TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-82/5+210-5		

4. Title and Subtitle	5. Report Date
An Economic and Environmental Analysis Program Using The Results For The FREQ3CP Model	September 1981
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Jesse L. Buffington and Gene P. Ritch	Research Report 210-5
9. Performing Organization Name and Address	10. Work Unit No.
Texas Transportation Institute The Texas A&M University System College Station, TX 77843	11. Contract or Grant No. Study 2-18-77-210
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address Texas State Department of Highways and Public Transportation Transportation Planning Division P. O. Box 5051; Austin, TX 77863	Interim-September 1976 September 1981
	14. Sponsoring Agency Code

15. Supplementary Notes

Work done in cooperation with FHWA, DOT.
Study title: Evaluation of Urban Freeway Modifications.

16. Abstract

An economic analysis computer program (ECOANA) was developed in FORTRAN to generate economic measures from included rate tables and stored traffic operation data. The traffic data used are stored by the modified FREQ3CP freeway simulation program. The measures include monetary costs for travel time, vehicle operation and accidents as well as fuel consumption and pollution emission quantities. The derivation of each economic measure is discussed by listing how the simulated traffic data are used to manipulate the appropriate cost or usage table. A discussion of how to set up the program cards for the ECOANA program is given along with a listing, sample printout and flowchart of the program. The engineer can now have realistic data from which benefit-to-cost figures can be developed.

17. Key Words	18. Distribution Statement
Ecomomic analysis computer program, urban freeway modifications	No Restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	151	

Form DOT F 1700.7 (8-69)

AN ECONOMIC AND ENVIRONMENTAL ANALYSIS PROGRAM USING THE RESULTS FOR THE FREQ3CP MODEL

by

Jesse L. Buffington
Research Economist

and

Gene P. Ritch
Associate Research Specialist

Research Report 210-5

Evaluation of Urban Freeway Modifications

Research Study Number 2-18-77-210

Sponsored by
State Department of Highways and Public Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

Texas Transportation Institute
The Texas A&M University System
College Station, Texas

September 1981

ABSTRACT

An economic analysis computer program (ECOANA) was developed in FORTRAN to generate economic measures from included rate tables and stored traffic operation data. The traffic data used are stored by the modified FREQ3CP freeway simulation program. The measures include monetary costs for travel time, vehicle operation and accidents as well as fuel consumption and pollution emission quantities. The derivation of each economic measure is discussed by listing how the simulated traffic data are used to manipulate the appropriate cost or usage table. A discussion of how to set up the program cards for the ECOANA program is given along with a listing, sample printout and flowchart of the program. The engineer can now have realistic data from which benefit-to-cost figures can be developed.

SUMMARY

The development of an economic analysis (ECOANA) computer program that provides economic measures based on FREQ3CP simulated traffic operations has been developed. The data requirements and assumptions necessary to perform the calculation of the measures were outlined in Research Report 210-3, "Analyzing the FREQ3CP Freeway Operations Simulation Model". In each of the five economic areas in which quantitative measures were determined, a discussion is given concerning the data required from the FREQ3CP simulation and the manipulation of the appropriate economic rate tables. The five economic measures include monetary costs for travel time, vehicle operation, and accidents, as well as the quantitative measures of fuel consumed and pollution emissions.

The economic rate tables generally provide for four vehicle types with the user supplying the percentage of each vehicle type in the traffic stream. All of the economic tables utilized by the ECOANA program are permanently stored on a remote computer tape. As the simulation data are calculated, they are stored on a unique file. After the user has determined that reasonable FREQ3CP simulation results were obtained, then ECOANA can be executed independent of the simulation program. Unlike FREQ3CP, there is not a calibration sequence to follow in the ECOANA program. If the FREQ3CP simulation results are invalid, the ECOANA results will likewise be invalid. The merit of the FREQ3CP simulation program is that the engineer can compare before and after control measures to determine the most advantageous control scheme. In this manner, the engineer can now be provided with economic measures, which provides a more realistic data base for a benefit-to-cost evaluation which is explained in more detail in this report.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (CONT.)

INTRODUCTION

One of the objectives of the research study entitled "Evaluation of Urban Freeway Modifications," being conducted by the Texas Transportation Institute and sponsored by the State Department of Highways and Public Transportation (SDHPT) in cooperation with the Federal Highway Administration, calls for examining and applying techniques, such as the FREQ3CP Freeway Operations Simulation Model designed for evaluating proposed freeway improvement projects before and after implementation. One of the tasks of this objective calls for adapting, calibrating, and testing the FREQ3CP simulation model to a specific freeway problem. Another task calls for the development of an economic analysis program to provide economic measures based on FREQ3CP simulated traffic operations.

The I.H. 10 West (Katy) Freeway in Houston, Texas was chosen as a site on which the FREQ3CP simulation model could be tested for calibration. Traffic volume data were collected and converted to useable form by a separate computer program called SYNODM. In the attempt to calibrate the FREQ3CP computer program, it became evident that the user of the program can distort the program results by the choice of subsectional capacities and Origin-Destination (O-D) input data. The SYNODM program provides a method by which actual demand data at each entry and exit point along a freeway system can be synthesized in such a way that the total inputs and outputs of the O-D matrix are equal.

The output data of the SYNODM program can be used as direct inputs into the FREQ3CP program. In turn, the output of the FREQ3CP program becomes part of the input data for the economic analysis program, ECOANA, which is described in this report. The data requirements and assumptions necessary to use ECOANA are outlined in Research Report 210-3. They are repeated in this report, and the unit cost data are presented in tabular form. Also, procedures to update the unit costs are presented in this report.

ECOANA uses peak period FREQ3CP output data collected from each subsection of the project by 15-minute time slice intervals as well as data summarized over all subsections and time slices to simulate before and after construction traffic conditions. The peak period assumed in the FREQ3CP program is specified by the user. The sample output data used for the trial run analysis of ECOANA is based on a peak period, beginning at 6:00 a.m. and ending at 9:30 a.m. on the Southwest Freeway.

ECOANA enables the engineer to compare before and after economic measures and provides realistic data for a benefit-to-cost evaluation. The possible alternative uses of the ECOANA output are discussed in the next section of this report.

DATA REQUIREMENTS AND ASSUMPTIONS FOR ECONOMIC ANALYSIS PROGRAM

FREQ3CP output data, the economic data and assumptions used in the economic analysis program, ECOANA, are covered here. The program determines peak period time costs, vehicle operating costs, fuel consumed, pollution emissions, and accident costs. More specifically, ECOANA determines time costs, vehicle operating costs, etc. for simulated traffic on the freeway's main lanes, on the entrance ramps, and on the diversion route. ECOANA provides for separate calculations on four vehicle types, as described in Table 1. These vehicle types are those customarily used in user benefit analyses (1, 2) and represent the major vehicle types using freeways and highways. Further, these vehicle types represent significant differences in vehicle operating costs. The unit costs, fuel consumption rates, and pollution emission factors used in ECOANA are based on the more recent information found in the literature. The time and vehicle operating unit costs are those reported in the Texas Transportation Institute (TTI) Research Report 202-2 (3), except that they are combined into four vehicle types and updated to represent January 1980 costs. The unit values of time recommended in the ASSHTO Redbook (1) are not too different from those recommended in the TTI 202 report. Since the values of time recommended in the TTI report are based on truck and driver costs prevailing in the Southwest, they are preferred over those recommended in the Redbook for evaluation of Texas Freeway improvement projects. The vehicle operating unit costs recommended in the TTI report are given in tabular form, and hence, are easier to computerize than those recommended in graphic form in the Redbook. Also, the unit costs of the TTI report are more responsive to Level of Service F speeds and speed changes than those of the Redbook. Unit costs of the TTI report increase consistently as vehicle speeds decrease, whereas, those of the Redbook increase and decrease alternately with vehicle speeds. Finally, the unit costs of the TTI report are especially adapted to analyzing freeway modification projects. The fuel consumption rates are based on the unit costs reported in the TTI 202-2 report and the fuel costs reported by Winfrey (4) and the ASSHTO Redbook (1). The data source for fuel consumption rates is more or less dictated by the choice of vehicle operating unit costs used. Since the unit costs of the TTI report are used in ECOANA, fuel consumption rates based on these costs are also used. The pollution rates are predicted 1977 rates and are based on a 1975 Environmental Protection Agency (EPA) report (5). The accident unit costs are based on those reported in the ASSHTO Redbook (1) and updated to represent January 1980 costs. The accident unit costs used in ECOANA represent the most complete accounting of costs that might be incurred as a result of an accident. The accident unit costs in the TTI 202 report are not recommended primarily because corresponding accident rates are not available in up-to-date form. The accident rates are based on 1978 accident information obtained from the SDHPT files.

The unit costs used in ECOANA represent estimated January 1980 prices. The unit costs chosen from a particular data source were updated by using the appropriate component of the National Consumer Price Index (CPI) of or the Producer Price Index (PPI) and the appropriate updating formulas, where applicable, that are recommended in the ASSHTO Redbook (1). The PPI replaces the old Wholesale Price Index (WPI). The same procedure can be used to update ECOANA's unit costs beyond the January 1980 base, but a less detailed procedure, as presented in this section, can be used to account for changes in appropriate components of the above price indexes.

A discussion of the possible uses of the ECOANA output data is presented later in this section of the report.

Time Costs

The portion of the economic package described here pertains to time costs. The FREQ3CP output (simulation) data, economic data (values of time), assumptions and calculations required to determine the total time cost for estimating time cost for on freeway, on ramp, and diversion route travel are covered below.

On Freeway Travel Time Costs

The FREQ3CP output required to calculate travel time costs on the freeway proper is the cumulative sum of on freeway travel times for all subsections for the entire peak period in the form of:

- Total vehicle-hours and
- Total passenger-hours

The economic data required are the values of time by vehicle type for moving vehicles, as presented in Table 2. These data are presented in dollars ($) per hour for the driver and the passenger, because they are different for each vehicle type, except Vehicle Type 1.

The assumptions and given data required to generate time costs are as follows:

- Percentage distribution of the four vehicle types (TABLE 1),
- Number of passengers per vehicle for Vehicle Types 1 and 4,
- Percentage destribution of vehicles and number of passengers are the same for all subsections over all time slices,
- Total passenger-hours generated by the FREQ3CP program includes trucks driver-hours, and
- FREQ3CP output data takes into account the time required for speed changes and stops.

Table 1

Vehicle Type Number	Vehicle Type Description
1	Automobiles, pickups, and panel trucks (2-axle, 4-tire)
2	Single-unit trucks (other than 2-axle, 4-tire)
3	Truck-tractor-semitrailer or trailer combinations
4	Buses

Note: A decimal value for each is entered via card entry at program execution time. The sum of all four values must equal 1.

Table 2. Value of Time, by Vehicle Type and Driving Mode[a]

Vehicle Type	In Moving Vehicle[a]		In Stopped Vehicle[b]	
	Driver	Passenger	Driver	Passenger
	-----------Dollars Per Hour---------------			
1	6.31	6.31	9.47	9.47
2	11.72	6.31	18.21	9.47
3	16.36	6.31	24.54	9.47
4	17.66	6.31	26.49	9.47

[a]Update of values of time reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2.

[b]Represents 1.5 times the in stopped vehicle values of time, and is based on waiting data reported in the 1977 ASSHTO Redbook.

The calculations required to arrive at the total driver time cost are as follows:

1. Multiply the total vehicle-hours by the vehicle type (TABLE 1) percentage distribution to arrive at the total driver-hours per vehicle type.
2. Multiply the total driver-hours per vehicle type by the moving vehicle values of time for the corresponding vehicle types presented in Table 2 to obtain the time costs for drivers of each vehicle type.
3. Sum the driver-time costs for the four vehicle types.

The calculations required to arrive at the total passenger-time cost are as follows:

1. Subtract the total passenger-hours from the total driver-hours to obtain the total net passenger-hours.
2. Multiply the total net passenger-hours by the moving vehicle passenger time value presented in Table 2 to obtain the total passenger time costs.

Finally, the total driver-time cost is added to the total passenger-time cost to arrive at the total on freeway time cost per peak period.

<u>On Ramp Travel Time Costs</u>

To calculate on ramp travel time costs resulting from input or on ramp delay, the cumulated total input delay in vehicle-hours and passenger-hours for all time slices must be obtained as output from the FREQ3CP program.

The economic data required for the calculation are the values of time for drivers and passengers waiting in stopped vehicles by vehicle type. These values are presented in Table 2 in dollars per hour.

The assumptions and given data are the same as those required for the on freeway calculations, except for the following:

- Time while vehicles are moving on the ramp is not calculated and
- Value of time while waiting in vehicle is worth more than the value of time in a moving vehicle due to increased mental anguish and patience required.

The calculations required to arrive at the total on ramp time cost are the same as those enumerated above to arrive at the total on freeway time cost.

Diversion Route Travel Time Cost

Travel time costs for persons voluntarily or involuntarily diverted from the freeway's main lanes during the peak period can be calculated from the cumulative data for all time slices combined. The assumption is made that the diverted vehicles will travel the same distance as would be traveled on the main lanes. (While this assumption is conservative and does not account for back-tracking, it does provide a means of comparing the before and after conditions of a control scheme or geometric change to the freeway facility.) The following FREQ3CP output or given data are needed to make such calculations.

- Number of vehicle-miles and passenger-miles traveled by vehicles diverted from the freeway's main lanes, and
- Average speed (mph) on the diversion route.

The economic data required for calculating diversion travel time costs are the values of time for drivers and passengers in moving vehicles. These values are shown in Table 2 in dollars per hour.

The same assumptions required for freeway and ramp travel time costs apply in the calculation of diversion travel time costs, except for the following:

- Average diversion speed takes into account the time required for speed changes and stops, and
- Average diversion speed is the same for all subsections and time slices.

The following calculations are required to arrive at the diversion travel time costs:

1. Divide the number of vehicle-miles and passenger-miles by the average miles per hour to obtain total vehicle-hours and total-passenger-hours.
2. Using vehicle-hours and passenger-hours, proceed in the same manner as enumerated above in calculating "on freeway" time costs to arrive at the total diversion travel time cost.

To arrive at the overall total travel time cost for one peak period, sum the time costs for on freeway, on ramps and diversion route.

Vehicle Operating Costs

Vehicle operating costs during peak periods can be estimated for simulated freeway travel on freeway's main lanes, the on ramps, and the diversion route using the FREQ3CP outputs, economic data, assumptions, and calculations indicated below. Vehicle operating costs are the mileage dependent costs of running motor vehicles on freeways and city streets, including fuel, tire, engine oil, maintenance, and depreciation costs.

On Freeway Vehicle Operating Costs

The FREQ3CP output required to calculate the on freeway vehicle operating costs consist of the following individual subsection data per time slice:

- Average speed (mph)
- Volume-to-capacity ratio (v/c)
- Total vehicle-miles of travel.

The economic or given data required are the vehicle operating unit costs by average speed, vehicle type, and level of service, as shown in Tables 3, 4, and 5. Also, the v/c ratios (range) applicable for each level of service must be given, as shown in Table 6. The v/c ratio ranges vary somewhat depending upon the number of lanes of capacity.

The following assumptions apply to the vehicle operating cost calculations:

- The unit costs in the above tables account for speed changes and stops that are normally experienced by vehicles on freeways, and
- The percentage of vehicles by type must be assumed by the user.

Table 3. Running Costs for Vehicle Type 1 on Freeways, by Level of Service and Average Speed[a]

Average Speed	Level of Service A	B	C	D	E	F
Miles Per Hour[b]	Cents Per Vehicle Mile[c]					
5						40.693
10						23.010
15						17.360
20						14.725
25						13.189
30					9.571	12.413
35				9.512	9.708	9.758
40			9.694	9.787	9.977	
45		9.713	10.033	10.200	10.537	
50	9.706	10.056	10.451	10.770		
55	10.647	10.504	11.077			
60	10.563	11.081				
65	11.268					

[a]Update of costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from cents per miles to cents per kilometer, multiply by 0.6214.

Table 4. Running Costs of Vehicle Types 2 and 4 on Freeways, by Level of Service and Average Speed[a]

Average Speed	Level of Service A	B	C	D	E	F
Miles Per Hour[b]	---------- Cents Per Vehicle Mile[c] ----------					
5						113.307
10						57.891
15						41.223
20						33.982
25						30.653
30					21.362	28.945
35				22.413	22.970	23.652
40			23.208	23.512	24.359	
45		23.834	24.596	25.087	25.809	
50	24.956	25.239	26.238	27.067		
55	25.883	27.067	23.388			
60	27.812	29.065				
65	30.081					

[a]Update of costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2.

[b]To convert from miles per hour to kilemeters per hour, multiply by 1.609344.

[c]To convert from costs per mile to cents per kilometer, multiply by 0.6214.

Table 5. Running Costs for Vehicle Type 3 on Freeways, by Level of Service and Running Speed[a]

Average Speed	Level of Service A	B	C	D	E	F
Miles Per Hour[b]	Cents Per Vehicle Mile[c]					
5						306.167
10						132.349
15						84.947
20						65.049
25						56.442
30					31.980	49.898
35				32.305	33.366	34.730
40			33.594	34.415	36.177	
45		35.301	36.668	37.685	38.185	
50	37.711	38.402	40.294	41.845		
55	40.299	42.651	45.283			
60	44.472	46.901				
65	49.283					

[a]Update of costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from cents per mile to cents per kilometer, multiply by 0.6214.

Table 6. Freeway Volume to Capacity Ratios, by Number of Lanes and Level of Service

Number Of Lanes	V/c Ratio Limits by Level of Service[a]					
	A	B	C	D	E	F[b]
4	0.00-0.35	0.36-0.50	0.51-0.75	0.75-0.90	0.91-1.00	1.00-0.00
6	0.00-0.40	0.41-0.58	0.59-0.80	0.81-0.90	0.91-1.00	1.00-0.00
8	0.00-0.42	0.43-0.63	0.64-0.83	0.84-0.90	0.91-1.00	1.00-0.00

[a]Volume to capacity ratios based on 70 miles per hour design speeds, ignoring the peak-hour factor. These v/c limits are assumed to be acceptable for other design speeds.

[b]The Level of Service F is considered independent of v/c values.

Source: Curry, David A. and Anderson, Dudley G., "Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects," National Cooperative Highway Research Program, Report 133, 1972.

The calculations required to arrive at the total vehicle operating costs for each subsection per time slice are as follows:

1. Multiply the total vehicle-miles of travel in the subsection by the vehicle type percentage distribution (Table 1) to arrive at the total vehicle-miles by vehicle type.
2. Select the appropriate unit cost for each vehicle type by taking the following steps:
   a. Determine the level of service corresponding to the v/c ratio and number of lanes by referring to Table 6.
   Note: Level of Service F designations are considered independent of the v/c ratios.
   b. Look up the unit cost (cents per mile) for each vehicle type corresponding to the designated level of service and average speed of the subsection by referring to the appropriate unit cost table (Table 3, 4, or 5). Note: Since unit costs are given only in five-miles-hour increments for each level of service, the unit cost representing a speed in between these incremental speeds must be computed by: (1) subtracting the lower unit cost from the higher unit cost bracketing the subsection speed; (2) dividing that difference by five to determine the additional cost for each additional mile per hour; (3) subtracting the subsection speed from the lower of the bracketed incremental speeds to determine the additional miles per hour; (4) multiplying the additional miles per hour by the additional cost per mile per hour, and (5) adding the extra unit cost to the lower of the two bracketed unit cost.

3. Multiply the selected unit cost of each vehicle type found in Tables 3, 4, and 5 by the corresponding total vehicle-miles of each vehicle type.
4. Sum the vehicle operating costs of each vehicle type.

