = 13
        PRINT #12, "  "
        DO UNTIL linenum% = 28
           LINE INPUT #13, text$
           PRINT #12, text$
           linenum% = linenum% + 1
        LOOP
        CLOSE #13

END SUB

'*************************************************************************
'*                  SUB PROCEDURE OutputScreen1                          *
'*                                                                       *
'* Operation:     Displays the first output screen.                      *
'*                                                                       *
'* Parameter(s):  none                                                   *
'*                                                                       *
'*************************************************************************
SUB OutputScreen1
        SCREEN 12
'********************** Print Cost Summary *******************************
        CLS
        COLOR 15
        LINE (2, 43)-(637, 43)
        LINE (637, 43)-(637, 193)
        LINE (637, 193)-(2, 193)
        LINE (2, 193)-(2, 43)
        COLOR 5
        LOCATE 4, 3
        PRINT "COST SUMMARY"
        LOCATE 5, 3
        PRINT "(in $1000s)"
        COLOR 15
        LOCATE 4, 31
        PRINT "Base Case                  Alternative Case"
        LOCATE 6, 4
        PRINT "                 No Traffic incr.   Traffic incr.   Traffic incr.
  => Net Costs"
        COLOR 3
        LOCATE 7, 2
        PRINT "Resurfacing Lanes"
        LOCATE 8, 2
        PRINT "Vehicle Operation"
        LOCATE 9, 2
        PRINT "New Construction"
        LOCATE 10, 2
        PRINT "Right Of Way"
        LOCATE 12, 2
        PRINT "Total"
        NetCost! = F4RCost - COF4RCost + FRunCost - COFRunCost + ConstrucCost + R
  => ightOfWayCost
        LOCATE 7, 19
        PRINT USING "$$#############"; COC4RCost; COF4RCost;
        LOCATE 7, 49
        PRINT USING "$$#############"; F4RCost; (F4RCost - COF4RCost)
        LOCATE 8, 19
        PRINT USING "$$#############"; COCRunCost; COFRunCost;
        LOCATE 8, 49
        PRINT USING "$$#############"; FRunCost; (FRunCost - COFRunCost)
        LOCATE 9, 19
        PRINT USING "$$#############"; 0, 0;
        LOCATE 9, 49
        PRINT USING "$$#############"; ConstrucCost; ConstrucCost
        LOCATE 10, 19
        PRINT USING "$$#############"; 0, 0;
        LOCATE 10, 49
        PRINT USING "$$#############"; RightOfWayCost; RightOfWayCost
        LOCATE 12, 19
        PRINT USING "$$#############"; COC4RCost + COCRunCost; COF4RCost + COFRun
  => Cost;
        LOCATE 12, 49
        PRINT USING "$$#############"; F4RCost + FRunCost + ConstrucCost + RightO
  => fWayCost; NetCost!

'*************************************************************************
' Print Benefits Box

        COLOR 15
        LINE (2, 203)-(637, 203)
        LINE (637, 203)-(637, 338)
        LINE (637, 338)-(2, 338)
        LINE (2, 338)-(2, 203)
        COLOR 5
        LOCATE 14, 3
        PRINT "BENEFIT SUMMARY"
        LOCATE 15, 3
        PRINT "(in $1000s)"
        COLOR 15
        LOCATE 14, 31
        PRINT "Base Case                  Alternative Case"
        LOCATE 16, 4
        PRINT "                 No Traffic incr.   Traffic incr.   Traffic incr.   Ne
  => t Benefits"
        COLOR 3
        LOCATE 17, 2
        PRINT "Travel Time"
        LOCATE 18, 2
        PRINT "Accident Costs"
        LOCATE 19, 2
        PRINT "Accident Delays"
        LOCATE 21, 2
        PRINT "Total"
        NetBenefit! = -FTrvTime + COFTrvTime - FAccCost + COFAccCost - FDelayCost
  =>  + COFDelayCost
        LOCATE 17, 19
        PRINT USING "$$#############"; COCTrvTime; COFTrvTime;
        LOCATE 17, 49
        PRINT USING "$$#############"; FTrvTime; (-FTrvTime + COFTrvTime)
        LOCATE 18, 19
        PRINT USING "$$#############"; COCAccCost; COFAccCost;
        LOCATE 18, 49
        PRINT USING "$$#############"; FAccCost; (-FAccCost + COFAccCost)
        LOCATE 19, 19
```