To calculate the total on freeway vehicle operating cost for all time slices (peak period), sum the total vehicle operating cost for each time slice.

On Ramp Vehicle Operating Costs

To calculate on ramp vehicle operating costs resulting from input or on ramp delay, the cumulated total input delay in vehicle-hours for all time slices must be obtained as output from the FREQ3CP program.

The economic data required for calculating vehicle operating cost resulting from on ramp delay are the idling costs by vehicle type obtained from Table 7.

The assumptions and given data required for the on ramp vehicle operating costs are as follows:

- Percentage distribution by vehicle type is given and is the same over all subsections and time slices.
- Vehicle operating costs while the vehicle is moving is not calculated.

The calculations required to arrive at the total on ramp vehicle operating costs are as follows:

1. Multiply the total vehicle-hours by the percentage distribution of vehicles to arrive at the total idling vehicle-hours per vehicle type.
2. Multiply the appropriate idling cost (cents per hour) of each vehicle type by the corresponding total idling vehicle-hours of each vehicle-type.

Table 7. Idling Costs, by Type of Vehicle[a]

Vehicle Type	Idling Costs
	Cents per Hour
1	37.540
2 & 4	78.214
3	80.218

[a]Update of Costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2.

3. Sum the idling vehicle operating costs of each vehicle type to arrive at the total on ramp idling vehicle operating cost for the peak period.

Diversion Route Vehicle Operating Costs

Vehicle operating costs of vehicles diverted from the freeway on to a service road or another parallel street during the peak period can be calculated from data for all subsections and time slices combined. The following FREQ3CP output or given data are needed to make such calculations:

- Number of vehicle-miles traveled by vehicles diverted from the freeway's main lanes,
- The uniform (approach) speed (mph) between intersections on the diversion route,
- Number of stops per vehicle-mile at intersections,
- Average vehicle-hours per stop,
- Number of speed changes (including stops) per vehicle mile, and
- Average speed (mph) reduction caused by speed change.

The economic data required for calculating diverted vehicle operating costs are as follows:

- Running unit costs on city streets by vehicle type and uniform speed, as shown in Table 8.
- Excess running unit costs of speed cycle changes on city streets by vehicle type and initial speed, as shown in Tables 9, 10, and 11.
- Idling Costs, by vehicle type, as shown in Table 7.

Table 8. Running Costs on City Streets, by Vehicle Type and Uniform Speed[a]

Uniform Speed	Vehicle Type		
	1	2 & 4	3
Miles Per Hour[b]	---Cents Per Vehicle Mile[c]---		
5	19.202	36.497	66.960
10	14.556	28.608	46.590
15	12.866	25.627	39.346
20	12.022	24.275	36.051
25	11.534	23.834	34.718
30	11.292	23.969	34.581
35	11.276	24.528	35.273
40	11.345	25.357	36.896
45	11.544	26.458	39.073
50	11.858	27.829	41.951

[a]Update of Costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from cents per mile to cents per kilometer, multiply by 0.6214.

Table 9. Excess Running Costs of Speed Cycle Changes on City Streets for Vehicle Type 1, by Initial Speed[a]

Initial Speed	Speed Reduced to and Returned From (MPH)				
	Stop	10	20	30	40
Miles Per Hour[b]	-----------Cents Per Cycle Change------------------				
5	0.250				
10	0.545				
15	0.956	0.353			
20	1.457	0.768			
25	2.031	1.355	0.516		
30	2.738	2.032	1.178		
35	3.580	2.886	2.017	0.794	
40	4.611	3.888	3.003	1.795	
45	5.864	5.125	4.211	3.001	1.191
50	7.453	6.627	5.681	4.442	2.616

[a]Update of Costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

Table 10. Excess Running Costs of Speed Cycle Changes on City Streets for Vehicle Type 2 & 4, by Initial Speed[a]

Initial Speed	Speed Reduced to and Returned from (MPH)				
	Stop	10	20	30	40
Miles Per Hour[b]	Cents Per Cycle Change				
5	0.680				
10	1.668				
15	2.930	1.036			
20	4.420	2.440			
25	6.232	4.145	1.602		
30	8.369	6.232	3.627		
35	10.927	8.758	6.119	2.395	
40	14.051	11.833	9.098	5.358	
45	17.775	15.492	12.708	8.904	3.545
50	22.227	19.879	17.014	13.161	7.754

[a]Update of Costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

Table 11. Excess Running Costs of Speed Cycle Changes on City Streets for Vehicle Type 3, by Initial Speed[a]

Initial Speed	Speed Reduced to and Returned from (MPH)				
	Stop	10	20	30	40
Miles Per Hour[b]	---Cents Per Cycle Change---				
5	3.001				
10	6.822				
15	11.256	6.576			
20	17.151	11.601			
25	24.456	17.208	7.038		
30	33.491	26.075	15.789		
35	44.599	37.019	26.598	10.847	
40	65.305	50.630	39.955	24.129	
45	75.125	67.157	56.342	40.209	16.371
50	95.601	87.425	76.325	60.093	35.965

[a]Update of Costs reported by Buffington and McFarland in Texas Transportation Institute Research Report 202-2.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

The assumptions required for calculating diverted vehicle operating costs are as follows:

- The uniform or initial speed, average vehicle-hours per stop, and the average speed reduction due to speed changes are the same for all subsections and time slices, and
- The percentage distribution by vehicle type is given by the user, and is the same over all subsections and time slices.

The following calculations are required to arrive at the diverted vehicle operating costs resulting from the uniform speed:

1. Multiply the total diverted vehicle-miles of travel by the vehicle type percentage distribution (Table 1) to arrive at the total vehicle-miles per vehicle type.
2. Multiply the appropriate unit cost of each vehicle type found in Table 8 by the corresponding total vehicle-miles of each vehicle type.
3. Sum the uniform vehicle operating costs per vehicle type to obtain the total uniform vehicle operating costs.

The following calculations are required to arrive at the speed change costs for diverted vehicles:

1. Multiply the number of speed changes by the vehicle type percentage distribution (Table 1) to arrive at the total number of speed changes by vehicle type.
2. Multiply the number of speed changes for each vehicle type by the appropriate excess running cost (cents per cycle change) for the given average initial speed and average speed reduction.
3. Sum the excess running costs per vehicle type to obtain the total running costs due to speed changes.

The following calculations are required to arrive at the total idling vehicle operating costs of diverted vehicles:

1. Multiply the total vehicle hours of idling time at intersections by the vehicle type percentage distribution (Table 1) to obtain the total idling hours by vehicle type.
2. Multiply the total idling hours per vehicle type by the appropriate idling unit costs found in Table 7.
3. Sum the idling costs per vehicle type to obtain the total idling cost of diverted vehicles.

The total peak hour operating cost for diverted vehicles is the sum of the uniform, speed change, and idling costs.

Fuel Consumption Costs

Vehicle fuel consumption during peak periods can be estimated for simulated freeway travel on the freeway's main lanes, the on ramps, and the diversion route using the FREQ3CP outputs, economic data, assumptions, and calculations indicated below. For the vehicle fuel consumption calculations, Vehicle Types 2 and 4 are combined.

On Freeway Fuel Consumption

The FREQ3CP output required to calculate the on freeway vehicle fuel consumption consist of the following individual subsection data per time slice:

- Average speed (mph)
- Volume-to-capacity ratio (v/c)
- Total vehicle-miles of travel.

The economic or given data required are the vehicle fuel consumption costs by average speed, vehicle type, and level of service, as shown in Table 12, 13, and 14. Also, the v/c ratios (range) applicable for each level of service must be given, as shown in Table 6. The v/c ratio ranges vary somewhat depending upon the number of lanes of capacity.

The following assumptions apply to the fuel consumption calculations:

- The unit consumption in the above account for speed changes and stops that are normally experienced by vehicles on freeways, and
- The percentage of vehicles by type must be assumed by the user.

The calculations required to arrive at the total fuel consumption for each subsection per time slice are as follows:

1. Multiply the total vehicle-miles of travel in each subsection by the vehicle type percentage distribution (Table 1) to arrive at the total vehicle-miles by vehicle type.

2. Select the appropriate unit rates for each vehicle type by taking the following steps:

   a. Determine the level of service corresponding to the v/c ratio and number of lanes of subsection by referring to Table 6.

   b. Look up the unit rate (gallons per vehicle mile) for each vehicle type corresponding to the designated level of service and average speed of the subsection by referring to the appropriate unit rate table (Table 12, 13, or 14). Note: Since unit rates are given only in five-miles-hour increments for each level of service, the rate representing a speed in between these incremental speeds can be computed in a similar fashion to that method described in the earlier operating cost methodology.

3. Multiply the selected unit rate of each vehicle type found in Tables 12, 13 and 14 by the corresponding total vehicle-miles of each vehicle type.

4. Sum the vehicle fuel consumption of each vehicle type.

To calculate the total on freeway vehicle fuel consumption for all time slices (peak period), sum the total vehicle fuel consumption for each time slice.

Table 12. Fuel Consumption Rates for Vehicle Type 1 on Freeways, by Level of Service and Average Speed[a]

Average Speed	Level of Service A	B	C	D	E	F
Miles Per Hour[b]	---- Gallons Per Vehicle Mile -----					
5						.3970
10						.1649
15						.1028
20						.0772
25						.0641
30					.0433	.0574
35				.0420	.0428	.0431
40			.0426	.0429	.0444	
45		.0427	.0443	.0450	.0465	
50	.0438	.0454	.0471	.0486		
55	.0468	.0489	.0512			
60	.0494	.0519				
65	.0567					

[a]Based on proportion of fuel cost to total cost at various speeds as reported in the 1977 AASHTO Redbook and applied to total costs as reported in the Texas Transportation Research Institute Report 202-2 for vehicle types 1 and 2 in .97 and .03 proportions, and then converted to fuel consumption rates by using the appropriate cost per gallon. The fuel costs of the latter report were originally based on the fuel consumption rates reported in NCHRP Report 111, Highway Research Board, 1971 by Paul Claffey and associates and in "Economics Analysis for Highways," International Textbook Company, Scranton, Pennsylvania, 1969 by Robley Winfrey.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

Table 13. Fuel Consumption Rates for Vehicle Types 2 & 4 on Freeways, by Level of Service and Average Speed[a]

Average Speed	Level of Service					
	A	B	C	D	E	F
Miles Per Hour[b]	- - - - Gallons Per Vehicle Mile - - - - -					
5						.6765
10						.3491
15						.2249
20						.1772
25						.1635
30					.1139	.1577
35				.1250	.1281	.1319
40			.1329	.1346	.1395	
45		.1412	.1457	.1486	.1528	
50	.1486	.1542	.1603	.1654		
55	.1613	.1687	.1769			
60	.1782	.1862				
65	.1981					

[a]Based on Fuel Consumption rates and fuel costs as a proportion of total costs as reported in the 1977 ASSHTO Redbook and on total costs reported by Buffington and McFarland in Texas Transportation Research Report 202-2 for Vehicle Types 3 and 6.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

Table 14. Fuel Consumption Rates for Vehicle Type 3 on Freeways, by Level of Service and Average Speed[a]

Average Speed	Level of Service A	B	C	D	E	F
Miles Per Hour[b]	- - - - Gallons Per Vehicle Mile - - - - -					
5						3.1346
10						1.055
15						.5660
20						.3784
25						.2963
30					.1567	.2445
35				.1503	.1552	.1613
40			.1529	.1566	.1646	
45		.1613	.1676	.1722	.1745	
50	.1778	.1860	.1951	.2026		
55	.1928	.2041	.2167			
60	.2017	.2128				
65	.2208					

[a]Based on Fuel Consumption rates and fuel costs as a proportion of total costs as reported in the 1977 ASSHTO Redbook and on total costs reported by Buffington and McFarland in Texas Transportation Research Report 202-2 after combining vehicle types 4 and 5 in .26 and .74 proportions, respectively.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

On Ramp Fuel Consumption

To calculate on ramp vehicle fuel consumption resulting from input or on ramp delay, the cumulated total input delay in vehicle-hours for all time slices must be obtained as output from the FREQ3CP program.

The economic data required for calculating vehicle fuel consumption resulting from on ramp delay are the idling fuel consumption by vehicle type obtained from Table 15.

The assumptions and given data required for the on ramp vehicle fuel consumption are as follows:

- Percentage distribution by vehicle type is given and is the same over all subsections and time slices.
- Vehicle fuel consumption while the vehicle is moving is not calculated.

The calculations required to arrive at the total on ramp vehicle fuel consumption are as follows:

1. Multiply the total vehicle-hours by the percentage distribution of vehicles (Table 1) to arrive at the total idling vehicle-hours per vehicle type.
2. Multiply the appropriate idling fuel rate (gallons per hour) of each vehicle type by the corresponding total idling vehicle-hours of each vehicle-type.
3. Sum the idling vehicle fuel consumption of each vehicle type to arrive at the total on ramp idling vehicle fuel consumption for the peak period.

Table 15. Idling Fuel Consumption, by Vehicle Type

Vehicle Type	Idling Fuel Consumption Rate
	Gallons Per Hour[a]
1	.370
2 & 4	.650
3	.400

[a]To convert gallons per hour to liters per hour, multiply by 3.7854.

Source: Winfrey, Robley, Economic Analysis for Highways, International Textbook Co., Scranton, Pennsylvania, 1969.

Diversion Route Vehicle Fuel Consumption

Fuel consumption of vehicles diverted from the freeway on to a service road on another parallel street during the peak period can be calculated from data for all subsections and time slices combined. The following FREQ3CP output or given data are needed to make such calculations:

- Number of vehicle-miles traveled by vehicles diverted from the freeway's main lanes,
- The uniform (approach) speed (mph) between intersections on the diversion route,
- Number of stops per vehicle-mile at intersections,
- Average vehicle-hours per stop,
- Number of speed changes (including stops) per vehicle mile, and
- Average speed (mph) reduction caused by speed change.

The economic data required for calculating diverted vehicle fuel consumption are as follows:

- Fuel consumption rate on city streets by vehicle type and uniform speed, as shown in Table 16.
- Excess fuel consumption rates of speed cycle changes on city streets by vehicle type and initial speed, as shown in Tables 17, 18, and 19.
- Idling fuel rates, by vehicle type, as shown in Table 15.

The assumptions required for calculating diverted vehicle fuel consumption are as follows:

- The uniform or initial speed, average vehicle-hours per stops, and the average speed reduction due to speed changes are the same for all subsection and time slices, and
- The percentage distribution by vehicle type is given by the user, and is the same over all subsections and time slices.

The following calculations are required to arrive at the diverted vehicle fuel consumption resulting from the uniform speed:

1. Multiply the total diverted vehicle-miles of travel by the vehicle type percentage distribution (Table 1) to arrive at the total vehicle-miles per vehicle type.
2. Multiply the appropriate fuel usage of each vehicle type found in Table 16 by the corresponding total vehicle-miles of each vehicle type.
3. Sum the uniform vehicle fuel consumption per vehicle type to obtain the total uniform vehicle fuel consumption.

The following calculations are required to arrive at the speed change usage for diverted vehicles:

1. Multiply the number of speed changes per vehicle-mile by the vehicle type percentage distribution (Table 1) to arrive at the total number of speed changes by vehicle type.
2. Multiply the number of speed changes for each vehicle type by the appropriate excess fuel usage (gallons per cycle change) for the given average initial speed and average speed reduction.
3. Sum the excess fuel use per vehicle type to obtain the total fuel use due to speed changes.

The following calculations are required to arrive at the total idling vehicle fuel used of diverted vehicles:

1. Multiply the total vehicle hours of idling time at intersections by the vehicle type percentage distribution to obtain the total idling hours by vehicle type.
2. Multiply the total idling hours per vehicle type by the appropriate idling unit costs found in Table 15.

3. Sum the idling fuel per vehicle type to obtain the total idling fuel used of diverted vehicles.

The total peak hour fuel consumption for diverted vehicles is the sum of the uniform, speed change, and idling fuel use. Also, the fuel consumption tables that correspond to vehicle operating cost tables are shown in Table 20.

Table 16. Fuel Consumption Rates on City Streets, by Vehicle Type and Uniform Speed

Uniform Speed	Vehicle Type		
	Type 1	Types 2&4	Type 3
Miles Per Hour[a]	------Gallons Per Mile[bc]-----		
5	.1025	.1906	.5099
10	.0634	.1273	.2648
15	.0511	.1075	.1861
20	.0460	.0988	.1558
25	.0436	.0947	.1300
30	.0429	.0932	.1205
35	.0434	.0936	.1125
40	.0449	.0954	.1195
45	.0460	.0988	.1271
50	.0499	.1040	.1452

[a]To convert miles per hour to kilometers per hour, multiply by 1.609344.

[b]To convert gallons per mile to liters per kilometer, multiply by 2.351.

[c]Fuel consumption rates are based on those reported in Winfrey, Robley, Economic Analysis for Highways, Internation Textbook Co., Scranton, Pennsylvania, 1969. Passenger cars and commercial vehicles, in proportions of .97 and .03 respectively, make up Type 1 vehicles. The 2-S2 gasoline trucks and 3-S2 diesel trucks, in proportions of .26 and .74 respectively, make up Type 3 vehicles.

Table 17. Excess Fuel Consumption Rates for Speed Cycle Changes of Vehicle Type 1 on City Streets, by Initial Speed

	Speed Reduced to and Returned from (MPH)				
Initial Speed	Stop	10	20	30	40
Miles Per Hour[a]	------- Gallons Per Cycle Change[bc] --------				
5	.00025				
10	.00101				
15	.00268	.00078			
20	.00438	.00202			
25	.00613	.00378	.00135		
30	.00792	.00565	.00311		
35	.00980	.00766	.00524	.00198	
40	.01180	.00986	.00753	.00474	
45	.01399	.01228	.01005	.00750	.00277
50	.01647	.01511	.01287	.01046	.00601

[a]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[b]To convert from gallons per cycle to liters per cycle, multiply by 3.7854.

[c]Fuel consumption rates are based on those reported in Winfrey, Robley, Economic Analysis for Highways, International Textbook Co., Scranton, Pennsylvania, 1969. Passenger cars and commercial vehicles, in proportions of .97 and .03 respectively make up Type 1 vehicles.

Table 18. Excess Fuel Consumption Rates for Speed Cycle Changes of Vehicle Types 2 and 4 on City Streets, by Initial Speed

Initial Speed	Speed Reduced to and Returned from (MPH)				
	Stop	10	20	30	40
Miles Per Hour[a]	------- Gallons Per Cycle Change[bc] --------				
5	-				
10	.00333				
15	.00756	.00206			
20	.01179	.00554			
25	.01602	.00972	.00333		
30	.02025	.01389	.00750		
35	.02448	.01805	.01170	.00447	
40	.02871	.02220	.01587	.00887	
45	.03294	.02635	.01989	.01300	.00508
50	.03717	.03050	.02389	.01697	.00945

[a]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[b]To convert from gallons per cycle to liters per cycle, multiply by 3.7854.

[c]Fuel consumption rates are those reported 12-kip single unit trucks in Winfrey, Robley, Economic Analysis for Highway, International Textbook Co., Scranton, Pennsylvania, 1969.

Table 19. Excess Fuel Consumption Rates for Speed Cycle Changes of Vehicle Type 3 on City Streets, by Initial Speed

Initial Speed	Speed Reduced to and Returned from (MPH)				
	Stop	10	20	30	40
Miles Per Hour[a]	------- Gallons Per Cycle Change[bc] --------				
5	.00112				
10	.00708				
15	.01735	.00722			
20	.02866	.01820			
25	.04097	.03094	.01360		
30	.05430	.04440	.02843		
35	.06860	.05865	.04349	.01929	
40	.08381	.07301	.05839	.03694	
45	.09990	.08821	.07341	.05336	.02376
50	.11682	.10429	.08867	.06916	.04312

[a]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[b]To convert from gallons per cycle to liters per cycle, multiply by 3.7854.

[c]Fuel consumption rates are based on those reported in Winfrey, Robley, Economic Analysis of Highways, International Textbook Co., Scranton, Pennsylvania, 1969. Vehicle Type 3 rates represent 2-S2 gasoline trucks and 3-S2 diesel trucks combined in .26 and .74 proportions, respectively.

Table 20. Fuel Consumption Tables Which Correspond to the Operating Cost Tables, by Location of Vehicle Travel

Location of Vehicle Travel	Corresponding Tables	
	Operating Costs	Fuel Consumption Rates
On Freeway Travel	3, 4, and 5	12, 13, and 14
"On" Ramp Travel	7	15
Diversion Route Travel	8, 9, 10, and 11	16, 17, 18, and 19

Vehicle Pollution Emissions

Vehicle pollution emissions can be calculated for simulated travel on the freeway's main lanes, on ramps, and diversion routes by using the appropriate FREQ3CP output data, pollution emission rates, and calculations detailed in this section.

The three principal pollutants emitted by motor vehicles are: (1) carbon monoxide, (2) hydrocarbons, and (3) nitrogen oxides. Table 21 shows the Federal pollution rate standards, as of March 1978, for the above pollutants. Particulates and sulfur oxides are pollutants of lesser importance but are also emitted by motor vehicles. Pollution rates are available for all five of these pollutants from an Environmental Protection Agency (EPA) study (5).

The pollution rates presented here are the projected 1977 rates based on the above EPA study and were adjusted to represent the temperature and altitude conditions in Texas. The fraction of in-user vehicles by model year (vehicle age) weighted on the basis of annual miles driven was developed from nationwide statistics and was used to adjust the pollution rates. Speed correction factors were used to generate the pollution rates for average speeds of 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, and 55 miles per hour. Actually, the pollution rates for speeds above 45 miles per hour are out of the range of the supporting data and should be used with caution. The speed correction factors are based on a composite of driving modes (idle, cruise, acceleration, deceleration) encountered at lower speeds in urban areas as well as at higher speeds in rural areas. The hot and cold correction factor varies according to vehicle type. For light-duty vehicles (automobiles, pick-ups and panel trucks), the pollution rates represent a 20 percent cold and 80 percent hot operation. For heavy-duty gasoline and diesel powered trucks, the pollution rates represent a 100 percent warmed-up operation.

Type 1 vehicles are represented by the EPA's light-duty vehicles (including pickups and panel trucks). Types 2 and 4 vehicles are represented by the EPA's heavy duty gasoline trucks and buses. Type 3 vehicles are represented by the EPA's heavy duty diesel trucks.

On Freeway Pollution Emissions

The FREQ3CP output data required to calculate on freeway pollution emissions per subsection and time slice are as follows:

- Total vehicle miles of travel, and
- Average speed.

Pollution rates have not been related to level of service or the v/c ratio. However, the pollution emissions for a particular level of service could be determined by identifying the v/c ratio which corresponds to the average speed and then referring to level of service Table 6.

The economic or given data required to calculate the emissions of the three primary pollutants are the pollution emission rates by vehicle type and average speed, as shown in Tables 22, 23 and 24. To calculate the particulate and sulfur oxide emissions, based only on total vehicle-miles, use the pollution rates given in Table 25.

The following assumptions apply to the vehicle emission calculations:

- The vehicle emission rates in Tables 22, 23 and 24 account for speed changes and stops normally experienced by vehicles on freeways in Texas, and
- The percentage of vehicles by type must be assumed by the user.

The calculations required to arrive at the total vehicle emissions for each subsection per time slice are as follows:

1. Multiply the total vehicle-miles of travel in each subsection by the vehicle type percentage distribution to arrive at the total vehicle-miles by vehicle type.

Table 21. Pollution Rate Standards by Vehicle Type, Model Year, and Type of Pollutant[a]

Vehicle Type and Model Year	Type of Pollutant		
	Carbon Monoxide	Hydro-Carbons	Nitrogen Oxide
	Grams Per Mile[b]		
Light Duty Gasoline Vehicles			
1970-71	23.0	2.20	none
1972	39.0	3.40	none
1973-74	39.0	3.40	3.00
1975-76	15.0	1.50	3.00
1977-79	15.0	1.50	2.00
1980	7.0	0.41	2.00
1981	3.4	0.41	1.00
Heavy Duty Gasoline Vehicles			
1970-73	1.5%[c]	275.00[d]	none
1974-78	159.0	12.40	15.30
1979-82	140.0	3.20	13.30
1983-84 (predicted)	29.7	2.85	13.30
1985- (predicted)	29.7	2.85	5.35
Heavy Duty Diesel			
1973	1.5%[c]	none	none
1974-78	159.0	12.40	15.30
1979-82	140.0	5.00	10.00
1983- (predicted)	29.7	2.85	5.35

[a]As of March 1978.

[b]To convert from grams per mile to grams per kilometer, multiply by 0.6214.

[c]Percent of molecular volume.

[d]Parts per million.

Source: U.S. Environmental Protection Agency, Mobile Source Emission Factors for Low Altitude Areas Only, Final Document, Office of Air and Waste Management, Washington, D.C., March 1978.

Table 22. Pollution Emission Rates of Vehicle Type 1, by Type of Pollutant and Average Speed[a]

Average Speed	Type of Pollutant		
	Carbon Monoxide	Hydro-Carbons	Nitrogen Oxides
Miles Per Hour[b]	--------Grams Per Mile[c]---------		
5	176.37	12.07	4.46
10	95.29	7.07	4.06
15	59.96	5.35	3.80
20	46.40	4.38	3.95
25	36.84	3.69	4.10
30	30.35	3.21	4.25
35	25.80	2.86	4.41
40	22.62	2.63	4.57
45	20.46	2.48	4.72
50	19.10	2.42	4.77
55	18.40	2.42	5.02
60	18.23	2.49	5.18

[a]Derived from pollution emission and speed correction factors published in U.S. Environmental Protection Agency, Supplement No. 5 for Compilation of Air Pollutant Emission Factors, Second Edition, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, December 1975. Light duty gasoline automobiles and trucks are combined in .97 and .03 proportions, respectively.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from grams per mile to grams per kilometer, multiply by 0.6214.

Table 23. Pollution Emission Rates of Vehicle Types 2 and 4, by Type of Pollutant and Average Speed[a]

Average Speed	Type of Pollutant		
	Carbon Monoxide	Hydro-Carbons	Nitrogen Oxides
Miles Per Hour[b]	-------- Grams Per Mile[c] --------		
5	571.82	54.35	11.49
10	328.02	29.63	11.03
15	237.16	24.30	10.64
20	191.42	19.65	11.00
25	159.16	16.37	11.35
30	136.32	14.05	11.70
35	120.28	12.42	12.06
40	109.32	11.31	12.41
45	102.36	10.61	12.76
50	98.72	10.25	13.11
55	98.07	10.20	13.47
60	100.37	10.45	13.82

[a]Derived from pollution emission and speed correction factors published in U.S. Environmental Protection Agency, Supplement No. 5 for Compilation of Air Pollutant Emission Factors, Second Edition, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, December 1975. Represents heavy duty gasoline single-unit trucks and buses.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from grams per mile to grams per kilometer, multiply by 0.6214.

Table 24. Pollution Emission Rates of Vehicle Type 3, by Type of Pollutant and Average Speed[a]

Average Speed	Type of Pollutant		
	Carbon Monoxide	Hydro-Carbons	Nitrogen Oxides
Miles Per Hour[b]	------- Grams Per Mile[c]		-----------
5	34.25	7.37	29.83
10	30.41	5.45	23.65
15	29.13	4.81	21.59
20	25.37	4.26	21.92
25	19.38	3.66	23.85
30	15.39	3.26	25.14
35	12.53	2.97	26.03
40	10.40	2.76	26.70
45	8.73	2.59	27.23
50	7.40	2.45	27.66
55	6.31	2.34	28.00
60	5.40	2.25	28.30

[a]Derived from pollution emission and speed correction factors published in U.S. Environmental Protection Agency, Supplement No. 5 for Compilation of Air Pollutant Emission Factors, Second Edition, Office of Air Quality Planning and Standards, Research Triangle Parks, North Carolina, December 1975. Represents heavy duty diesel trucks and buses.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from grams per mile to grams per kilometer, multiply by 0.6214.

Table 25. Particulate and Sulfur Oxide Pollution Rates, by Vehicle Type[a]

Vehicle Type	Particulates	Sulfur Oxides
	--------Grams Per Mile[b]------------	
1[c]	0.36	0.13
2 & 4[d]	1.31	0.36
3[e]	2.20	2.80

[a]Derived from pollution emission factors published in U.S. Environmental Protection Agency, Supplement No. 5 for Compilation of Air Pollutant Emission Factors, Second Editions, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, December 1975.

[b]To convert from grams per mile to grams per kilometer, multiply by 0.6214.

[c]Based on light duty vehicle and light duty gasoline vehicle rates combined in proportions of .97 and .03, respectively.

[d]Represents heavy duty gasoline trucks and buses.

[e]Represents heavy duty diesel trucks and buses.

2. Look up or calculate the pollution rate for each vehicle type corresponding to the average speed of the subsection by referring to the appropriate pollution rate table. Note: For the three primary pollutants, use the same procedure as described in the vehicle operating cost calculations to compute the pollution rate for a speed between the incremental speeds listing in the tables.
3. Multiply the selected or calculated pollution rate of each vehicle type by the corresponding total vehicle-miles of each vehicle type.
4. Sum the vehicle pollution emissions (grams) of each vehicle type per time slice.

To calculate the total on freeway vehicle pollution emissions for a peak period, sum the emissions for all time slices.

On Ramp Vehicle Pollution Emissions

To calculate on ramp vehicle pollution emissions resulting from input or ramp delay, the same FREQ3CP output, economic data, assumptions or given data, and calculations as described earlier for estimating on ramp vehicle operating costs are used here. However, substitute the pollution rates in Table 26 for the unit idling costs in Table 7. Note: The idling pollution emissions for particulate and sulfur oxide are not available and, therefore, can not be calculated.

Diversion Route Vehicle Pollution Emissions

Pollution emissions resulting from diverting vehicles from the freeway's main lanes onto a service road or on another parallel street during the peak period can be calculated from data for all subsections and time slices combined.

The following FREQ3CP output or given data are needed to calculate total diverted vehicle pollution emissions:

Table 26. Idling Pollution Rates, by Vehicle Type and Type of Pollutant[a]

Vehicle Type	Type of Pollutant		
	Carbon Monoxide	Hydro-Carbons	Nitrogen Oxides
	Grams Per Minute		
1[b]	14.74	0.83	0.12
2[c]	61.72	3.68	0.33
3[d]	0.64	0.32	1.03

[a]Derived from pollution emission factors published in U.S. Environmental Protection Agency, Supplement No. 5 for Compilation of Air Pollutant Emission Factors, Second Edition, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, December 1975.

[b]Based on light duty vehicles and light duty gasoline trucks combined in proportions of .97 and .03, respectively.

[c]Represents heavy duty gasoline trucks and buses.

[d]Represents heavy duty diesel trucks and buses.

- Number of vehicle-miles traveled by diverted vehicles, and
- Average speed

The economic data necessary to calculate diverted vehicle pollution emissions are the pollution rates found in Tables 22, 23, 24, and 25.

The assumptions applicable for calculating diverted vehicle pollution emissions are the same as those used for calculating on freeway vehicle pollution emissions.

The calculations required to arrive at the total diverted vehicle pollution emissions are the same as those used for calculating diverted vehicle operating costs resulting from a uniform speed, except that average speed is used instead.

Accident Costs

This portion of the economic package pertains to motor vehicle accident costs experienced by the persons and vehicles directly involved (in collision) in an accident. These costs include direct out-of-pocket costs as well as certain indirect costs such as the loss of future gross earnings of accident victims killed or permanently disabled and costs for loss of services to home and family, and cost of pain and suffering of victims partially disabled from the accident. Other costs resulting from an accident such as extra time costs, extra vehicle operating costs, additional fuel consumed and air pollution emissions are not covered here. The literature does contain procedures for estimating extra time costs due to accidents or bottlenecks on a freeway (6, 7), but considerable time would be required to implement them here. Also, procedures for estimating extra vehicle operating costs, extra fuel consumption, and air pollution emissions due to accidents have not been fully developed.

If the FREQ3CP Program has the capability of generating the output required to calculate such extra costs due to an accident, then the unit time costs, vehicle operating costs, etc. presented earlier in this package can be used essentially in the same form as previously described to make such estimates.

The FREQ3CP output data, economic data, assumption or given data, and calculations required to determine accident costs for on freeway, on ramp, and diversion route accidents are covered below.

<u>On Freeway and On Ramp Accident Costs</u>

Accident costs experienced by persons and vehicles directly involved in an accident on the freeway's main lanes and on the on ramps require the following FREQ3CP output:

- Number of vehicle-miles by highway type and accident location, i.e., number of lanes and whether rural, urban or metered urban for all subsections and time slices.

The economic data required to determine accident costs due to the accident vehicles and occupants are as follows:

- Motor vehicle accident unit costs by severity and location accident, as given in Table 27, and
- Motor vehicle accident rates by highway type and location of accident, as given in Table 28, if actual accident rate is not known.

The assumptions and given data required to generate such accident costs are as follows:

- Percentage distribution of accidents by severity of accident. (The percentage distribution used in the Highway Economic Evaluation Model HEEM (6) for Texas urban freeways, particularly in

Table 27. Motor Vehicle Accident Unit Costs per Reported Accident by Severity and Location of Accident[a]

Severity of Accident	Location of Accident		
	Rural	Suburban	Urban
	---------Dollars Per Accident--------------		
Fatal[b]	566,103	506,304	446,503
Injury[c]	27,709	24,630	21,551
Property Damage Only	1,264	1,084	904

[a]Based on NHTSA accident costs adjusted for location using CALTRANS accident cost data and then updated to August 1979 using the automobile insurance component of the U.S. Consumer Price Index.

[b]Includes direct accident costs and discounted gross future earnings which includes future maintenance costs of the decedent.

[c]Includes direct accident costs as well as costs for pain and suffering, loss of earnings, and loss of services to home and family in partial or total disability accidents.

Source: American Association of State Highway and Transportation Officials, A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements (new Redbook), 444 North Capital Street, N.W. Suite 225, Washington, D.C., 1977.

Table 28. Motor Vehicle Accident Rates, by Highway Type and Location Accident

Highway Type	Location of Accident		
	Rural	Urban	Urban Metered
	--Per Million Vehicle Miles--		
Freeways			
4-lane	1.4	2.8	2.5
6-lane	1.3	2.6	2.3
8-lane	1.2	2.4	2.2
10-lane	1.1	2.2	2.0
12-lane	1.0	2.0	1.8
14-lane	-	1.8	1.6
16-lane	-	1.6	1.4
Expressways			
2-lane	3.0	6.0	-
4-lane	2.8	5.6	-
6-lane	2.6	5.2	-
Conventional Highways			
Undivided			
2-lane	6.0	12.0	-
4-lane	5.6	11.2	-
6-lane	5.2	10.4	-
Divided			
4-lane	2.8	-	-
6-lane	2.6	-	-

Source: Texas Department of Highways and Public Transportation, Guide to the Highway Economic Evaluation Model, Austin, Texas, February 1976.

Houston, is 0.4% fatal accidents, 14.6% injury accidents, and 85.0% property damage only accidents.)

- The accident unit costs are not adjusted for unreported accidents.
- The accident unit costs are the same for wet and dry days.
- The accident unit costs are representative of actual accident costs in Texas.

The calculations required to estimate on freeway accident costs involving only the accident vehicles and occupants are as follows:

1. Multiply the total vehicle-miles (in millions) for each freeway segment (one of more subsections) separated according to number of lanes and location by the actual accident rate of each segment or by the appropriate rate found in Table 28 to arrive at the total number of accidents on each freeway segment for all time slices in peak period.
2. Multiply the total number of accidents on each freeway segment by the percentage distribution of accidents by severity of accident (Table 29) to arrive at the total number of fatal, injury and property damage only accidents for each freeway segment.
3. Sum the number of accidents by freeway segment to arrive at the overall total number of fatal, injury, and property damage accidents for all time slices in peak period.
4. Multiply the total number of accidents of each severity type by the appropriate accident unit cost found in Table 27 to arrive at the total accident cost by severity type.
5. Sum the accident costs by severity type to arrive at the grand total accident cost for all time slices in the peak period. This sum must be generated before and after the freeway improvement to determine the total on freeway accident savings, if any, resulting from such an improvement.

Diversion Route Accident Costs

Accident costs experienced by persons and vehicles directly involved in an accident on a diversion route can be estimated by using essentially the same FREQ3CP output, economic data, assumptions and given data, and calculations as outlined above with the following exceptions:

- The accident rates for a 2-lane undivided conventional highway, as shown in Table 28, would be the most appropriate for a diversion route.
- If the actual percentage distribution of accidents by severity of accident is not known, the urban 2-lane distribution based on California data (9), as presented in Table 29, might be more appropriate than that used in the HEEM Model (6).

The resulting accident cost estimate must be generated before and after the freeway improvement to determine the total diversion route savings (dissavings), if any, resulting from such an improvement. Then, the net savings of the freeway improvement can be generated by adding (subtracting) the diversion route accident savings (dissavings) to the on freeway accident savings.

Table 29. Percentage Distribution by Accident Severity

Highway Type	Fatal	Injury	Fatal and Injury	Property Damage Only	Total
Rural					
2-lane	2.9	43.0	45.9	54.1	100.0
3-lane	3.4	38.7	42.1	57.9	100.0
4 or more lane undivided	1.7	39.7	41.4	58.6	100.0
4 or more lane divided	2.2	39,8	42.0	58.6	100.0
Divided expressway	3.2	42.0	45.2	54.8	100.0
Freeway	3.6	43.2	46.8	53.2	100.0
Urban					
2-lane	0.7	31.0	31.7	68.3	100.0
3-lane	0.9	28.4	29.3	70.7	100.0
4 or more lane undivided	0.6	33.8	34.4	65.6	100.0
4 or more lane divided	0.6	31.5	32.1	67.9	100.0
Divided expressway	1.3	35.6	36.9	63.1	100.0
Freeway	1.1	40.7	41.8	58.2	100.0

Source: Tamburri, T.N. and Smith, R.N., "The Safety Index: A Method of Evaluating and Rating Safety Benefits," Highway Research Record 332, Highway Research Board, Washington, D.C., 1970.

Procedures for Updating the ECOANA Unit Costs

The unit costs used by any benefit-cost procedure, such as ECOANA, should be updated in order to furnish accurate outputs. There are three reasons for updating unit costs:

(1) Correct for changes in the general price level (inflation),

(2) Correct for changes in relative prices of the specific elements determining each unit cost, and

(3) Correct for changes in the unit costs brought about by technological innovations.

Updating for changes in the general price level should be performed on a continuous basis. Updating for relative price changes between cost elements should be performed about every two or three years. Updating for technological changes should be performed about every 10 years. The updating procedures persented here are limited to changes in the general price level. These procedures are based on those presented in TTI Research Report 225-8 [10].

Values of Time

Values of time presented in Table 2 were updated to the January 1980 general price level, as reflected by the composite Consumer Price Index (CPI) and the composite Producer Price Index (PPI) for the United States (U.S.). The assumption is that the values of time will escalate with these indexes.