```
      PRINT USING "$$############"; COCDelayCost; COFDelayCost;
      LOCATE 19, 49
      PRINT USING "$$############"; FDelayCost; (-FDelayCost + COFDelayCost)
      LOCATE 21, 19
      PRINT USING "$$############"; COCTrvTime + COCAccCost + COCDelayCost; CO
 => FTrvTime + COFAccCost + COFDelayCost
      LOCATE 21, 49
      PRINT USING "$$############"; FTrvTime + FAccCost + FDelayCost; NetBenef
 => it!

'*****************************************************************************
' Print Benefit/Cost Ratio Box

      COLOR 5
      LINE (2, 348)-(637, 348)
      LINE (637, 348)-(637, 425)
      LINE (637, 425)-(2, 425)
      LINE (2, 425)-(2, 348)
      LOCATE 24, 2
      PRINT "    With Vehicle Operating Costs"
      LOCATE 24, 43
      PRINT "  Without Vehicle Operating Costs"
      COLOR 15
      LOCATE 23, 3
      PRINT "BENEFIT/COST RATIOS"
      COLOR 3
      LOCATE 25, 2
      PRINT "Net Present Value   ="
      LOCATE 26, 2
      PRINT "Benefit/Cost Ratio  = "
      LOCATE 25, 23
      PRINT USING "$$#########"; (NetBenefit! - NetCost!)
      LOCATE 26, 23
      PRINT USING "#######.###"; NetBenefit! / NetCost!
      LOCATE 25, 43
      PRINT "Net Present Value   = "
      LOCATE 26, 43
      PRINT "Benefit/Cost Ratio  = "
      LOCATE 25, 65
      NetCost! = F4RCost - COF4RCost + ConstrucCost + RightOfWayCost
      PRINT USING "$$############"; (NetBenefit! - NetCost!)
      LOCATE 26, 65
      PRINT USING "##########.###"; NetBenefit! / NetCost!
      COLOR 15
      LOCATE 27, 53
      PRINT "Press enter to invoke menu"

END SUB

'************************************************************************
'*                   SUB PROCEDURE OutputScreen2                        *
'*                                                                      *
'* Operation:     Displays the second output screen.                    *
'*                                                                      *
'* Parameter(s):  none                                                  *
'*                                                                      *
'************************************************************************
SUB OutputScreen2
      SCREEN 12
'********************** Statistics Summary ********************************
      CLS
      COLOR 15
      LINE (2, 40)-(637, 40)
      LINE (637, 40)-(637, 180)
      LINE (637, 180)-(2, 180)
      LINE (2, 180)-(2, 40)
      COLOR 5
      LOCATE 4, 3
      PRINT "STATISTICS SUMMARY"
      COLOR 15
      LOCATE 4, 31
      PRINT "Base Case                    Alternative Case"
      LOCATE 6, 4
      PRINT "                  No Traffic incr.   Traffic incr.   Traffic incr.
=>  Net Diff."
      COLOR 3
      LOCATE 7, 2
      PRINT "Total VMT (in 1000s)"
      LOCATE 8, 2
      PRINT "Total Accidents"
      LOCATE 9, 2
      PRINT "Avg. Accident Cost"
      LOCATE 10, 2
      PRINT "Avg. Delay Cost"
      LOCATE 11, 2
      PRINT "Avg. Travel Speed   "
      LOCATE 7, 23
      PRINT USING "###########"; COCTotVMT! / 1000;
      LOCATE 7, 39
      PRINT USING "###########"; COFTotVMT! / 1000;
      LOCATE 7, 55
      PRINT USING "###########"; FTotVMT! / 1000; (FTotVMT! - COFTotVMT!) / 100
=> 0
      LOCATE 8, 23
      PRINT USING "###########"; COCAccidents!;
      LOCATE 8, 39
      PRINT USING "###########"; COFAccidents!;
      LOCATE 8, 55
      PRINT USING "###########"; FAccidents!; (FAccidents! - COFAccidents!)
      LOCATE 9, 23
      PRINT USING "$$#########"; COCAvgAccCost!;
      LOCATE 9, 39
      PRINT USING "$$#########"; COFAvgAccCost!;
      LOCATE 9, 55
      PRINT USING "$$#########"; FAvgAccCost!; (FAvgAccCost! - COFAvgAccCost!)
      LOCATE 10, 23
      PRINT USING "$$#########"; COCAvgDelayCost!;
      LOCATE 10, 39
      PRINT USING "$$#########"; COFAvgDelayCost!;
      LOCATE 10, 55
      PRINT USING "$$#########"; FAvgDelayCost!; (FAvgDelayCost! - COFAvgDelayC
=> ost!)
      LOCATE 11, 23
      PRINT USING "########.##"; COCAvgTrvSpeed!;
      LOCATE 11, 39
      PRINT USING "########.##"; COFAvgTrvSpeed!;
      LOCATE 11, 55
      PRINT USING "########.##"; FAvgTrvSpeed!; (FAvgTrvSpeed! - COFAvgTrvSpeed
=> !)
      COLOR 15
      LOCATE 28, 53
      PRINT "Press enter to invoke menu"