The CPI and PPI are more appropriate for use in adjusting for inflation or changes in the general price level, especially on a continuous basis, than a per capita or hourly income series. However, the appropriate income series should be used periodically, every two or three years, to adjust the values of time to more nearly reflected actual income levels.

The use of the U.S. CPI and PPI does offer the advantage of being published (by the U.S. Bureau of Labor Statistics) more frequently than the personal or hourly income data. In fact, CPI and PPI are published monthly, and the unit values of time can be updated continuously, with only a month's lag required. Therefore, it is recommended that such indexes be used to keep all unit costs, including values of time, adjusted for inflation.

The formulas to use in obtaining the updating multipliers for each value of time are as follows:

(1) Multiplier of passenger vehicle occupants $= \dfrac{\text{CPI for all commodities at latest date reported}}{\text{CPI for January 1980}}$

(2) Multiplier for drivers of commercial vehicles and buses $= \dfrac{\text{PPI for industrial commodities at latest date reported}}{\text{PPI for industrial commodities for January 1980}}$

The CPI and PPI, based on 1967 = 100, for January 1980 were 233.2 and 260.0, respectively.

Updating unit values of time to reflect relative price changes or changes in technology will require new base studies similar to those conducted to derive the presently used values of time. This would be especially true in the case of unit values of time for drivers of commercial vehicles. This type of updating is overdue since over ten years have passed since these base studies were conducted.

Vehicle Operating Costs

To update the ECOANA's 1980 vehicle operating unit costs for changes in the general price level, one component of the national or local CPI and one component of the national or local PPI should be used. For updating operating costs for passenger cars (Vehicle Type 1), the private transportation component of the CPI is the most relevent index to use. For updating operating costs for trucks and large buses (Vehicle Types 2, 3 and 4), the industrial commodities component of the PPI should be used. The formulas to use in obtaining the general price level updating multipliers (factors) for each vehicle type are as follows:

(1) Multipliers for Passenger Cars (Vehicle Type 1) = $\dfrac{\text{CPI for private transportation at latest date reported}}{\text{CPI for private transportation for January 1980}}$

(2) Multipliers for Trucks and Buses (Vehicle Types 2, 3, and 4) = $\dfrac{\text{PPI for industrial commodities at latest date reported}}{\text{PPI for industrial commodities for January 1980}}$

Using a base of 1967 = 100, the private transportation component of the CPI was 233.5 in January 1980 and the industrial commodities component of the WPI was 260.0.

After two or three years have passed, the vehicle operating unit costs should be adjusted for relative price or nonproportional changes. Since the overall vehicle operating unit costs are made up of several components priced separately in the market place, such an adjustment is necessary. The components of vehicle operating unit costs used by the ECOANA are as follows: (1) fuel costs, (2) maintenance costs, and (3) depreciation. During a two-or three-year period, the cost of fuel components experience a greater percentage increase than the other cost components. If such be the case, then each cost component should be adjusted separately, using the appropriate price index. Also, since each component represents a greater or lesser share of the total vehicle operating unit cost, an adjustment must be made to keep the correct proportions between the components before arriving at an overall updating multiplier for a particular driving condition and vehicle type.

TTI Research Report 225-8 [10] presents appropriate formulas for updating the separate components of unit vehicle operating costs. These formulas were adapted from those appearing in the new AASHTO Redbook [1]. Technological changes could bring about a significant shift in the proportion of vehicle operating costs among the separate component costs to the extent that the coefficients used in the formulas would be invalid. Therefore, new base studies should be conducted about every 10 years to update the assumed costs.

Accident Costs

The overall CPI is recommended for updating the ECOANA's 1980 accident unit costs for the first two to three years, at the most. After three years, they should be updated with relevant component indexes of the CPI. For fatal and injury unit costs, automobile insurance rates components should be used. For property damage unit costs, the automobile repairs and maintenance cost components should be used.

The formula for a general price level multiplier for all accident unit costs is as follows:

(1) Multiplier for all types of accidents = $\dfrac{\text{CPI for all commodities at latest date reported}}{\text{CPI for all commodities for 1980 (annual index)}}$

The latest available index should be used to calculate the above updating multiplier.

Like the other user unit costs used in the ECOANA, accident unit costs change not only due to inflation or general price level changes but also due to other factors, such as changes in the design of motor vehicles, design and condition of roads, and incomes of the vehicle occupants. Therefore, about every 10 years new accident cost base studies should be conducted to update accident unit costs for these factors. Some of the base studies still in use are already too old.

Fuel Consumption Rates

The fuel consumption rates used in the ECOANA should be updated to reflect changes in the fuel efficiency of vehicles making up the stream of traffic being analyzed. Changes in the overall fuel efficiency of vehicles in a stream of traffic can result from changes in type of fuel consumed, vehicle weight, engine design, etc. Starting with the 1978 models, the federal government has set fuel efficiency standards for passenger cars to be achieved annually through the 1985 model year [11]. Therefore, the fuel efficiency of automobiles must increase considerably above 1980's overall average fleet fuel consumption rate of 14.1 miles per gallon for Texas. During the next 10 years the fuel efficiency of the Texas automobile fleet is expected to increase to 18.2 miles per gallon. This is an increase of 29% over a 10 year period or 2.9% per year.

In lieu of developing a detailed and more accurate procedure (which needs to be done) for updating Type 1 vehicle consumption rates used in the ECOANA, the tabular rates can be updated by multiplying each rate by a derived factor. To calculate the updating factor, use the following formula:

$$\text{Updating Factor} = 0.02816 \times \begin{array}{c}\text{Number of Years} \\ \text{since 1980}\end{array} - 1.00000.$$

Such an updating factor should be used only until a more reliable updating procedure is developed.

Arriving at a temporary updating factor for Vehicle Types 2, 3, and 4 fuel consumption rates used in ECOANA is even more difficult, due to data deficiencies. Historical series of vehicle-miles per gallon for each of these vehicle types appear in the U.S. Department of Transportation's "Highway Statistics" [12]. The data for single-unit trucks (Type 3) reveal very little change in vehicle miles per gallon between 1970 and 1978. On the other hand, the data for Vehicle Types 3 and 4 indicate that vehicle-mile per gallon have increased by about 12 percent between 1970 and 1978. This increase in fuel efficiency is primarily the result of switching from gasoline powered to diesel powered vehicle. As yet, there are no federal fuel efficiency standards in effect for trucks and buses.

Since Type 2 vehicles have experienced little change in fuel efficiency and Type 4 vehicle is designated to use the Type 2 vehicle consumption rates, no updating factor is given for Types 2 and 4 fuel consumption rates. In the case of Type 3 vehicles, the tabular fuel consumption rates can be updated by multiplying each rate by a derived factor. To calculate the updating factor, use the following formula:

$$\text{Updating Factor} = 0.01687 \times \frac{\text{Number of Years}}{\text{since 1980}} - 1.00000.$$

Again, this updating factor should only be used until a more accurate updating procedure can be developed.

Pollution Emission Factors

The 1977 pollution emission factors used in ECOANA should be updated at least every five years. Since the calculation of the 1977 factors, new base data for calculating pollution emissions have been published by the EPA [12]. Updating the ECOANA factors will require additional study of the new base data to develop appropriate updating multipliers. Considerable time and effort will be needed to perform this task.

Uses of ECOANA Output Data

The initial output of ECOANA is the total time costs, vehicle operating costs, accident costs, gallons of fuel consumed, and pounds of air pollutants generated from motor vehicles using the study facility during one peak period, computed separately before and after the proposed improvement. The difference in the before and after amounts of each of these measures of effectiveness represents the benefits (disbenefits) of the proposed improvement for one peak period of operation. Each differential quantity can be expanded to reflect the magniture of benefits (disbenefits) for as many peak periods as might be relevant to study.

Although the magnitude of the indicated first year benefits (disbenefits) can be used as one measure of the effectiveness of a proposed improvement, a better measure is one which compares the present value (in dollars) of a stream of annualized future benefits, if any, with the present value of the capital, maintenance, and operation costs of the facility improvement. The relevant period for this comparison is the expected life (economic, not only physical) of the improvement. If the present value of the stream of benefits is greater than the present value of the stream of improvement costs, then the improvement is justifiable from an economic point of view. This amount is a measure of the net benefits of the improvement. A benefit/cost ratio can be calculated to indicate the magnitude of the benefits to costs relationship. A benefit/cost ratio of one or more indicates that the proposed improvement is economically feasible.

Of the five measures of effectiveness used by ECOANA, three (time, vehicle operating, and accident costs) are measured in dollars. These costs can be combined to calculate the net dollar benefits and the benefit/cost ratio. The other two measures of effectiveness are measured in physical quantities, and thus have to be calculated separately from those in dollars. Then, the analyst has to consider all five measures together to make a valid decision.

The relevant assumptions that must be made to calculate net benefits and the benefit/cost ratio are listed below:

1. Life of the improvement. This is the economic life which takes into consideration physical life. The life of the improvement is the analysis period.
2. Traffic growth rate over the life of the project. Even though it is not very realistic, the simplest analysis assumes a constant growth rate.

3. Discount rate to apply to future benefits and costs and calculate the present value of benefits and costs. If inflation is assumed to be zero over the life of the improvement, allowing future benefits and costs to be calculated in constant dollars, a discount rate of 3 to 5 percent is recommended. If inflation is assumed to be 8 percent, a discount rate of 10 to 12 percent should be used. Again, the simplest analysis assumes that inflation is zero. As a note of caution, the initial capital costs of an improvement do not have to be discounted to arrive at the present value of improvement costs.

To calculate the present value (PV) of future benefits over the analysis period, a present worth factor (PWF) is used. The PWF depends on the length of the analysis period and the discount rate assumed. The PWF can be looked up in present worth tables in highway economy, financial, or real estate appraisal text books. The PWF is multiplied by the annual benefits (AB) of the improvement to arrive at the PV of the future benefits. PV of the annualized improvement costs (maintenance and operation costs, not including capital costs) is derived the same way. Only capital costs other than the initial year capital costs have to be discounted from the year of expenditure. Capital, maintenance, and operating costs of the facility improvement must be supplied by the user. All discounted costs plus initial capital costs are divided into the present value of the benefits to derive the benefit/cost ratio.

ECOANA furnished the output data to calculate vehicle user costs and benefits but furnished only air pollution data that can be used to evaluate nonuser costs and benefits. Such nonuser impacts as land use, property value, noise, etc, need evaluating to complete the impact evaluation of an improvement.

ECOANA USER'S NOTE

The ECOANA program was developed to operate on generated output measures from FREQ3CP (13). All concepts, assumptions and definitions as set forth in the FREQ3CP model are carried into the ECOANA program. The ECOANA user must be familiar with the FREQ3CP simulation model's assumptions and definitions to properly evaluate the economic measures.

ECOANA PROGRAM SPECIFICATION AND OPERATION

The successful implementation of the ECOANA program was assured upon a detailed inspection of the FREQ3CP program. Traffic measures (speed, v/c ratios, travel, etc.) by time period are required for ECOANA calculations. Within the FREQ3CP program logic, definitive points exist where these necessary measures can be reserved for ECOANA's use without inhibiting the execution or integrity of the FREQ3CP operation. After the appropriate program steps were implemented into the FREQ3CP program, the traffic data to be utilized by ECOANA were placed, in an orderly fashion, on a remote storage tape. Upon completion of a FREQ3CP simulation program run, a decision can be made to execute the ECOANA program. If the simulation results from FREQ3CP are not satisfactory, it is not necessary to execute ECOANA. ECOANA depends upon the last data stored by the FREQ3CP program. Therefore, careful examination of the FREQ3CP simulation results should be accomplished before advancing to the next simulation run. If, at a later date, previous simulation results are needed for an ECOANA execution, the FREQ3CP data cards can be reassembled as in the previous configuration and executed. ECOANA can then be run on the newest data set. As previously described, the utility of ECOANA is not so much as to the accuracy or importance given to any one set of measurements (i.e. travel time costs, operating costs, etc.), but in the relative changes of these measurements between FREQ3CP runs where before and after conditions are simulated.

FREQ3CP Data Storage

The traffic data measures to be retained for use by ECOANA must be captured at the points in the execution steps of FREQ3CP where they are encountered. FREQ3CP is two programs that have been merged; i.e. the simulation portion is FREQ3(the third generation of freeway simulation) and the optimizing ramp metering control portion PREFLO (13). It is in the FREQ3 freeway simulation portion of FREQ3CP that the required freeway measures are generated. As set forth in the previous discussions, ECOANA must use measures from subsection by time slice units as well as data summarized over all subsections and time slices. FREQ3CP processes the simulation of freeway traffic by subsection and time slice. The individual measures for the subsections are unique only for that time slice. Before the next time slice is processed, these unique measures must be remotely stored for use by ECOANA. FREQ3 does accumulate summary information throughout all time slices. These accumulated measures are available at the conclusion of the FREQ3 simulation for retention for ECOANA use.

The first record of data stored by FREQ3CP pertains to the dimensionings of the overall freeway system. As shown in Table 30, the number of lanes in each subsection, the number of subsections and the ratio of persons per vehicle are given in Record 1. The number of diverted vehicle-miles of travel will contain valid information only if an after control simulation is conducted. In a before control simulation, vehicles may be diverted (due to excess queue waiting time or an overcapacity demand), but these vehicles were not observed to be processed in the same manner as were the diverted vehicles in the optimization routines. If valid information is not to be included in any of the information, all elements of the diverted vehicle-miles array are set to numeric zeros. Each record from 2 through the total number of time slices (ICT(2)value) contains identical information for each time slices. The measures by subsection are speed, the volume to

Table 30. FREQ3CP Data Storage Order

RECORD	VARIABLES STORED	VARIABLE DEFINITION
1	LANE(1-40)	LANE = Number of lanes per subsection 1 through subsection 40
	DVM(1-40)	DVM = Diverted vehicle-miles travel by subsection 1 through subsection 40
	NSEC	NSEC = Number of subsections
	ICT(2)	ICT(2) = Total number of time slices
	FAC(3)	FAC(3) = Average vehicle occupancy (pass/veh)
2	USP(1-40)	USP = Speed (MPH) per subsection
	VOC(1-40)	VOC = Volume to capacity ratio per subsection
↓	FVM(1-40)	FVM = Total vehicle-miles of freeway travel per subsection
ICT(2)	IQUE(1-40)	IQUE = Queue status per freeway subsection = 0 No queue = -1 Partial queue = -2 Total queue
	CUM(1-10)	CUM = Cumulative values per time slice CUM(1) = Freeway vehicle-hours of delay CUM(2) = Freeway passenger-hours of delay CUM(3) = Vehicular input delay at Entrance Ramps CUM(4) = Passenger input delay at Entrance Ramps CUM(5) = Vehicular output delay at Exit Ramps CUM(6) = Passenger output delay at Exit Ramps CUM(7) = Total travel time (veh-hrs) CUM(8) = Total travel time (Pass-hrs) CUM(9) = Total travel distance (veh-miles) CUM(10) = Total travel distance (Pass-miles)

capacity ratio, freeway travel and queueing status. Cumulative measures are routinely retained for future processing. Only in the last time slice period will the cumulative measures be meaningful to the present ECOANA logic.

ECOANA Program Input Tables

In the first half of this report, 29 tables of economics information were given. Twenty six of the tables are stored on a remote file for use by ECOANA. The other three tables are not needed. Many of the tables are combined into three dimensional arrays when accessed by ECOANA. Table 32 lists the three dimensional arrays and the included tables. The other economic tables are listed in the documentation and retain the same numeric number in the program. Table 28, for example, in the report is TAB28 array in the ECOANA program. Subroutine FIRST accesses the storage file and places all the economic data into the correct tables.

ECOANA Program Input Cards

There are a total of five data cards that must be created and used each time that ECOANA is executed. The cards must always be stacked in the following order:

CARD 1 - contains VTYPE values
CARD 2 - contains TABA through TABE values
CARD 3 - first line of page heading information
CARD 4 - second line of page heading information
CARD 5 - contains values for accident analysis of MROAD, NTYPE, MHIGHT, LSEVER, and IDVER

The user is urged to take note of the formats for these cards as shown in Table 31. If strict adherence to the order or format is not observed, a program error will unequivocally occur. All other information required by the ECOANA program will be taken from the stored FREQ results or the stored ECOANA input tables.

Table 31. ECOANA Input Variables with Values and Description of Use

VARIABLE NAME	# ELEMENTS	FORMAT	VALUES (1)	(2)	(3)	(4)	DESCRIPTION OF USE
VTYPE	4	4F10.2	.915	.070	.010	.055	Fractional number of each of 4 types of vehicles in traffic as denoted in Table 1
TABA	4	4F3.0	35.	35.	35.	35.	Uniform approach speed (MPH) on Diversion Route by Vehicle Type
TABB	4	4F3.0	2.3	2.3	2.3	2.3	Number of stops per vehicle mile on Diversion Route by vehicle type due to intersections
TABC	4	4F3.0	32.	36.	36.	36.	Seconds per stop on Diversion Route by vehicle type
TABD	4	4F3.0	3.6	4.7	4.7	4.7	Number of speed changes per mile on Diversion Route by vehicle type
TABE	4	4F3.0	10.	10.	10.	10.	Amount of speed change (MPH) on Diversion Route by vehicle type
HEAD	20	20A4					First line of Page Heading
HEADB	20	20A4					Second line of Page Heading
MROAD	1	A2	b	-	-	-	Location of Accidents (Table 28) Urban by default
NTYPE	1	A2	b	-	-	-	Highway Type (Table 28) Freeway by default
MHIGHT	1	I2	b	-	-	-	Highway Type (Table 28) Urban Freeway by default
LSEVER	1	I2	b	-	-	-	Location of Accident (Table 27) Urban Freeway by default
IDVER	1	I2	b	-	-	-	Diversion Route (Table 28) Undivided 2 Lane by default

Table 32. Three Dimensional Array Assignment

VARIABLE	DIMENSIONS	CONTAINS TABLES	DESCRIPTION
RCOSTS	3,13,6	3,4,5	Running cost on freeways by vehicle type, speed and level of service (LS)
EXCOST	3,10,5	9,10,11	Excess running costs on City Streets by speed cycle change, VT, speed and LS
FRATES	3,13,6	12,13,14	Fuel consumption rates on Freeways by vehicle type, speed and LS
FUELCN	3,10,5	17,18,19	Excess Fuel Consumption Rates on City Streets by speed cycle change, speed and LS
EMPOL	3,12,3	22,23,24	Pollution Emission Rates on Freeways by vehicle type and speed

Program Input Variables

A general objective in the development of the ECOANA program was to provide a minimum number of input variables (from cards) at execution time. The vast number of economic tables required by ECOANA are stored in discrete files separate from ECOANA. The tables can be updated on a yearly basis without accessing the ECOANA program. A description of the variables entered via cards are contained in Table 31. The variable, VTYPE, provides the fractional number of vehicles by type as defined in Table 1. This mix of vehicles can greatly influence the measures, such as operating costs. No provision was made to provide separate vehicle type percentages for on freeway and diversion routes.

The variables, TABA through TABE, provide a means for designating individuality by vehicle types for diversion route travel. The TABA variable is the uniform approach speed on the diversion route. Most frontage road facilities have 35 MPH speed limits and, as such, were the speed values used for all vehicles types. The units used for variable TABB were 2.3 stops per vehicle mile for type 1 and 3.3 for the remaining vehicle types. Correspondingly, there are fewer seconds used at each stop for Type 1 (32 seconds) and the other vehicle types (36 seconds) contained in TABC. The number of speed changes per mile are fewer with Vehicle Type 1 than the remaining vehicle types. There are 3.6 speed changes per mile by Type 1 vehicles and 4.7 for the rest as contained in variable TABD. TABE contains the magnitude of each speed change for each vehicle type. Ten miles per hour was the value chosen in the scenario.

The values used in variables TABA through TABE were taken from travel run studies conducted along the frontage roads on the North Central Expressway in Dallas, Texas. The user may chose to use these values given in Table 31 or may choose to develop their own. The authors could not find a source other than the Dallas studies from which to draw values.

There are two variables (HEAD & HEADB) that are presently used as a means for the user to document each ECOANA run. The user may place any alphanumeric character from Column 1 through Column 80 on 2 consecutive cards. The information will be printed on each of the five pages of economic measures basically centered on a 132 column page.

The final input card to ECOANA contains selective units for utilizing the accident analysis tables. Table 28 has been divided into a matrix of fifteen horizontal rows by three vertical columns. The variable MROAD is used to select the vertical column of Table 28. Only the alpha characters "R" for rural or "M" for metered urban are used. By default, if no alpha character is present, the urban column is selected. Similarily, the horizontal rows are selected using variable NTYPE by "E" expressway, "U" undivided conventional or "D" divided conventional. By default, a blank character will cause freeways to be selected. The remaining three variables are all entered as integer values.

The MHIGHT variable is used to select the horizontal row of Table 29; an integer value from one to twelve. The freeway is selected by default if no value is entered. LSEVER, by default, will cause the urban column to be chosen in Table 27 unless another is selected. While the above variables are primarily used to select accident rates for freeways, the IDVER variable can be used to select a different accident rate for the diversion route. The default value is the undivided conventional urban roadway accident rate.

General Program Operation

The ECOANA program can be separated into three basic execution steps. At first, it is necessary to obtain card and file information. All FREQ data that has been stored is then accessed and processed. Finally, the summary information for the five economic measures is calculated and printed. The ECOANA program documentation in the Appendices contains information that will help the user in being able to follow the explanation that is to follow.

The five data cards are read by the ECOANA ~~program and placed~~ into the appropriate arrays. Subroutine FIRST brings the stored economic tables into dimensioned arrays from the remote file. The first record of data stored by FREQ3CP is read. From these data, the number of lanes per subsection, the total vehicle-miles of travel by time-slice ~~on the diversion route, the~~ number of subsections, the number of time slices and the passenger occupancy per vehicle are obtained. At this point, the processing of time slice data is ready to begin.

FREQ3CP can process a freeway system composed of a maximum of 40 subsections. All ECOANA variables were set up to process this same maximum. Records 2 through the total number of time slices are each read and processed in the same manner. Even though each array contains 40 elements (one per subsection) only the number of subsections read in from Record 1 are analyzed. The data read in each time slice is given in Table 30.

The first objective to be accomplished is to match speed and level of service in each subsection against Tables 3, 4, 5, and 12, 13, 14. A close inspection of these two groups of tables (Operating Costs and Fuel Consumption) will show that in each level of service column only a finite number of speeds will yield valid rates. For example, a speed of 53 mph and a level of service

D will not yield a valid rate. Therefore, there is a certain amount of logic that must be processed to enable factual rates to be selected. All speeds, from FREQ, are real numbers and the decimal places are removed for earlier limit checks. The maximum speed allowed in any of the economic tables is 65 mph. A limit check of the speed assures a maximum of 65 mph. The queue check is performed. If the queue extends throughout the subsections, a level of service F must be applied and the speed cannot be greater than 35 mph. A limited or non-existent queue causes the volume to capacity (v/c) ratio to be limited to two decimal places. The v/c by number of lanes is compared to Table 6. A Table 6 examination will find the appropriate level of service from A to E (1 to 5). At this point a search is conducted of Tables 3, 4, 5 (or 12, 13, 14) where the level of service selected above is used to assert that the speed is within the range of allowable rates. If the speed is below the range of acceptable rates, then the minimum speed is selected for the lowest rate. If speed is above, the maximum speed is chosen. There are two working variables (RATE and RAT) which are used to contain the operating costs and fuel consumption rates by vehicle type. These two arrays are used to calculate the total on freeway operating costs of travel (TFVM) and the total on freeway fuel consumption (TFCON) by vehicle types. The freeway vehicle miles of travel in this subsection (FVM), cost or consumption rate by vehicle type and vehicle type percentage all multiplied together yields the appropriate cost or consumption by vehicle type. When the pollutant emissions are to be accumulated, the highest speed range allowed is 60 mph so a maximum speed check is again performed. A working array (EMPOL) is used to hold the pollution rates for the speed and v/c values in the subsection. Once again the pollution rate, vehicle miles of travel and the fractional vehicle types multiplied together yields the quantity of pollutant (EMPOL) by pollutant types in Table 22, 23, 24 and vehicle types. This processing concludes after subsections through all slices are accomplished.

When all time-slice processing within ECOANA has concluded there are three measures calculated; the operating cost, the fuel consumed and the quantity of pollutants all by vehicle types. The five measures tabulated by ECOANA will be printed in the order presented in the report; i.e., time costs, operating costs, fuel consumption, emissions and accidents. The remainder of the ECOANA program is directed towards building arrays best suited to output formatting. In the program the building of each measure's output is clearly evident because of the grouping of large output formats.

Travel time delays (vehicle-hours TVH and passenger-hours TPH) are accumulated by the FREQ program and stored in the last array in each time slice data record (CUM). Delay and cost for both driver and passenger are calculated for the freeway, entrance, exit and diversion route (for after control simulations). Horizontal and vertical sums are totalled as shown in Appendix B.

The operating costs and fuel consumption are calculated in a similar manner. During the calculation of the operating costs, the fuel consumed is also summarized whenever convenient. Operating costs are found for the freeway, entrance and exit ramps. The diversion route has three separate cost figures; operating costs due to uniform speeds, speed changes and idling time conditions. It is during the calculations of these diversion route costs that the program variables (TABA through TABE) read from data cards are utilized. All costs figures are totalled in a horizontal and vertical fashion as before.

The fuel consumption measures have, for the most part, already been calculated. The ramps are the only measures which must be calculated. Outputting the sum total through the appropriate formats is the final processing for this measure.

The pollution measures for the freeway traffic for carbon monoxides, hydrocarbons and nitrogen-oxides are calculated during the time slice calculations. The other locations (entrance, exit and diversion route) also must be calculated. Two additional pollutants (particulates and sulfur oxides) are also determined for the appropriate locations. Sum totals are outputted.

The accident costs are determined for only two locations; the freeway main lanes and the diversion route. The assumptions entered on card five of the program entry (Table 31) are used to select the desired accident rates, severities, and costs. Summary total are outputted as before.

Speed Versus V/C Ratio Test

During each time slice, calculations performed by FREQ3 provide a volume-to-capacity (V/C) ratio and a speed for each subsection. These values are stored for use by ECOANA. The V/C ratio is used in ECOANA to determine the level of service (L/S) from Table 6 based on the number of lanes in the subsection. This L/S value (1-6) is next combined with the speed for the subsection to select rate values for operating cost and fuel consumption. Inspection of the rates tables (3,4,5 or 12,13,14) indicates that not all choices of L/S and speed will yield valid rates. It is for this reason that limit checks are performed on the speed to insure that valid rates are chosen.

There is a question as to which value (V/C ratio or speed) should be assumed to be more correct. The V/C ratio is derived from the input-output and number of vehicles per subsection. Speed is computed from a program included or user installed speed and V/C curves. One of the tasks performed during the tuning of the freeway simulation model is to modify the parameters and input data to FREQ3CP until the freeway traffic queues and subsectional speeds reasonably match the field observations. The speed in each subsection is dependent upon the calculated V/C value. Also, the V/C value for the next time slice is dependent on the progression of the traffic stream which utilizes the speed for movement. Also, the speed can be adversely affected by the improper selection of the V/C-speed curve.

To justify the selection of the V/C as the more stable value from the FREQ3 program for the ECOANA calculations, a test was devised and conducted. The ECOANA computer program was constructed in two different versions. The first version assumed that the V/C ratio was correct as stored by FREQ. The speed from FREQ was then modified until valid rates could be found in the aforementioned rate tables. This ECOANA version was executed on before and after control FREQ3CP simulations. The second ECOANA version assumed speed was correct as stored by FREQ and the V/C was used as a variable. This second version was also executed on the identical before and after control FREQ3CP simulation results. The comparison of the ECOANA results are given in Table 33.

Inspection of Table 33 will indicate that the travel time and accident costs for both versions are the same. This is because these measures use only the total vehicle miles of travel for their calculations and do not depend on speed or the V/C ratio. The other ECOANA measures are affected by other the V/C ratio and speed. The operating cost, fuel consumption, and pollution emissions do show similar changes between before and after control simulations as shown in Table 34. The operating cost in the version that assumes V/C is correct indicates approximately the same relative change from the before to after condition as does the speed version. The fuel consumption and pollutants also show similar tendencies between versions. The V/C ratio assumption was chosen and included in the final ECOANA computer program. This version provides the more conservative costs, fuel consumed, and pollutants. Also, the user may change the speed vs. V/C ratio curves in the FREQ3CP program and effect only minor differences in the ECOANA analysis results.

Table 33. Speed and V/C versions of ECOANA based on Before and After Control FREQ3CP Simulation

Version	Total Travel Time Costs	Operating Costs	Fuel Consumption	Pollution Emissions					Accident Costs
				CO	HC	NO	PR	SO	
V/C Correct Before Control	$68020	$26166	14565 gals.	8971kg.	899kg.	1119kg.	92kg.	34kg.	$6537
V/C Correct After Control	$40415	$22159	10972 gals.	5824kg.	666kg.	1202kg.	415kg.	158kg.	$6087
Speed Correct Before Control	$68020	$30340	16362 gals.	17977kg.	1801kg.	2237kg.	184kg.	68kg.	$6537
Speed Correct After Control	$40415	$26306	12750 gals.	11643kg.	1332kg.	2406kg.	830kg.	316kg	$6087

Table 34. Relative Differences between V/C and Speed Versions of ECOANA

Version		Operating Costs	Fuel Consumption	Pollution Emissions				
				CO	HC	NO	PR	SO
V/C Assumed Correct-Speed Variable	BEFORE Control	$26166	14565 gals.	8971 kg.	899 kg.	1119 kg.	92 kg.	34 kg.
	-AFTER Control	-$22159	-10972 gals.	-5824 kg.	-666 kg.	-1202 kg.	-415 kg.	-158 kg.
	NET CHANGE	$ 4007	3593 gals.	3147 kg.	233 kg.	- 83 kg.	-323 kg.	-124 kg.
	PERCENT Change from Before	15.3%	24.7%	35.1%	25.9%	-107.4%	351.1%	-364.7%
Speed Assumed Correct-V/C Variable	BEFORE Control	$30340	16362 gals.	17911 kg.	1801 kg.	2237 kg.	184 kg.	68 kg.
	-AFTER Control	-$26306	-12750 gals.	-11643 kg.	-1332 kg.	-2406 kg.	-830 kg.	-316 kg.
	NET CHANGE	$ 4034	3621 gals.	6334 kg.	469 kg.	- 169 kg.	-646 kg.	-248 kg.
	PERCENT Change from Before	13.3%	22.1%	35.2%	26.0%	-107.6%	351.0%	-364.7%

CONCLUSIONS AND RECOMMENDATIONS

The ECOANA program provides a direct way of obtaining economic measures from the FREQ3CP freeway traffic simulation program. By using the economic measures in a before and after freeway improvement scenario, the user can develop benefits associated with the improvement. The benefits can, in turn, be compared to the costs of the improvement if the costs are known. The user can quickly develop a number of freeway improvements and obtain the economic measures of each. In this manner, the user can secure a complete inventory of proposed improvements and the relative benefits of each. The ECOANA program can provide decision makers with more complete information concerning proposed improvements.

There are three areas that are recommended for further development. At the inception of the research project, FREQ3CP was the current freeway simulation model. Since then, the simulation work has been updated to FREQ6PE. It would be beneficial for the SDHPT to keep (within the computer storage facilities) only one freeway simulation program instead of two. An inspection of FREQ6PE revealed that modifications can be made that will enable ECOANA to function based on FREQ6PE inputs instead of FREQ3CP inputs.

A portion of the FREQ6PE simulation outputs are two usage measures; fuel consumption and emissions. It would be of interest to execute ECOANA based on FREQ6PE outputs and compare the two methods of determination. This comparison could reveal differences in the methods used to quantify the measures. Analysis of the differences could be insignificant which would mean that the FREQ6PE measures were adequate. Significant differences could mean that ECOANA measures should continue to be used.

The third area concerns the modifications to the ECOANA program that would enable total "life-of-the-improvement" measures to be calculated. At present, to determine the economic measures throughout the life expectancy of the improvement, FREQ3CP must be executed for each year of the life of the improvement with a fixed growth applied. A 20 year life would require 20 FREQ3CP and ECOANA program executions. Modifying ECOANA would reduce the output to only one total summary output of the economic measures.

REFERENCES

REFERENCES

1. American Association of State Highway and Transportation Officials, A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements, (new Redbook), 444 North Capital Street, N.W. Suite 225, Washington, D.C., 1977.

2. Curry, David A. and Anderson, Dudley G., "Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects," NCHRP Report 133, Highway Research Board, Washington, D.C., 1972.

3. Buffington, Jesse L. and McFarland, William F., "Benefit-Cost Analysis: Updated Unit Costs and Procedures," Research Report 202-2, Texas Transportation Institute, Texas A&M University, College Station, Texas, 1976.

4. Winfrey, Robley, Economic Analysis for Highways, International Textbook Company, Scranton, Pennsylvannia, 1969.

5. U.S. Environmental Protection Agency, Supplement No. 5 for Compilation of Air Pollutant Emission Factors, Second Edition, Office of Air Quality Planning Standards, Research Triangle Park, North Carolina, December, 1975.

6. Agnello, Richard J., "Measuring Time Losses at Highway Bottlenecks and Empirical Findings for the Chesapeake Bay Bridge," Highway Research Record No. 467, Highway Research Board, Washington, D.C., 1973.

7. Lytton, R.L. and McFarland, W.F., Systems Approach to Pavement Design - Implementation Phase, Final Report, Prepared for the National Cooperative Highway Research Program, Highway Research Board, by Texas Transportation Institute, College Station, Texas, March 1974.

8. Texas Department of Highways and Public Transportation, Guide to the Highway Economic Evaluation Model, Austin, Texas, February 1976.

9. Tamburri, T.N., and Smith, R.N., "The Safety Index: A Method of Evaluating and Rating Safety Benefits," Highway Research Record 332, Highway Research Board, Washington, D.C. 1970.

10. Buffington, Jesse L., McFarland, William F., and Rollins, John, "Texas Highway Economic Evaluation Model: A Critical Review of Assumptions and Unit Costs and Recommended Updating Procedures," Research Report 225-8, Texas Transportation Institute, Texas A&M University, College Station, Texas, 1979.

11. Christiansen, Dennis, L., "Energy and Texas Transportation," Technical Report 1059-2F, Texas Transportation Institute, Texas A&M University, College Station, Texas, 1980.

12. U.S. Environmental Protection Agency, Mobile Source Emission Factors for Low-Altitude Areas, Final Document, Office of Air and Waste Management, Washington, D.C., March 1978.

13. Ovaici, Khosrow., May, Adolf D., Teal, Roger F. and Ray, James K., "Simulation of Freeway Priority Strategies (FREQ3CP)", Department of Transportation, Federal Highway Administration, Washington, D.C., 1975.

APPENDIX A

DESCRIPTION OF VARIABLES USED IN ECOANA

APPENDIX A

DESCRIPTION OF VARIABLES USED IN ECOANA

CUM(10)	- CUMULATIVE MEASURES AT END OF EACH TIME SLICE CUM(1) - FREEWAY VEHICLE-HOURS OF DELAY CUM(2) - FREEWAY PASSENGER-HOURS OF DELAY CUM(3) - VEHICULAR IMPUT DELAY AT RAMPS CUM(4) - PASSENGER INPUT DELAY AT RAMPS CUM(5) - VEHICULAR OUTPUT DELAY AT RAMPS CUM(6) - PASSENGER OUTPUT DELAY AT RAMPS CUM(7) - TOTAL TRAVEL TIME (VEH-HRS) CUM(8) - TOTAL TRAVEL TIME (PASS-HRS) CUM(9) - TOTAL TRAVEL DISTANCE (VEH-MILES) CUM(10) - TOTAL TRAVEL DISTANCE (PASS-MILES)
DVM(40)	- NUMBER OF DIVERTED VEHICLE-MILES OF TRAVEL IN EACH SUBSECTION - STORED BY FREQ3CP
EMPOL(3,12,3)	- POLLUTION EMISSION RATES (GRAMS PER MILE) BY VEHICLE TYPES (1 TO 3), SPEED RANGE (5 TO 60 MPH IN 5 MPH INCREMENTS), AND POLLUTANT (CARBON MONOXIDE = 1, HYDROCARBONS = 2, NITROGEN OXIDES = 3)
EPOL(3,3)	- POLLUTANT RATES (GRAMS PER MILE) FOR CURRENT SPEED RANGE IN THIS SUBSECTION BY VEHICLE TYPE (1 TO 3) AND POLLUTANT (CO = 1, HC = 2, NO = 3)
EXCOST(3,10,5)	- EXCESS RUNNING COSTS DUE TO SPEED CHANGES (¢ PER CYCLE CHANGE) EXCOST(VEHICLE TYPE (1-3), SPEED RANGE (5-50 MPH IN 5 MPH INCREMENTS, SPEED REDUCTIONS (0-50 MPH IN 10 MPH INCREMENTS)
FAC	- PASSENGER OCCUPANCY AS USED IN FREQ3CP
FRATES(3,13,6)	- FUEL CONSUMPTIONS RATES ON FREEWAYS (GALLONS PER VEHICLE-MILE) BY VEHICLE TYPE, SPEED RANGE AND LEVEL OF SERVICE.

FRATES(I,J,K) - IDENTICAL TO RCOSTS ARRAY

FUELCN(3,10,5) - EXCESS FUEL CONSUMPTION RATES (GALLONS PER CYCLE CHANGE) BY VEHICLE TYPE (1-3), SPEED RANGE (5-50 MPH IN 5 MPH INCREMENTS), SPEED REDUCTIONS (0-50 MPH IN 10 MPH INCREMENTS)

FVM(40) - VEHICLE-MILES OF TRAVEL ON THE FREEWAY IN EACH SUBSECTION

HEAD(20) - CONTAINS HEADING INFORMATION IN 20A4 FORMAT

HEADB(20) - CONTAINS HEADING INFORMATION IN 20A4 FORMAT

IAX(7,4) - SUMMARY INFORMATION FOR OPERATING COSTS

IAX(1,1-4) - CONTAINS ON FREEWAY OPERATING COSTS
IAX(2,1-4) - CONTAINS ON RAMP OPERATING COSTS
IAX(3,1-4) - CONTAINS OFF RAMP OPERATING COSTS
IAX(4,1-4) - CONTAINS DIVERSION - UNIFORM SPEED FOR OPERATING COSTS
IAX(5,1-4) - CONTAINS DIVERSION - SPEED CHANGE FOR OPERATING COSTS
IAX(6,1-4) - CONTAINS DIVERSION - IDLING COSTS FOR OPERATING COSTS
IAX(7,1-4) - CONTAINS VERTICAL TOTALS FOR OPERATING COSTS

IDVER - HIGHWAY TYPE FOR ACCIDENT ANALYSIS

IQUE(40) - "*" IN EACH SUBSECTION IF FREEWAY QUEUE THROUGHOUT.