      COLOR 15
      LINE (2, 188)-(637, 188)
      LINE (637, 188)-(637, 440)
      LINE (637, 440)-(2, 440)
      LINE (2, 440)-(2, 188)
      LOCATE 28, 53
      PRINT "Press enter to invoke menu"

      OPEN "CASE.PRN" FOR INPUT AS #13              'Info. related to the cas
```

```
  => e type
       linenum% = 13
       DO UNTIL linenum% = 28
          LINE INPUT #13, text$
          LOCATE linenum%, 2
          PRINT text$
          linenum% = linenum% + 1
          IF linenum% = 16 THEN
             COLOR 3
          END IF
       LOOP
       CLOSE #13
       COLOR 15
END SUB

'*************************************************************************
'*                       SUB PROCEDURE ReadInput                         *
'*                                                                       *
'* Operation:     Reads all of the input files.                          *
'*                                                                       *
'* Parameter(s):  ErrorCode%                                             *
'*                                                                       *
'*************************************************************************
SUB ReadInput (ErrorCode%)

DIM DataDouble    AS DOUBLE
DIM DataLong      AS LONG

'******************************************************
'* Read SITEINFO.PRN file                             *
'******************************************************
       LINE INPUT #1, LocationType$
       LocationType$ = LTRIM$(RTRIM$(UCASE$(LocationType$)))
       IF (LTRIM$(RTRIM$(UCASE$(LocationType$))) <> "R") AND (LTRIM$(RTRIM$(UCAS
  => E$(LocationType$))) <> "S") AND (LTRIM$(RTRIM$(UCASE$(LocationType$))) <> "
  => U") THEN
          ErrorCode% = 1
       END IF
       INPUT #1, CML%
       INPUT #1, FML%
       INPUT #1, FLL%
       INPUT #1, FHL%
       IF (FML% > 0) AND (FHL% > 0) THEN
          ErrorCode% = 12
       END IF
       INPUT #1, RightOfWayLanes%
       LINE INPUT #1, BarrierSeparated$
       BarrierSeparated$ = LTRIM$(RTRIM$(UCASE$(BarrierSeparated$)))
       IF (BarrierSeparated$ <> "Y") AND (BarrierSeparated$ <> "N") THEN
          ErrorCode% = 2
       END IF
       INPUT #1, SectionLength!
       INPUT #1, NumIntersection%
       INPUT #1, DataReal!
       Grade% = DataReal! * 100
       IF (Grade% < -8) OR (Grade% > 8) THEN
          ErrorCode% = 6
       END IF
       INPUT #1, Curvature%
       IF (Curvature% < 1) OR (Curvature% > 30) THEN
          ErrorCode% = 7
       END IF

'******************************************************
'* Read TRAFFIC.PRN file                              *
'******************************************************
       INPUT #2, CADT
       INPUT #2, FAIDT!
       INPUT #2, DataDouble, CPkV
       IF CPkV = 0 THEN
          CPkV = DataDouble
       END IF
       INPUT #2, DataDouble, FPkV
       IF FPkV = 0 THEN
          FPkV = DataDouble
       END IF
       INPUT #2, DataDouble, COfPkV
       IF COfPkV = 0 THEN
          COfPkV = DataDouble
       END IF
       INPUT #2, DataDouble, FOfPkV
       IF FOfPkV = 0 THEN
          FOfPkV = DataDouble
       END IF
       INPUT #2, DataInteger%, LVmph
       IF LVmph = 0 THEN
          LVmph = DataInteger%
       END IF
       IF (LVmph < 5) OR (LVmph > 80) THEN
          ErrorCode% = 8
       END IF
       INPUT #2, DataInteger%, HVmph
       IF HVmph = 0 THEN
          HVmph = DataInteger%
       END IF
       IF (HVmph < 5) OR (HVmph > 80) THEN
          ErrorCode% = 9
       END IF

       INPUT #2, DataReal!, CLVpct
       IF CLVpct = 0 THEN
          CLVpct = DataReal!
       END IF
       INPUT #2, DataReal!, FLVpct
       IF FLVpct = 0 THEN
          FLVpct = DataReal!
       END IF
       INPUT #2, DataReal!, CSUpct
       IF CSUpct = 0 THEN
          CSUpct = DataReal!
       END IF
       INPUT #2, DataReal!, FSUpct
       IF FSUpct = 0 THEN
          FSUpct = DataReal!
       END IF
       INPUT #2, DataReal!, CCVpct
       IF CCVpct = 0 THEN
          CCVpct = DataReal!
       END IF
       INPUT #2, DataReal!, FCVpct
       IF FCVpct = 0 THEN
          FCVpct = DataReal!
       END IF
       IF ((CLVpct * 100 + CSUpct * 100 + CCVpct * 100) - 100) > .05 THEN
          ErrorCode% = 10
       ELSEIF ((CLVpct * 100 + CSUpct * 100 + CCVpct * 100) - 100) < -.05 THEN
          ErrorCode% = 10
       END IF
       IF ((FLVpct * 100 + FSUpct * 100 + FCVpct * 100) - 100) > .05 THEN
          ErrorCode% = 11
       ELSEIF ((FLVpct * 100 + FSUpct * 100 + FCVpct * 100) - 100) < -.05 THEN
          ErrorCode% = 11
```

```
      END IF

'Compute yearly increments

      FPkIV = (FPkV - CPkV) / 10
      FOfPkIV = (FOfPkV - COfPkV) / 10
      LVincr = (FLVpct - CLVpct) / 10
      SUincr = (FSUpct - CSUpct) / 10
      CVincr = (FCVpct - CCVpct) / 10

'******************************************************
'* Read FACILITY.PRN file                             *
'******************************************************
      INPUT #3, DataLong, ConstrucCostPM
      IF ConstrucCostPM = 0 THEN
         ConstrucCostPM = DataLong
      END IF
      ConstrucCostPM = ConstrucCostPM * 1000
      INPUT #3, DataLong, ConstrucCostPIntg
      IF ConstrucCostPIntg = 0 THEN
         ConstrucCostPIntg = DataLong
      END IF
      ConstrucCostPIntg = ConstrucCostPIntg * 1000
      INPUT #3, DataLong, RightOfWayPM
      IF RightOfWayPM = 0 THEN
         RightOfWayPM = DataLong
      END IF
      RightOfWayPM = RightOfWayPM * 1000
      INPUT #3, DataLong, bConstrucCostPM
      IF bConstrucCostPM = 0 THEN
         bConstrucCostPM = DataLong
      END IF
      bConstrucCostPM = bConstrucCostPM * 1000
      INPUT #3, DataLong, bConstrucCostPIntg
      IF bConstrucCostPIntg = 0 THEN
         bConstrucCostPIntg = DataLong
      END IF
      bConstrucCostPIntg = bConstrucCostPIntg * 1000
      INPUT #3, DataLong, bRightOfWayPM
      IF bRightOfWayPM = 0 THEN
         bRightOfWayPM = DataLong
      END IF
      bRightOfWayPM = bRightOfWayPM * 1000
      INPUT #3, DataLong, MajorResurfcPM
      IF MajorResurfcPM = 0 THEN
         MajorResurfcPM = DataLong
      END IF
      MajorResurfcPM = MajorResurfcPM * 1000
      INPUT #3, DataReal!, PSIdelta
      IF PSIdelta = 0 THEN
         PSIdelta = DataReal!
      END IF
      INPUT #3, DataReal!, PSIbeta
      IF PSIbeta = 0 THEN
         PSIbeta = DataReal!
      END IF
      INPUT #3, DataReal!, PSIMin
      IF PSIMin = 0 THEN
         PSIMin = DataReal!
      END IF
      INPUT #3, DataReal!, PSIResurf
      IF PSIResurf = 0 THEN
         PSIResurf = DataReal!
      END IF
      INPUT #3, DataReal!, AvgLEsal
      IF AvgLEsal = 0 THEN
         AvgLEsal = DataReal!
      END IF
      INPUT #3, DataReal!, AvgSEsal
      IF AvgSEsal = 0 THEN
         AvgSEsal = DataReal!
      END IF
      INPUT #3, DataReal!, AvgCEsal
      IF AvgCEsal = 0 THEN
         AvgCEsal = DataReal!
      END IF