ITT(5,5) - SUMMARY INFORMATION FOR TRAVEL TIME COSTS

KAX(7,4) - SUMMARY INFORMATION FOR FUEL CONSUMPTION (SAME ASSIGNMENTS AS IAX(7,4))

LANE(40) - NUMBER OF LANES IN EACH SUBSECTION - STORED BY FREQ3CP

LOX(5,4,5)	- SUMMARY POLLUTANT INFORMATION BY TRAVEL METHOD, VEHICLE TYPE AND POLLUTANTS LOX(1,I,J) - ON FREEWAY LOX(2,I,J) - ON RAMP LOX(3,I,J) - OFF RAMP LOX(4,I,J) - DIVERSION LOX(5,I,J) - TOTALS LOX(L,1,J) - VEHICLE TYPE 1 LOX(L,2,J) - VEHICLE TYPES 2 & 4 LOX(L,3,J) - VEHICLE TYPE 3 LOX(L,4,J) - TOTALS LOX(L,I,1) - CARBON MONOXIDES (GRAMS PER MINUTE) LOX(L,I,2) - HYDROCARBONS (GRAMS PER MINUTE) LOX(L,I,3) - NITROGEN OXIDES (GRAMS PER MINUTE) LOX(L,I,4) - PARTICULATES (GRAMS PER MILE) LOX(L,I,4) - SULFUR OXIDES (GRAMS PER MILE)
LSEVER	- LOCATION OF ROADWAY FOR ACCIDENT ANAYLSIS
LX(15)	- HEADING INFORMATION FOR SUMMARY REPORT
MHIGHT	- ROADWAY TYPE FOR ACCIDENT ANALYSIS
MONEY(3,7)	- SUMMARY INFORMATION ON ACCIDENTS AND COSTS BY TRAVEL METHOD
MRØAD	- ROADWAY TYPE FOR ACCIDENT ANALYSIS
NSEC	- NUMBER OF SUBSECTIONS - STORED BY FREQ3CP
NTS	- NUMBER OF TIME SLICES - STORED BY FREQ3CP
NTYPE	- ROAD TYPE AS INPUT PARAMETER TO ACCIDENT ANALYSIS
POLLS(3,3)	- SUMS POLLUTANTS BY VEHICLE TYPE (1-3) FOR ALL SUBSECTIONS AND TIME SLICES BY POLLUTANTS (1-3)

ØPLIST(196) - HEADING INFORMATION FOR SUMMARY PRINTOUTS IN 7A4 FORMAT

RAT(3) - CURRENT FUEL CONSUMPTION (GAL/V-M) BY VEHICLE TYPE BASED ON SPEED AND LEVEL SERVICE IN THIS SUBSECTION AND TIME SLICE

RATE(3) - CURRENT RUNNING COSTS (¢/V-M) BY VEHICLE TYPE BASED ON SPEED AND LEVEL SERVICE PER SUBSECTION AND TIME SLICE

RCOSTS(3,13,6) - RUNNING COSTS (¢ PER VEH-MI) ON FREEWAYS BY VEHICLE TYPE, SPEED RANGE, AND LEVEL OF SERVICE

RCOSTS(I,J,K) - I=1 FOR VEHICLE TYPE 1
I=2 FOR VEHICLE TYPES 2 AND 4
I=3 FOR VEHICLE TYPE 3
J=1-13 FOR SPEEDS RANGES IN 5 MPH INCREMENTS
K=1-6 FOR 6 LEVEL OF SERVICES A-F

SPED(40) - SPEED IN MPH FOR EACH SUBSECTION

NOTE: TABA - TABE FOR DIVERSION ROUTE

TABA(4) - AVERAGE INITIAL SPEED (MPH) BY VEHICLE TYPES (1-4)

TABB(4) - AVERAGE NUMBER OF STOPS PER VEHICLE-MILE AT INTERSECTIONS

TABC(4) - AVERAGE VEHICLE-HOURS PER STOP

TABD(4) - AVERAGE NUMBER OF SPEED CHANGES PER VEHICLE-MILE

TABE(4) - AVERAGE SPEED REDUCTION PER SPEED CHANGE

TAB2(4,4) - VALUES OF TIME ($) BY VEHICLE TYPE (1-4) AND DRIVING MODE (1-MOVING, 2-STOPPED)

TAB6(3,6) - V/C RATIOS GROUPED BY LEVEL OF SERVICE (L/S) AND NUMBER OF LANES

TAB7(3) - IDLING COSTS (¢/HR) BY VEHICLE TYPE

TAB8(10,3)	- RUNNING COSTS (¢/V-M) ON CITY STREETS BY (SPEED GROUP, VEHICLE TYPE)
TAB15(3)	- IDLING FUEL CONSUMPTION (GALS/HR) BY VEHICLE TYPE
TAB16(10,3)	- FUEL CONSUMPTION RATES (GAL/MI) ON CITY STREETS
TAB25(3,2)	- PARTICULATE AND SULFUR OXIDE POLLUTION (GRAMS/MILE) (VEHICLE TYPE, POLLUTANT)
TAB26(3,2)	- IDLING POLLUTION RATES (GRAMS/MINUTE) (VEHICLE TYPE, POLLUTANT)
TAB27(3,3)	- MOTOR VEHICLE ACCIDENT UNIT COSTS ($/ACCIDENT) PER REPORTED ACCIDENT (SEVERITY, LOCATION)
TAB28(15,3)	- MOTOR VEHICLE ACCIDENT RATES (PER 10^6 V-M) (HIGHWAY TYPE, LOCATION)
TAB29(12,4)	- PERCENTAGE DISTRIBUTION (HIGHWAY TYPE, ACCIDENT SEVERITY)
TFCON(4)	- SUMS THE FUEL CONSUMED BY VEHICLE TYPES (1-4) FOR ALL SUBSECTIONS AND TIME SLICES
TFVM(4)	- SUMS THE RUNNING COSTS BY VEHICLE TYPES (1-4) FOR ALL SUBSECTIONS AND TIME SLICES
TRICK(4)	- MIRROR COPY OF VTYPE ARRAY EXCEPT ELEMENT (4) IS ADDED TO ELEMENT (2) AND SANED IN (2)
VC(40)	- VOLUME TO CAPACITY RATIO FOR EACH SUBSECTION
VMBLN(8)	- VEHICLE-MILES OF TRAVEL BY LANE
VTYPE(4)	- FRACTION OF EACH TYPE VEHICLE IN TRAFFIC STREAM