'******************************************************
'* Read USERCOST.PRN file                             *
'******************************************************
      INPUT #4, DataReal!, LVTimeValuePH
      IF LVTimeValuePH = 0 THEN
         LVTimeValuePH = DataReal!
      END IF
      INPUT #4, DataReal!, SUtimeValuePH
      IF SUtimeValuePH = 0 THEN
         SUtimeValuePH = DataReal!
      END IF
      INPUT #4, DataReal!, CVtimeValuePH
      IF CVtimeValuePH = 0 THEN
         CVtimeValuePH = DataReal!
      END IF

      INPUT #4, DataReal!, LVaccPLVmvm
      IF LVaccPLVmvm = 0 THEN
         LVaccPLVmvm = DataReal!
      END IF

      INPUT #4, DataReal!, SUaccPSUmvm
      IF SUaccPSUmvm = 0 THEN
         SUaccPSUmvm = DataReal!
      END IF

      INPUT #4, DataReal!, CVaccPCVmvm
      IF CVaccPCVmvm = 0 THEN
         CVaccPCVmvm = DataReal!
      END IF

      INPUT #4, DataLong, AccCostPFatal
      IF AccCostPFatal = 0 THEN
         AccCostPFatal = DataLong
      END IF
      INPUT #4, DataLong, AccCostPInjury
      IF AccCostPInjury = 0 THEN
         AccCostPInjury = DataLong
      END IF
      INPUT #4, DataLong, AccCostPPDO
      IF AccCostPPDO = 0 THEN
         AccCostPPDO = DataLong
      END IF
      INPUT #4, DataReal!, Block0Lanes
      IF Block0Lanes = 0 THEN
         Block0Lanes = DataReal!
      END IF
      INPUT #4, DataReal!, Block1Lanes
      IF Block1Lanes = 0 THEN
         Block1Lanes = DataReal!
      END IF
      INPUT #4, DataReal!, Block2Lanes
      IF Block2Lanes = 0 THEN
         Block2Lanes = DataReal!
      END IF
```

```
      INPUT #4, DataReal!, LClrDur
      IF LClrDur = 0 THEN
         LClrDur = DataReal!
      END IF
      INPUT #4, DataReal!, HClrDur
      IF HClrDur = 0 THEN
         HClrDur = DataReal!
      END IF
      INPUT #4, DataReal!, MaxQlen
      IF MaxQlen = 0 THEN
         MaxQlen = DataReal!
      END IF

'*****************************************************
'* Read OTHER.PRN file                               *
'*****************************************************
      INPUT #5, Yrs
      IF Yrs = 0 THEN
         ErrorCode% = 3
      END IF
      INPUT #5, YrsConstruc
      IF YrsConstruc = 0 THEN
         ErrorCode% = 4
      END IF
      INPUT #5, DRate
      IF DRate = 0 THEN
         ErrorCode% = 5
      END IF

'*****************************************************
'* Read Operating Cost related Data                  *
'*****************************************************
      FOR s% = 5 TO 80 STEP 5
         FOR g% = -8 TO 8
            INPUT #6, RunCost(s%, g%).LV
         NEXT g%
      NEXT s%