APPENDIX B

ECOANA PROGRAM LISTING

```
      INTEGER*2 MRCAD,NTYPE,MHIGHT
      INTEGER*2 IRURAL/'R '/,MURBAN/'M '/,NEXY/'E '/,NHU/'U '/,NHD/'D '/
      INTEGER LX(15)/' ON ','FREE','WAY ',' ON ','RAMP','    ',' OFF','
     *RAM','P   ',' DIV','ERSI','ON  ',' TOT','ALS ','    '/
      REAL MONEY(3,7)
      INTEGER CPLIST(49)
     *                  /'  ON',' FRE','EWAY','4*' ',' ','  ON',' RAM','P   ',
     *4*' ',' ','  OF','F RA','MP  ',4*' ',' ','  DI','VERS','ION ','- UN',
     1'IFOR','M SP','EED ',' ','  DI','VERS','ION ','- SP','EED ','CHAN',
     2'GES ',' ','  DI','VERS','ION ','- ID','LING',2*' ',' ','  **','*   ',
     3' TOT','ALS ',' ','   *','**  ',' ','    '/
      DIMENSION ITT(5,5), IAX(7,4), KAX(7,4)
      DIMENSION VTYPE(4), TABA(4), TABB(4), TABC(4), TABD(4),TABE(4)
      DIMENSION TFVM(4),TFCON(4),EPOL(3,3), POLLS(3,3), VMBLN(8)
      DIMENSION LCX(5,4,5)
      DIMENSION HEAD(20),HEADB(20),TRICK(4),DVM(40),FVM(40),CUM(10)
      COMMON/IDA/RATE(3),RAT(3),LANE(40),IQUE(40),VC(40),SPED(40)
      COMMON/IDATA/RCOSTS(3,13,6),FRATES(3,13,6),EXCOST(3,10,5),
     *TAB6(3,12),TAB8(10,3),TAB7(3),TAB15(3),TAB2(4,4),
     1TAB16(10,3),TAB29(12,3),EMPOL(3,12,3),TAB28(15,3),TAB27(3,3),
     2TAB26(3,3),TAB25(3,2),FUELCN(3,10,5)
C
      READ(5,1111) ( VTYPE(I),I=1,4) , ITABLE
 1111 FORMAT(4F10.3,9X,I1)
C
C     VTYPE    = % OF EACH TYPE VEHICLE IN TRAFFIC STREAM
C     VTYPE(1) = AUTOS,PU $ PANELS (2-AXLE,4-TIRES)
C     VTYPE(2) = SU TRUCKS (OTHER THAN 2 AXLE,4-TIRES)
C     VTYPE(3) = T.T. SEMI OR TRAILER COMBOS
C
C     IF VEHICLE TYPES TABLE IS NOT DESIRED PUT INTEGER FROM 1 - 9 IN COL 50
C     OF THE VEHICLE PERCENTAGES LIST  - CARD 1 OF INPUT TO ECOANA
C     A BLANK IN COL 50 WILL CAUSE TABLE TO BE PRINTED
C
      READ(5,564)(TABA(I),I=1,4),(TABB(I),I=1,4),(TABC(I),I=1,4),
     *            (TABD(I),I=1,4),(TABE(I),I=1,4)
  564 FORMAT(4F3.0,4F3.0,4F3.0,4F3.1,4F3.0)
C
      ITIME=0
C
      READ( 5,5357 ) HEAD
 5357 FORMAT( 20A4 )
      READ(5,5357) HEADB
      READ( 5,5588) MRCAD,NTYPE,MHIGHT,LSEVER,IDVER
 5588 FORMAT(2(1X,A2 ),3I2)
C

      CALL FIRST
C
      DO 399 I=1,4
  399 TRICK(I) = VTYPE(I)
      TRICK(2) = TRICK(2) + TRICK(4)
```

```
C
C      OBTAIN GENERAL INFORMATION FROM FREQ STORAGE
C
       TVM=0.
       DO 7070 IKX=1,4
       TFVM(IKX)=0.
       TFCON(IKX)=0.
       VMBLN(IKX)=0.
 7070  VMBLN(IKX+4)=0.
       DO 7071 IKX=1,3
       DO 7071 IKY=1,3
 7071  POLLS(IKX,IKY)=0.
       REWIND 3
       READ(3) LANE,DVM,NSEC,NTS,PAC
C      LANE(40) = NUMBER OF LANES IN EACH SUBSECTION
C      DVM( 40 ) - DIVERTED VEH-MILES TRAVEL IN EACH TIME SLICE
C      NSEC = NUMBER OF SUBSECTIONS
C      NTS = NUMBER OF TIME SLICES
C      PAC - PASSENGER OCCUPANCY USED IN FREQ
C
C      BEGIN TIME SLICE CALCULATIONS
C
C*************************************************************************************
C*************************************************************************************
       DO 100 I=1,NTS
       READ(3) SPED,VC,FVM,IQUE,CUM
C
C      SPED(40) = AVEGE SPEED( MPH ) PER S-SECTION
C      VC(40) = V/C RATIO PER S-SECTION
C      FVM(40) = ON FREEWAY VEH-MILES OF TRAVEL
C      IQUE(40)   PARTIAL QUEUE=-1   TOTAL QUEUE=-2
C      CUM - CUMULATIVE TOTALS DELAY AND TRAVEL FROM FREQ
C------------------------------------------------------------------------------------
C------------------------------------------------------------------------------------
        DO 10 NS = 1 , NSEC
C
C
       IP=SPED(NS)
       SPED(NS) = 1.* IP
        IF( IP .GT. 65) SPED(NS) = 65.
       IF( IQUE( NS ) .EQ. -2 ) GO TO 11
       IF( LANE(NS) .LE. 2 ) J=1
       IF( LANE(NS) .EQ. 3 ) J=2
       IF( LANE(NS) .GE. 4) J=3
C      TAB6 CONTAINS LEVEL OF SERVICE BY V/C BY LANES
       JJ=0
       IP=VC(NS)*100.
       VC(NS) = (1.*IP)/100.
       DO 13 K=2,10,2
       IPA = 100. * TAB6( J,K-1 )
       IPB = 100. * TAB6( J,K )
       IF( IP .GE. IPA .AND. IP .LE. IPB ) JJ= K/2
   13  CONTINUE
       IF( JJ .NE. 0 ) GO TO 14
   11  JJ = 6
 1193  IF(SPED(NS) .GE. 35.) GO TO 1192
       KK=SPED(NS) /5.
       AI=(SPED(NS)-(5.*KK))/5.
```

```
      GO TC 26
 1192 KK=7
      GO TO 25
C
C
   14 KK= SPED(NS) / 5.0
      AI = ( SPED(NS) - ( 5.0 * KK ) ) / 5.0
C
  115 IA = 5
      IB = 6
      IC = 9
      DO 120 KA = 1,5
      IF( JJ .NE. IA ) GC TC 119
      IF( KK .LE. IB ) KK = IB
      IF( KK .GT. IC ) KK = IC
      GO TO 26
  119 IA = IA - 1
      IB = IB + 1
      IC = IC + 1
  120 CONTINUE
      GO TO 29
C
   25 DO 28 IA = 1,3
      RATE( IA ) = RCOSTS( IA,KK,JJ )
   28 RAT  ( IA ) = FRATES( IA,KK,JJ )
      GO TC 29
C
C
C     RCOSTS( VTYPES,SPEED RANGE,L/S ) - RUNNING COSTS ON FREEWAYS
C     VTYPES( 1 , 2 + 4& 3
C     SPEEDS RANGED BY 5 MPH FROM 5 TO 65 MPH
C     LEVEL OF SERVICE ( L/S ) FROM AA TO F
C
C     RATE1 FOR RUNNING COSTS VEH-TYPE 1 AT SPEED AND L/S
C     RATE2 FOR RUNNING COSTS VEH-TYPE 2 $ 4 AT SPEED AND L/S
C     RATE3 FOR RUNNING COSTS VEH-TYPE 3      AT SPEED AND L/S
C
C     FRATES( VTYPES,SPEED RANGE, L/S ) - FUEL CONSUMED RATES ON FREEWAYS
C     GALS. PER VEH - MILE
C     RAT1 FUEL CONSUMPTION VEH-TYPE 1
C     RAT2 FUEL CONSUMPTION VEH-TYPE 2 $ 4
C     RAT3 FUEL CONSUMPTION VEH-TYPE 3
C
   26 DO 27 IA = 1,3
      RATE( IA ) = RCOSTS( IA,KK,JJ ) + AI * ( RCOSTS( IA,KK+1,JJ ) -
     *                                         RCOSTS( IA,KK   ,JJ ) )
      RAT  ( IA ) = FRATES( IA,KK,JJ ) + AI * ( FRATES( IA,KK+1,JJ ) -
     1                                         FRATES( IA,KK   ,JJ ) )
   27 CONTINUE
C
C.......................................................................
   29 CONTINUE
C
C
C
C     SUM FOR THIS S-SECTION ON FREEWAY VEH-MILES BY VTYPE - OPER'G COST
C      TFVM( 1 - 4 ) - TOTAL ON FREEWAY OPERATING COST OF TRAVEL BY
C     VEH-TYPE
```

```
C
      DO 32 IA = 1,3
      TFVM( IA ) = TFVM( IA ) + FVM( NS ) * RATE( IA ) * VTYPE( IA )
      TFCON( IA ) = TFCON( IA ) + FVM( NS ) * RAT( IA ) * VTYPE( IA )
   32 CONTINUE
      TFVM( 4 ) = TFVM( 4 ) + FVM( NS ) * RATE( 2 ) * VTYPE( 4 )
      TFCON( 4 ) = TFCON( 4 ) + FVM( NS ) * RAT( 2 ) * VTYPE( 4 )
C     TFCON( 1-4 ) TOTAL ON FREEWAY FUEL CONSUMPTION BY VEH-TYPE
C            (  GALLONS FUEL USED )
C
      KP = KK
      IF( KP .LE. 11 ) GO TO 30
      DO 36 JA=1,3
      DO 33 JB = 1,3
   33 EPOL( JA,JB ) = EMPOL( JA,12,JB )
   36 CONTINUE
      GO TO 40
   30 DO 35 JA=1,3
      DO 34 JB = 1,3
   34 EPOL( JA,JB ) = EMPOL( JA,KP,JB ) + AI *( EMPOL( JA,KP+1,JB ) -
     *                                           EMPOL( JA,KP  ,JB ) )
   35 CONTINUE
   40 CONTINUE
C     JA FOR VEH-TYPES
C     JB FOR POLLUTANTS
      DO 50 JA = 1 , 3
      DO 51 JB = 1 , 3
      POLLS( JA,JB ) = POLLS( JA,JB ) + EPOL( JA,JB ) * FVM( NS ) *
     1                 TRICK( JA )
   51 CONTINUE
   50 CONTINUE
C
C
C     ACCUMULATE ON FREEWAY VEH-MILES OF TRAVEL
C
      TVM = TVM + FVM( NS )
C
C     ACCCUMULATE VEH-MILES TRAVELED BY LANE FOR ACCIDENT ANALYSIS
C
      VMBLN( LANE( NS ) ) = VMBLN( LANE( NS ) ) + FVM( NS )
C
C
C
C      THIS POINT ENDS THE S-SECTION CALCULATIONS
   10 CONTINUE
C
C<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
C<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
C
C
C
  100 CONTINUE
C
C     END OF ALL TIME SLICE SERVICING
C***********************************************************************
C***********************************************************************
C
C $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $
```

```
      WRITE(6,9999)
 9999 FORMAT(1H1,//,21X,'EEEEEEEEEE       CCCCCCC        COOOOO        AAAA
     *AAAAA     NNNN     NNN     AAAAAAAAA',/,21X,'EEEEEEEEEEE       CCCCCCCC
     1C     COOOOOOOO     AAAAAAAAAAA     NNNNN    NNN    AAAAAAAAAAA',/,21X,'
     2EEE',12X,'CCCC     CCC  COO       COO    AAA       AAA    NNNNNN   NNN    A
     3AA      AAA',/,21X,'EEE',11X,'CCCC',10X,'OOO       OOO    AAA       AAA
     4  NNNNNNN NNN    AAA       AAA',/,21X,'EEEEEEEEE      CCCC',10X,'OOO
     5    OOO    AAAAAAAAAAA    NNN NNNNNNN    AAAAAAAAAAA',/,21X,'EEEEEEEEE
     6       CCC',11X,'CCC      COO     AAAAAAAAAAA     NNN NNNNNNN     AAAAAAAAA
     7AA',/,21X,'EEE',11X,'CCC',11X,'OOO       OOO     AAAAAAAAAAA     NNN   NN
     8NNNN    AAAAAAAAAAA',/,21X,'EEE',12X,'CCCC     CCC  OOOO      OOO     AA
     9A      AAA    NNN     NNNNN    AAA       AAA')
      WRITE(6,9998)
 9998 FORMAT(21X,'EEEEEEEEEEE       CCCCCCCCCC    OOOOOOOOO     AAA       AAA
     *  NNN    NNNNN    AAA       AAA',/ ,21X,'EEEEEEEEEEE       CCCCCCCC
     1 OOOOOOO       AAA       AAA    NNN       NNNN    AAA       AAA',/)
C
C     SUM THE DIVERTED VEH-MI. OF TRAVEL   & PLACE IN DDVM
C     DVM( 1-NTS ) MAY NOT HAVE VALUES UNLESS  OPTIMIZATION HAS BEEN RUN IN FREQ
C     FAC HAS PASS OCCUPANCY AS USED IN LAST FREQ TIME SLICE ON FREEWAY
C     PDVM CONTAINS PASS-MI. OF TRAVEL ON DIVERSION ROUTE
      DDVM = 0.
      DO 1117 K=1,NTS
 1117 DDVM = DDVM + DVM( K )
      PDVM = DDVM * FAC
C
C
C     PRINT CUMULATIES VALUES FROM FREQ THAT USED BY ECOANA PROCESSING
C     PRINT OUT HEADING THAT TIES FREQ RUN TO THIS ECOANA RUN
      WRITE(6,5353) HEAD,HEADE
 5353 FORMAT(////,21X,20A4,//,21X,20A4,///,21X,
     *'THE FOLLOWING DATA WAS STORED BY FREQ3CP',//)
      WRITE( 6,9030 ) ( CUM( I ) , I=1,10 ), DDVM, PDVM
 9030 FORMAT(41X,'VEH-HRS',11X,'PASS-HRS',///,21X,'FREEWAY TRAVEL TIME',
     *2(F8.0,10X),//,29X,'INPUT DELAY', 2(F8.0,10X),///,28X,'OUTPUT DELA
     1Y',2(F8.0,10X),///,23X,'TOTAL TRAVEL TIME',2(F8.0,10X),/////,40X,
     2' VEH-MI.',10X,'PASS-MI.',///,19X,'TOTAL TRAVEL DISTANCE',2(F8.0,1
     30X),///,15X,'DIVERSION TRAVEL DISTANCE',2(F8.0,10X))
      IF( ITABLE .NE. 0 ) GO TO 9671
      WRITE(6,9669) (( I,VTYPE(I) ), I=1,2)
 9669 FORMAT('1',///,10X,'VEHICLE TYPES AND PERCENTAGES USED IN THIS CON
     *TROL PERIOD',//,6X,1HI,11(1H-),1HI,11(1H-),1HI,32(1H-),1HI,/,6X,1H
     1I,11X,1HI,11X,1HI,32X,1HI,/,6X,1HI,3X,'VEHICLE I PERCENTAGEI   DES
     2CRIPTION',18X,1HI,/,6X,'I    TYPE     I',11X,1HI,32X,1HI,/,6X,1HI,11
     3X,1HI,11X,1HI,32X,1HI,/,6X,1HI,11(1H-),1HI,11(1H-),1HI,32(1H-),1HI
     4,/,6X,1HI,11X,1HI,11X,1HI,32X,1HI,/,6X,1HI,I6,5X,1HI,F7.3,4X,1HI,3
     5X,'AUTOS,PU (2-AXLES,4-TIRES)',3X,1HI,/,6X,1HI,11X,1HI,11X,1HI,32X
     6,1HI,/,6X,1HI,I6,5X,1HI,F7.3,4X,1HI,3X,'SU TRUCKS (OTHER THAN ABOV
     7E) I',/,6X,1HI,11X,1HI,11X,1HI,32X,1HI)
      WRITE(6,9670) (( I,VTYPE(I) ),I=3,4)
 9670 FORMAT(6X,1HI,I6,5X,1HI,F7.3,4X,1HI,3X,'SEMI AND T.T. TRUCKS',9X,1
     *HI,/,6X,1HI,11X,1HI,11X,1HI,32X,1HI,/,6X,1HI,I6,5X,1HI,F7.3,4X,1HI
     1,3X,'BUSES',24X,1HI,/,6X,1HI,11X,1HI,11X,1HI,32X,1HI,/,6X,1HI,11(1
     2H-),1HI,11(1H-),1HI,32(1H-),1HI)
 9671 CONTINUE
      WRITE(6,5358) HEAD
 5358 FORMAT('1',///,2(A4,//)
      WRITE(6,5356) HEADB
```

```
 5356 FORMAT(20A4,////)
C
C $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $
C
C
C      TVH = TOTAL VEHICLE DELAY ( VEH-HRS )
C      TPH = TOTAL PASSENGER DELAY ( PASS-HRS )
C      TORVH = TOTAL ON RAMP VEH DELAY ( VEH-HRS )
C      TORPH = TOTAL ON RAMP PASS DELAY ( PASS-HRS )
C      TVM = TOTAL VEH-MILES ON FREEWAY
C      TPM = TOTAL PASS-MILES TRAVELED ON-FREEWAY
C      SUM ALL TRAVEL TIME DELAY AND COSTS
C      FIND ON FREEWAY DELAY AND COSTS
C
       TVH = CUM(1)
       TPH = CUM(2)
       TORVH = CUM(3)
       TORPH = CUM(4)
       OFFRV = CUM(5)
       OFFRP = CUM(6)
C
       DO 800 I=1,5
       DO 800  J=1,5
  800  ITT( I,J ) = 0
       T = 0.
       DO 801 I = 1,4
  801  T = T + ( TVH * VTYPE(I) * TAB2( I,1 ) )
C      TAB2(I,1) = VALUE OF TIME BY VEH TYPE AND DRIVER IN MOVING VEHICLE
       ITT( 1,1 ) = TVH
       ITT( 1,2 ) = TPH - TVH
       ITT( 1,3 ) = T
       ITT( 1,4 ) = ( TPH - TVH ) * TAB2( 1,2 )
C      TAB2(I,2) = VALUE OF PASS TIME BY VEH TYPE IN MOVING VEH
       ITT( 1,5 ) = ITT( 1,3 ) + ITT( 1,4 )
C
C     *******  ON - RAMP TRAVEL TIME COSTS   *******
C
       T = 0.
       DO 802 I= 1,4
  802  T = T + ( TORVH * VTYPE( I ) * TAB2( I,3 ) )
       ITT( 2,1 ) = TORVH
       ITT( 2,2 ) = TORPH - TORVH
       ITT( 2,3 ) = T
       ITT( 2,4 ) = ( TORPH - TORVH ) * TAB2( I,4)
       ITT( 2,5 ) = ITT( 2,3 ) + ITT( 2,4 )
C
C
C     *******  OFF- RAMP TRAVEL TIME COSTS   *******
       T=0.
       DO 808 I=1,4
  808  T=T+( OFFRV * VTYPE( I ) * TAB2( I,3) )
       ITT( 3,1 ) = OFFRV
       ITT( 3,2 ) = OFFRP - OFFRV
       ITT( 3,3 ) = T
       ITT( 3,4 ) =   ITT( 3,2 ) * TAB2( 1,4 )
       ITT( 3,5 ) =   ITT( 3,3 ) + ITT( 3,4 )
C
C      FIND DIVERSION ROUTE DELAY AND COSTS
```

```
C
C     CONVERT DVM INTC DVH AND DPH BY AVERAGE PASS OCCUPANCY AS ON FREEWAY
C
      APOC = TPH / TVH
      DPM = APCC * DDVM
      A   = DDVM / TAEA( 1 )
      T = 0.
      DO 803 I = 1,4
  803 T = T + ( A * VTYPE( I ) * TAB2( I,1 ) )
      E = ( DPM / TAEA( 1 ) ) - A
      ITT( 4,1 ) = A
      ITT( 4,2 ) = E
      ITT( 4,3 ) = T
      ITT( 4,4 ) = E * TAB2( 1,2 )
      ITT( 4,5 ) = ITT( 4,3 ) + ITT( 4,4 )
C     FIND TOTALS
      DO 805 J = 1,5
      DO 804 I = 1,4
  804 ITT( 5,J ) = ITT( 5,J ) + ITT( I,J )
  805 CONTINUE
C     THIS ENDS TRAVEL TIME CALCULATICNS
C
      WRITE(6,6000) (ITT(1,J),J=1,5)
 6000 FORMAT(//,50X,'TRAVEL TIME DELAY AND COSTS',//,6X,1HI,100(1H-),1HI
     *,/,2(6X,1HI,15X,1HI,27X,1HI,41X,1HI,14X,1HI,/),6X,1HI,15X,1HI,12X,
     1'DELAY',10X,1HI,2X,'VEHICLE & DRIVER',2X,1HI,4X,'PASS. ONLY',6X,
     21HI,2X,'TOTAL COST',2X,1HI,/,2(6X,1HI,15X,1HI,27X,1HI,20X,1HI,20X,
     $1HI,14X,
     31HI,/),6X,1HI,100(1H-),1HI,/,2(6X,1HI,15X,1HI,14X,1HI,12X,1HI,20X,
     41HI,20X,1HI,14X,1HI,/),6X,1HI,15X,1HI,4X,'VEH-HRS',3X,1HI,2X,'PASS
     5-HRS',2X,1HI,3X,'COST (DOLLARS)',3X,1HI,3X,'COST (DOLLARS)',3X,1HI
     6,3X,'(DOLLARS)',2X,1HI,/,2(6X,1HI,15X,1HI,14X,1HI,12X,1HI,20X,1HI,
     720X,1HI,14X,1HI,/),6X,1HI,3X,'ON FREEWAY',2X,1HI,I11,3X,1HI,I9,3X,
     81HI,6X,'$',I8,5X,1HI,7X,'$',I8,4X,1HI,3X,'$',I8,2X,1HI,/,6X,1HI,15
     9X,1HI,14X,1HI,12X,1HI,20X,1HI,20X,1HI,14X,1HI)
       WRITE(6,6003)
 6003 FORMAT( 6X,1HI,15X,1HI,14X,1HI,12X,1HI,20X,1HI,20X,1HI,14X,1HI)
      WRITE(6,6001) (( ITT(I,J),J=1,5),I=2,4)
 6001 FORMAT(6X,1HI,3X,'ON RAMP',5X,1HI,3X,I8,3X,1HI,1X,I8,3X,1HI,7X,I8,
     *5X,1HI,8X,I8,4X,1HI,4X,I8,2X,1HI,/,2(6X,1HI,15X,1HI,14X,1HI,12X,1H
     1I,20X,1HI,20X,1HI,14X,1HI,/),6X,1HI,3X,'OFF RAMP',4X,1HI,3X,I8,3X,
     21HI,1X,I8,3X,1HI,7X,I8,5X,1HI,8X,I8,4X,1HI,4X,I8,2X,1HI,/,2(6X,1HI
     3,15X,1HI,14X,1HI,12X,1HI,20X,1HI,20X,1HI,14X,1HI,/),6X,1HI,3X,'DIV
     4ERSION',3X,1HI,3X,I8,3X,1HI,1X,I8,3X,1HI,7X,I8,5X,1HI,8X,I8,4X,1HI
     5,4X,I8,2X,1HI,/,  6X,1HI,15X,1HI,14X,1HI,12X,1HI,20X,1HI,20X,1HI,1
     64X,1HI)
       WRITE(6,6002)(ITT(5,J),J=1,5)
 6002 FORMAT(6X,1HI,15X,1HI,14X,1HI,12X,1HI,20X,1HI,20X,1HI,14X,1HI,/,6X
     *,1HI,100(1H-),1HI,/,6X,1HI,15X,1HI,14X,1HI,12X,1HI,20X,1HI,20X,1HI
     1,14X,1HI,/,6X,1HI,3X,'TOTALS',6X,1HI,3X,I8,3X,1HI,2X,I7,3X,1HI,6X,
     2'$',I8,5X,1HI,7X,'$',I8,4X,1HI,3X,'$',I8,2X,1HI,/,6X,1HI,15X,1HI,
     314X,1HI,12X,1HI,20X,1HI,20X,1HI,14X,1HI,/,6X,1HI,100(1H-),1HI)
C
C
C     TFVM(1-4) = OPERATING COSTS CN FREEWAY BY VEH-TYPE
C     TORVH = TOTAL CN RAMP DELAY IN VEH-HRS
C
C     IAX( 1-7,1-4 ) CCNTAINS OPERATING COSTS
```

```
C      IAX ( 1 , 1 - 4 ) CONTAINS ON FREEWAY OPERATING COSTS
C      IAX ( 2 , 1 - 4 ) CONTAINS ON RAMP    OPERATING COSTS
C      IAX( 3 , 1 - 4 ) CONTAINS OFF RAMP    OPERATING COSTS
C      IAX( 4 , 1 - 4 ) CONTAINS DIVERSION - UNIFORM SPEED FOR OPERATING COSTS
C      IAX( 5 , 1 - 4 ) CONTAINS DIVERSION - SPEED CHANGE  FOR OPERATING COSTS
C      IAX( 6 , 1 - 4 ) CONTAINS DIVERSION - IDLING COSTS  FOR OPERATING COSTS
C      IAX( 7 , 1 - 4 ) CONTAINS VERTICAL TOTALS           FOR OPERATING COSTS
C
C      KAX( 1-7, 1-4 ) CONTAINS VALUES IN FUEL USED
C
       DO 999 I = 1,7
       DO 999 J = 1,4
       KAX( I,J ) = 0
  999  IAX( I,J ) = 0
C
C      COMBINE VM TRAVELED BY VEH-TYPES 2 $ 4
       TFVM( 2 ) = TFVM( 2 ) + TFVM( 4 )
       DO 1000 I = 1,3
       IAX( 1,I ) = TFVM( I ) / 100.