      FOR s% = 5 TO 80 STEP 5
         FOR g% = -8 TO 8
            INPUT #7, RunCost(s%, g%).SU
         NEXT g%
      NEXT s%

      FOR s% = 5 TO 80 STEP 5
         FOR g% = -8 TO 8
            INPUT #8, RunCost(s%, g%).CV
         NEXT g%
      NEXT s%

      FOR s% = 5 TO 80 STEP 5
         FOR c% = 1 TO 30
            INPUT #9, CurveCost(s%, c%).LV
         NEXT c%
      NEXT s%

      FOR s% = 5 TO 80 STEP 5
         FOR c% = 1 TO 30
            INPUT #10, CurveCost(s%, c%).SU
         NEXT c%
      NEXT s%

      FOR s% = 5 TO 80 STEP 5
         FOR c% = 1 TO 30
            INPUT #11, CurveCost(s%, c%).CV
         NEXT c%
```



```
      NEXT s%

'* Interpolate the costs in between               *

      FOR s% = 5 TO 75 STEP 5
         FOR g% = -8 TO 8
            Lincrement! = (RunCost(s% + 5, g%).LV - RunCost(s%, g%).LV) / 5
            Sincrement! = (RunCost(s% + 5, g%).SU - RunCost(s%, g%).SU) / 5
            Cincrement! = (RunCost(s% + 5, g%).CV - RunCost(s%, g%).CV) / 5
            J% = 1
            FOR i% = (s% + 1) TO (s% + 4)
               RunCost(i%, g%).LV = RunCost(s%, g%).LV + Lincrement! * J%
               RunCost(i%, g%).SU = RunCost(s%, g%).SU + Sincrement! * J%
               RunCost(i%, g%).CV = RunCost(s%, g%).CV + Cincrement! * J%
               J% = J% + 1
            NEXT i%
         NEXT g%
      NEXT s%

      FOR s% = 5 TO 75 STEP 5
         FOR c% = 1 TO 30

            Lincrement! = (CurveCost(s% + 5, c%).LV - CurveCost(s%, c%).LV) / 5
            Sincrement! = (CurveCost(s% + 5, c%).SU - CurveCost(s%, c%).SU) / 5
            Cincrement! = (CurveCost(s% + 5, c%).CV - CurveCost(s%, c%).CV) / 5
            J% = 1
            FOR i% = (s% + 1) TO (s% + 4)
               CurveCost(i%, c%).LV = CurveCost(s%, c%).LV + Lincrement! * J%
               CurveCost(i%, c%).SU = CurveCost(s%, c%).SU + Sincrement! * J%
               CurveCost(i%, c%).CV = CurveCost(s%, c%).CV + Cincrement! * J%
               J% = J% + 1
            NEXT i%
         NEXT c%
      NEXT s%

END SUB

'************************************************************************
'*                    SUB PROCEDURE TimeValueRatio                      *
'*                                                                      *
'* Operation:     Computes time value for each vehicle type in dollars.*
'*                                                                      *
'* Parameter(s):  CLVRatio! - Current time value ratio for light vehs. •
  =>
'*                FLVRatio! - Future time value ratio for light vehs.  *
'*                CSURatio! - Current time value ratio for SU vehicles.*
'*                FSURatio! - Future time value ratio for SU vehicles. *
'*                CCVRatio! - Current time value ratio for Comb-vehs.  *
'*                FCVRatio! - Future time value ratio for Comb-vehs.   *
'************************************************************************
SUB TimeValueRatio (CLVRatio!, FLVRatio!, CSURatio!, FSURatio!, CCVRatio!, FCVRa
  => tio!)

      Totpct! = CSUpct + CCVpct
      CLVRatio! = LVTimeValuePH
      CSURatio! = CSUpct / Totpct! * SUtimeValuePH
      CCVRatio! = CCVpct / Totpct! * CVtimeValuePH

      Totpct! = FSUpct + FCVpct
      FLVRatio! = LVTimeValuePH
      FSURatio! = FSUpct / Totpct! * SUtimeValuePH
      FCVRatio! = FCVpct / Totpct! * CVtimeValuePH

END SUB

'************************************************************************
```

```
'*                   SUB PROCEDURE TravelTime                         *
'*                                                                    *
'* Operation:     Computes travel time for given volume and capacity  *
'*                during peak or off-peak hours for current or future *
'*                traffic conditions and for light or heavy traffic.  *
'*                It also computes actual mph under given traffic     *
'*                conditions.                                         *
'*                                                                    *
'* Parameter(s):  Volume     - Vehicle volume for the analysis year.  *
'*                Capac      - Lane capacity for the analysis year.   *
'*                TrvTime!   - Travel time computed by this procedure. *
'*                ActualMPH% - Actual MPH for given traffic conditions.*
'*                Pk$        - Peak or Off-peak hours.                *
'*                CF$        - Current or Future traffic conditions.  *
'*                LH$        - Light or heavy traffic.                *
'**********************************************************************
SUB TravelTime (Volume AS DOUBLE, Capac AS DOUBLE, TrvTime!, ActualMPH%, Pk$, CF
 => $, LH$)
      IF LH$ = "L" THEN
         MPH! = LVmph%
      ELSE
         MPH! = HVmph%
      END IF

      Tbase! = SectionLength! / MPH!

      TTime! = Tbase! * (1! + .15 * ((Volume / Capac) ^ 4))
      IF Pk$ = "PK" THEN
         TrvTime! = TTime! * 3 * 365
      ELSEIF Pk$ = "OFPK" THEN
         TrvTime! = TTime! * 15 * 365
      ELSE
         PRINT "VALID PARAMETERS ARE ONLY PK OR OFPK"
      END IF

      CALL TimeValueRatio(CLVRatio!, FLVRatio!, CSURatio!, FSURatio!, CCVRatio!
 => , FCVRatio!)
      IF CF$ = "C" THEN
         IF LH$ = "L" THEN
            TrvTime! = TrvTime! * CLVRatio!
         ELSE
            TrvTime! = TrvTime! * (CSURatio! + CCVRatio!)
         END IF
      ELSEIF CF$ = "F" THEN
         IF LH$ = "L" THEN
            TrvTime! = TrvTime! * FLVRatio!
         ELSE
            TrvTime! = TrvTime! * (FSURatio! + FCVRatio!)
         END IF
      ELSE
         PRINT "ERROR IN SUB TRAVELTIME"
      END IF

TrvTime! = TrvTime! * Volume
ActualMPH% = SectionLength! / TTime!

END SUB

DEFSNG A-Z
'**********************************************************************
'*                   FUNCTION TruckAdjustFactor                       *
'*                                                                    *
'* Operation:     Computes truck adjustment factor for given traffic  *
'*                volume and vehicle combination type to be used in   *
'*                computing lane capacities.                          *
'*                                                                    *
'* Parameter(s):  TrafficPerHour - Vehicle volume per hour.           *
'*                VType$         - Vehicle type (SU or CV).           *
'*                VehPct!        - Percentages for VType$.            *
'**********************************************************************
FUNCTION TruckAdjustFactor! (TrafficPerHour AS DOUBLE, VType$, VehPct!)

       SELECT CASE VType$
          CASE "SU"
             IF TrafficPerHour < 600 THEN
                Equiv! = 1.1
             ELSEIF TrafficPerHour < 1000 THEN
                Equiv! = 1.2
             ELSEIF TrafficPerHour < 1500 THEN
                Equiv! = 1.3
             ELSEIF TrafficPerHour < 1800 THEN
                Equiv! = 1.4
             ELSE
                Equiv! = 1.6
             END IF
             IF Grade% >= 0 THEN
                Equiv! = Equiv! + (Equiv! / 1.6) * (Grade% - .03)
             END IF

          CASE ELSE
             IF TrafficPerHour < 600 THEN
                Equiv! = 1.1
             ELSEIF TrafficPerHour < 1000 THEN
                Equiv! = 1.2
             ELSEIF TrafficPerHour < 1500 THEN
                Equiv! = 1.4
             ELSEIF TrafficPerHour < 1800 THEN
                Equiv! = 1.8
             ELSE
                Equiv! = 2!
             END IF
             IF Grade% >= 0 THEN
                Equiv! = Equiv! + (Equiv! / 2!) * (Grade% - .01)
             END IF
       END SELECT

       TruckAdjustFactor! = 100 / (100 + (Equiv! - 1) * VehPct!)

END FUNCTION
```