       IAX( 2,I ) =(TONFVM * TRICK( I ) * TAB7( I ) ) / 100.
       IAX( 3,I ) =(OFFFV * TRICK( I ) * TAB7( I ) ) / 100.
C
C      TABA( 4 ) = AVERAGE INITIAL SPEED (MPH) PER VEH-TYPE
C      TABB( 4 ) = AVERAGE NUMBER OF STOPS PER VEH-MILE AT INTERSECTIONS
C      TABC( 4 ) = AVERAGE VEH-HRS PER STOP
C      TABD( 4 ) = NUMBER OF SPEED CHANGES PER VEH-MILE
C      TABE( 4 ) = AVERAGE SPEED REDUCTION PER SPEED CHANGE
C
       J = TABA( I ) / 5.
       C = DDVM * TRICK( I )
       IAX( 4,I ) = ( C*TAB8( J,I ) ) / 100.
       KAX( 4,I ) = C * TAB16( J,I )
C
C      DIVERSION ROUTE OPERATING COSTS
C      CALCULATE WHEN ALL TIME SLICES OPERATION ARE COMPLETE
C
       B = TABA( I ) - TABE( I )
       DO 1001 IY = 1,5
       A = ( ( 10 * IY ) - 10 ) * 1.0
       IF( B .EQ. A ) GO TO 1005
       IF( B .LT. A ) GO TO 1010
 1001  CONTINUE
C
       WRITE(6,631)
  631  FORMAT('   ERROR - INITIAL SPEED ON DIVERSION AND SPEED CHANGE GRE
      *ATER THAN 50 MPH')
       GO TO 1000
C
C      EXCOST( 3,10,5 ) ARE TABLES FOR EXCESS RUNNING COSTS DUE TO SPEED CHANGES
C      EXCOST( TYPE,SPEED RANGE,SPEED REDUCED )  CENTS / CYCLE CHANGE
C
 1005  RT = EXCOST( I,J,IY )
       RRT = FUELCN( I,J,IY )
       GO TO 1020
 1010  R = ( A-B ) / 10.
       RT = EXCOST(I,J,IY-1) - (EXCOST(I,J,IY-1) - EXCOST(I,J,IY)) * R
       RRT = FUELCN(I,J,IY-1) - (FUELCN(I,J,IY-1) - FUELCN(I,J,IY) ) * R
C
```

```
 1020 D= TAED(I) * C
      IAX( 5,I ) = ( D*RT ) / 100.
      KAX( 5,I ) = D * RRT
C
      E = ( TABC(I) * TABB(I) * C ) / 3600.
      IAX( 6,I ) = ( E*TAE7(I) ) / 100.
      KAX( 6,I ) = E * TAB15( I )
 1000 CONTINUE
C
C     SUM HOR AND VER TOTALS
      DO 1040 I = 1,6
      DO 1030 J = 1,3
      IAX( I,4 ) = IAX( I,4 ) + IAX( I,J )
      IAX( 7,J) = IAX( 7,J ) + IAX( I,J )
      IAX( 7,4) = IAX( 7,4 ) + IAX( I,J )
 1030 CONTINUE
 1040 CONTINUE
C     THIS ENDS OPERATING COSTSS ANALYSIS
      WRITE(6,5358) HEAD
      WRITE(6,5356) HEADB
      WRITE(6,6009)
 6009 FORMAT(///,50X,'VEHICLE OPERATING COSTS',/,58X,'( DOLLARS )')
      WRITE(6,6010)
 6010 FORMAT(//,6X,1HI,98(1H-),1HI,/,2(6X,1HI,30X,1HI,4(16X,1HI),/),
     *6X,1HI,30X,1HI,' VEHICLE TYPE 1 ',1HI,' VEHICLES 2 & 4 ',1HI,
     1' VEHICLE TYPE 3 ',1HI,5X,'TOTALS',5X,1HI,/,2(6X,1HI,30X,1HI,4(16X
     2,1HI),/),6X,1HI,98(1H-),1HI,/,  6X,1HI,30X,1HI,16X,1HI,16X,1HI,16X
     3,1HI,16X,1HI,/,6X,1HI,30X,1HI,16X,1HI,16X,1HI,16X,1HI,16X,1HI)
      DO 1080 I=1,6
      IA = 7 * ( I-1 ) + 1
      IB = 7 * I
      WRITE( 6,6012 ) ( OPLIST( IC ) , IC = IA,IB ) , ( IAX( I,J ) ,
     *J = 1,4 )
 6012 FORMAT(6X,1HI,7A4,2X,1HI,4(5X,1H$,I7,3X,1HI),/,  6X,1HI,30X,1HI,4(
     *16X,1HI),/,6X,1HI,30X,1HI,4(16X,1HI))
 1080 CONTINUE
      WRITE(6,6014) (OPLIST(IC),IC=43,49),(IAX(7,J),J=1,4)
 6014 FORMAT(6X,1HI,98(1H-),1HI,/,2(6X,1HI,30X,1HI,16X,1HI,16X,1HI,16X,1
     *HI,16X,1HI,/),6X,1HI,7A4,2X,1HI,4(5X,'$',I7,3X,1HI),/,2(6X,1HI,30X
     1,1HI,16X,1HI,16X,1HI,16X,1HI,16X,1HI,/),6X,1HI,98(1H-),1HI)
C
C
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
C     TFCON(1-4) FUEL CONSUMPTION ON FREEWAY BY VEH-TYPE
C     FUELCN( 3,10,5 ) ARE TABLES FOR FUEL CONSUMPTION     DUE TO SPEED CHANGES
C     FUELCN( TYPE,SPEED RANGE,SPEED REDUCED )  GALS. / CYCLE CHANGE
C
      TFCON( 2 ) = TFCON( 2 ) + TFCON( 4 )
      DO 1100 I = 1,3
C     FUEL CONSUMPTION ON FREEWAY
      KAX( 1,I ) = TFCON( I )
C     ON RAMP FUEL CONSUMPTION
      KAX( 2,I )= TONVH * TRICK( I ) * TAB15( I )
C     OFF RAMP FUEL CONSUMPTION
      KAX( 3,I ) = OFFFV * TRICK( I ) * TAB15( I )
 1100 CONTINUE
C
```

```
      DO 1120 I = 1,6
      DO 1110 J = 1,3
      KAX( I,4 ) = KAX( I,4 ) + KAX( I,J )
      KAX( 7,4 ) = KAX( 7,4 ) + KAX( I,J )
      KAX( 7,J ) = KAX( 7,J ) + KAX( I,J )
 1110 CONTINUE
 1120 CONTINUE
C
      WRITE(6,5358) HEAD
      WRITE(6,5356) HEADB
      WRITE(6,6019)
 6019 FORMAT(     ///,50X,'FUEL CONSUMPTION',//,53X,'( GALLONS )',//,6X,1
     *HI,122(1H-),1HI,/,2(6X,1HI,30X,1HI,22X,1HI,22X,1HI,22X,1HI,22X,1HI
     1,/),6X,1HI,30X,1HI,4X,'VEHICLE TYPE 1',4X,1HI,4X,'VEHICLES 2 & 4',
     24X,1HI,4X,'VEHICLE TYPE 3',4X,1HI,8X,'TOTALS',8X,1HI,/,2(6X,1HI,30
     3X,1HI,22X,1HI,22X,1HI,22X,1HI,22X,1HI,/),6X,1HI,122(1H-),1HI,/,6X,
     41HI,30X,1HI,22X,1HI,22X,1HI,22X,1HI,22X,1HI)
      DO 1130 I=1,6
      IA = ( 7 * ( I-1 ) ) + 1
      IB = 7 * I
      WRITE(6,6030) (CFLIST(IC),IC=IA,IB), (KAX(I,J),J=1,4)
 6030 FORMAT(6X,1HI,30X,1HI,22X,1HI,22X,1HI,22X,1HI,22X,1HI,/,6X,1HI,7A4
     *,2X,1HI,4(6X,I10,' GALS ',1HI),/,6X,1HI,30X,1HI,4(22X,1HI))
 1130 CONTINUE
      WRITE(6,6031) (CFLIST(IC),IC=43,49),(KAX(7,J),J=1,4)
 6031 FORMAT(6X,1HI,30X,1HI,4(22X,1HI),/,6X,1HI,122(1H-),1HI,/,6X,1HI,30
     *X,1HI,4(22X,1HI),/,6X,1HI,7A4,2X,1HI,4(6X,I10,' GALS ',1HI),/,6X,
     11HI,30X,1HI,4(22X,1HI),/,6X,1HI,122(1H-),1HI)
C
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     ON FREEWAY POLLUTANTS , PARTICULATES $ SULFUR OXIDES
C
C     LOX( 1,I,J ) - ON FREEWAY
C     LOX( 2,I,J ) - ON RAMP
C     LOX( 3,I,J ) - OFF RAMP
C     LOX( 4,I,J ) - DIVERSION
C     LOX( 5,I,J ) - TOTALS
C
C     LOX( L,1,J ) - VEHICLE TYPE 1
C     LOX( L,2,J ) - VEHICLE TYPES 2 & 4
C     LOX( L,3,J ) - VEHICLE TYPE 3
C     LOX( L,4,J ) - TOTALS
C
C     LOX( 5,3,5 ) CONTAINS POLLUTANTS BY VEHICLE TYPE & TRAVEL METHOD
C     LOX( L,I,1 ) - CARBON MONOXIDES          GRAMS PER MINUTE
C     LOX( L,I,2 ) - HYDROCARBONS              GRAMS PER MINUTE
C     LOX( L,I,3 ) - NITROGEN OXIDES           GRAMS PER MINUTE
C     LOX( L,I,4 ) - PARTICULATES              GRAMS PER MILE
C     LOX( L,I,5 ) - SULFUR OXIDES             GRAMS PER MILE
C
C     ON FREEWAY 1 - 3
C     TVM = TOTAL VEH-MILES ON FREEWAY
      DO 101 I=1,3
      DO 101 J=1,3
  101 LOX( 1,I,J ) = POLLS( I,J ) / 1000.
```

```
C       ON FREEWAY 4 & 5
        DO 102 I=1,3
        D = ( TVM * TRICK( I ) ) / 1000.
        LOX( 1,I,4 ) = D * TAB25( I,1 )
  102 LOX( 1,I,5 ) = D * TAB25( I,2 )
        A = 0.06
        DO 103 I=1,3
        D = TCRVH * TRICK( I )
        DO 103 J=1,3
C       ON RAMP
        LOX( 2,I,J ) = D * TAB26( I,J ) * A
C       OFF RAMP
  103 LOX( 3,I,J ) =    OFFRV * TRICK( I ) * TAB26( I,J ) * A
C       DIVERSION
        L = TABA( 1 ) / 5.
        DO 104 I=1,3
        D = (DDVM * TRICK( I ) ) / 1000.
        DO 105 J=1,3
  105 LOX( 4,I,J ) = D * EMFCL( I,L,J )
        LOX( 4,I,4 ) = D * TAB25( I,1 ) * 60.
  104 LOX( 4,I,5 ) = D * TAB25( I,2 ) * 60.
C       TOTALS
        DO 110 L=1,4
        DO 110 I=1,3
        DO 110 J=1,5
        LOX( L,4,J ) = LOX( L,4,J ) + LOX( L,I,J )
        LOX(5,I,J) = LOX(5,I,J) + LOX(L,I,J)
  110 LOX( 5,4,J ) = LOX( 5,4,J ) + LOX( L,I,J )
        WRITE(6,5358) HEAD
        WRITE(6,5356) HEADB
        WRITE( 6,6050 )
 6050 FORMAT(//,51X,'POLLUTION EMISSIONS',//,54X,'( KILOGRAMS )',//,2H I
     *,127(1H=),1HI,/,2H I,14X,1HI,3(26X,1HI),31X,1HI,/,2H I,14X,1HI,5X,
     1'VEHICLE TYPE 1',7X,1HI,4X,'VEHICLE TYPES 2 & 4',3X,1HI,5X,'VEHICL
     2E TYPE 3',7X,1HI,9X,' TOTALS',15X,1HI,/,  2H I,14X,1HI,26X,1HI,26X
     3,1HI,26X,1HI  ,31X,1HI,/,2H I,127(1H=),1HI,/,2H I,14X,1HI,3(26X,1HI
     4),31X,1HI)
        WRITE(6,6056)
 6056 FORMAT(2H I,14X,1HI,3('    CO    HC    NO    PR    SO I'),'    CO    HC
     *    NO    PR    SO I',/,2H I,14X,1HI,3(26X,1HI),31X,1HI)
        IB=1
        IC=3
        DO 112 L=1,4
        WRITE( 6,6051 ) ( LX( IA ),IA=IB,IC  ),(( LOX( L,I,J ),J=1,5),I=1,
     *4)
 6051 FORMAT(2H I,14X,1HI,3(26X,1HI),31X,1HI,/,2H I,3A4,2X,1HI,3(5I5,1X,
     *1HI),5I6,1X,1HI,/,2H I,14X,1HI,3(26X,1HI))
        IC=IC+3
  112 IB=IB+3
        WRITE(6,6052) (LX(IA),IA=13,15), ((LOX(5,I,J),J=1,5),I=1,4)
 6052 FORMAT(2H I,14X,1HI,3(26X,1HI),31X,1HI,/,2H I,127(1H=),1HI,/,2H I,
     *14X,1HI,3(26X,1HI),31X,1HI,/,2H I,3A4,2X,1HI,3(5I5,1X,1HI),5I6,1X,
     11HI,/,2H I,14X,1HI,3(26X,1HI),31X,1HI,/,2H I,127(1H=),1HI)
        WRITE(6,6053)
 6053 FORMAT(///,
     #          10X,'CO - CARBON MONOXIDE',/,10X,'HC - HYDROCARBONS',/,10X,
     *'NO - NITROGEN OXIDES',/,10X,'PR - PARTICULATES',/,10X,'SO - SULFU
     1R OXIDES')
```

```
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
 4040 CONTINUE
C       MROAD = (BLANK) OR 'R' OR 'M'
C       NTYPE = (BLANK) OR'E' OR 'U' OR 'D'
C
C
C       MROAD V (BLANK) OR 'R' OR 'M'
C       NTYPE = (BLANK) OR 'E' OR 'U' OR 'D'
C
C       URBAN FREEWAY BY DEFAULT
        M = 2
C       RURAL FOR TAB28 WILL HAVE 'R' FOR MROAD
C
        IF( MROAD .EQ. IRURAL ) M = 1
C       METERED URBAN FOR TAB28 WILL HAVE 'M'
        IF( MROAD .EQ. MURBAN ) M = 3
C
C       LANE ASSIGNMENT HAS FREEWAYS BY DEFAULT
        N = 0
C       EXPRESSWAYS WILL HAVE 'E'
        IF( NTYPE .EQ. NEXW ) N = 7
C       UNDIVIDED CONVENTIONAL WILL HAVE 'U'
        IF( NTYPE .EQ. NHU ) N = 10
C       DIVIDED CONVENTIONAL WILL HAVE 'D'
        IF( NTYPE .EQ. NHD ) N = 13
C
C
C       FREEWAYS BY DEFAULT IN TAB29
        NODE = 12
        IF( MHIGHT .EQ. 0 ) GO TO 300
        NODE = MHIGHT
  300   DO 308 I = 1,8
        IF( VMBLN( I ) .LE. 0. ) GO TO 308
        VMBLN( I ) = ( VMBLN( I ) * TAB28( N+I,M ) ) / 1000000.
  308   CONTINUE
C
        FATAL = 0.
        TINJUR = 0.
        PD = 0.
        DO 302 I = 1,8
        IF( VMBLN( I ) .LE. 0. ) GO TO 302
        FATAL = FATAL +(VMBLN( I ) * TAB29( NODE,1 ))/100.
        TINJUR = TINJUR +(VMBLN( I ) * TAB29( NODE,2 ))/100.
        PD = PD +(VMBLN( I ) * TAB29( NODE,3 ))/100.
  302   CONTINUE
C
C       MONEY( 3,7 ) CONTAINS ACCIDENTS & COSTS
        DO 303 I=1,3
        DO 303 J=1,7
  303   MONEY(I,J) = 0.
        MONEY( 1,1 ) = FATAL
        MONEY( 1,3 ) = TINJUR
        MONEY( 1,5 ) = PD
C
C       ACCIDENT COST ON URBAN FREEWAYS BY DEFAULT IN TAB27
```

```
      IACC = 3
      IF( LSEVER .NE. 0 ) IACC = LSEVER
      FATAL = FATAL * TAB27( 1,IACC )
      TINJUR = TINJUR * TAB27( 2,IACC )
      PD = PD * TAB27( 3,IACC )
C
      MONEY( 1,2 ) = FATAL
      MONEY( 1,4 ) = TINJUR
      MONEY( 1,6 ) = PD
  330 CONTINUE
      NN = 11
      MM = 2
      IF( IDVER .NE. 0 ) NN = IDVER
      MA = 7
      MB = 3
      ACCS = (        DDVM * TAB28( NN,MM ) ) / 1000000.
C     ACCS HAS # OF ACCIDENTS PER MVM
      FATS = ACCS * TAB29( MA,1 ) /100.
      TINJS = ACCS * TAB29( MA,2 ) / 100.
      TPD = ACCS * TAB29( MA,3 )  / 100.
C
      MONEY( 2,1 ) = FATS
      MONEY( 2,3 ) = TINJS
      MONEY( 2,5 ) = TPD
C
      FATS = FATS * TAB27( 1,MB )
      TINJS = TINJS * TAB27( 2,MB )
      TPD = TPD * TAB27( 3,MB )
      MONEY( 2,2 ) = FATS
      MONEY( 2,4 ) = TINJS
      MONEY( 2,6 ) = TPD
      DO 173 I=2,6,2
  173 MONEY(1,7) = MONEY(1,7) + MONEY( 1,I )
      DO 174 I=2,6,2
  174 MONEY(2,7) = MONEY(2,7) + MONEY( 2,I )
      DO 169 I=1,2
      MONEY(3,7) = MONEY(3,7) + MONEY(I,7)
      DO 169 J=1,6
  169 MONEY(3,J) = MONEY(3,J) + MONEY(I,J)
      WRITE(6,5358) HEAD
      WRITE(6,5356) HEADB
      WRITE( 6,6060 )
 6060 FORMAT(///,51X,'ACCIDENTS AND COSTS',//,54X,'( DOLLARS )',//,3H   I
     *,100(1H-),1HI,/,2(3H   I,14X,1HI,22X,1HI,22X,1HI,22X,1HI,16X,1HI,/)
     1,3H   I,14X,1HI,5X,'FATALITIES',7X,1HI,6X,'INJURIES',8X,1HI,3X,'PRO
     2PERTY DAMAGE',4X,1HI,5X,'TOTALS',5X,1HI,/,2(3H   I,14X,1HI,22X,1HI,
     322X,1HI,22X,1HI,16X,1HI,/),3H   I,14X,    86(1H-),1HI,/,2(3H   I,14X
     4,1HI,22X,1HI,22X,1HI,22X,1HI,16X,1HI,/),3H   I,14X,1HI,3(2X,'NUMBER
     5     $ COST     I'),3X,'$ COSTS       I',/,2(3H   I,14X,1HI,22X,1HI,22
     6X,1HI,22X,1HI,16X,1HI,/),3H   I,100(1H-),1HI,/,3H   I,14X,1HI,
     73(22X,1HI),16X,1HI)
      WRITE( 6,6061) ( LX(I),I= 1, 3),( MONEY( 1,J),J=1,7)
 6061 FORMAT(3H   I,14X,1HI,3(22X,1HI),16X,1HI,/,3H   I,    3A4,2X,1HI,3(
     * F8.4,  1X,'$',F9.0,3X,1HI),3X,'$',F10.0,2X,1HI,/,3H   I,14X,1HI,3(
     122X,1HI),16X,1HI)
      WRITE( 6,6061) ( LX(I),I=10,12),( MONEY( 2,J),J=1,7)
      WRITE(6,6062) (LX(I),I=13,15),(MONEY(3,J),J=1,7)
 6062 FORMAT(3H   I,14X,1HI,3(22X,1HI),16X,1HI,/,3H   I,100(1H-),1HI,/,
```

```
     *3H   I,14X,1HI,3(22X,1HI),16X,1HI,/,3H   I,3A4,2X,1HI,3( F8.4,   1X,
     1'$',F9.0,3X,1HI),3X,'$',F10.0,2X,1HI,/,2(3H   I,14X,1HI,22X,1HI,22X
     2,1HI,22X,1HI,16X,1HI,/),3H   I,100(1H=),1HI,/,'1')
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      RETURN
      END
```

```
      SUBROUTINE FIRST
      DIMENSION REC(234)
      COMMON/IDATA/RCOSTS(3,13,6),FRATES(3,13,6),EXCOST(3,10,5),
     *TAB6(3,12),TAB8(10,3),TAB7(3),TAB15(3),TAB2(4,4),
     1TAB16(10,3),TAB29(12,3),EMPOL(3,12,3),TAB28(15,3),TAB27(3,3),
     2TAB26(3,3),TAB25(3,2),FUELCN(3,10,5)
C
C     READ ALL TABLES FROM TAPE FILE 10
C
C     RECORD 1 HAS TABLES 3,4, + 5
      READ(10) (REC(L),L=1,234)
      L = 1
      DO 630 I=1,3
      DO 630 J=1,13
      DO 631 K=1,6
      RCOSTS( I,J,K ) = REC( L )
  631 L=L+1
  630 CONTINUE
C
C     RECORD 2 HAS TABLES 12,13, + 14
      READ(10) (REC(L),L=1,234)
      L = 1
      DO 635 I=1,3
      DO 635 J=1,13
      DO 636 K=1,6
      FRATES( I,J,K ) = REC( L )
  636 L=L+1
  635 CONTINUE
C
C     RECORD 3 HAS TABLES 9,10,11,6,8,7, + 15
      READ(10) (REC(L),L=1,234)
C
      L = 1
      DO 652 I=1,3
      DO 652 J=1,10
      DO 651 K=1,5
      EXCOST( I,J,K ) = REC( L )
  651 L=L+1
  652 CONTINUE
C
      L = 151
      DO 653 I=1,3
      DO 649 J=1,12
      TAB6( I,J ) = REC( L )
  649 L=L+1
  653 CONTINUE
C
      L = 187
      DO 654 I=1,10
      DO 648 J=1,3
      TAB8( I,J ) = REC( L )
  648 L=L+1
  654 CONTINUE
```

```
C
      L=217
      DO 655 I = 1,3
      TAB7( I ) = REC( L )
      TAB15( I ) = REC( L+3 )
  655 L = L + 1
C
C
C     RECORD 4 HAS TABLES 17,18,19,2,16, + 29
C
      READ(10) (REC(L),L=1,234)
C
      L = 1
      DO 656 I =1,3
      DO 656 J=1,10
      DO 670 K=1,5
      FUELCN( I,J,K ) = REC( L )
  670 L=L+1
  656 CONTINUE
C
      L = 151
      DO 657 I =1,4
      DO 671 J=1,4
      TAB2( I,J ) = REC( L )
  671 L=L+1
  657 CONTINUE
C
      L = 167
      DO 658 I = 1,10
      DO 672 J=1,3
      TAB16( I,J ) = REC( L )
  672 L=L+1
  658 CONTINUE
C
      L = 197
      DO 659 I =1,12
      DO 673 J=1,3
      TAB29( I,J ) = REC( L )
  673 L=L+1
  659 CONTINUE
C
C
C     RECORD 5 HAS TABLES 22,23,24,28,27,26, + 25
      READ(10) (REC(L),L=1,234)
      L = 1
      DO 660 I=1,3
      DO 660 J=1,12
      DO 674 K=1,3
      EMPOL( I,J,K ) = REC( L )
  674 L=L+1
  660 CONTINUE
C
      L = 109
      DO 661 I =1,15
      DO 675 J=1,3
      TAB28( I,J ) = REC( L )
  675 L=L+1
  661 CONTINUE
```

```
C
      L = 154
      DO 662 I = 1,3
      DO 676 J=1,3
      TAB27( I,J ) = REC( L )
       TAB26( I,J ) = REC( L+9 )
  676 L=L+1
  662 CONTINUE
C
      L = 172
      DO 663 I=1,3
       DO 677 J=1,2
      TAB25( I,J ) = REC( L )
  677 L=L+1
  663 CONTINUE
      REWIND 10
      RETURN
      END
```

```
EEEEEEEEEEE        CCCCCCC         OOOOOO         AAAAAAAAA        NNNN      NNN      AAAAAAAAA
EEEEEEEEEEE       CCCCCCCCCC      OOOOOOOOOO     AAAAAAAAAAA       NNNNN     NNN     AAAAAAAAAAA
EEE              CCCC      CCC   OOO      OOO    AAA     AAA       NNNNNN    NNN     AAA     AAA
EEE             CCCC             OOO      OOO    AAA     AAA       NNNNNNN   NNN     AAA     AAA
EEEEEEEEE       CCCC             OOO      OOO    AAAAAAAAAAA       NNN  NNNNNNN      AAAAAAAAAAA
EEEEEEEEE       CCC              OOO      OOO    AAAAAAAAAAA       NNN  NNNNNNN      AAAAAAAAAAA
EEE             CCC              OOO      OOO    AAAAAAAAAAA       NNN   NNNNNN      AAAAAAAAAAA
EEE              CCCC      CCC   OOOO     OOO    AAA     AAA       NNN    NNNNN      AAA     AAA
EEEEEEEEEEE       CCCCCCCCCC      OOOOOOOOOO     AAA     AAA       NNN    NNNNN      AAA     AAA
EEEEEEEEEEE        CCCCCCCC        OOOOOOO       AAA     AAA       NNN     NNNN      AAA     AAA
```

*** U.S. 59 (SOUTHWEST FREEWAY - HOUSTON,TEXAS INBOUND DIRECTION) ****

FREQ3CP ANALYSIS FROM 6:00 AM TO 9:30 AM   AFTER CONTROL

THE FOLLOWING DATA WAS STORED BY FREQ3CP

	VEH-HRS	PASS-HRS
FREEWAY TRAVEL TIME	3435.	4569.
INPUT DELAY	639.	850.
OUTPUT DELAY	0.	0.
TOTAL TRAVEL TIME	4074.	5419.

	VEH-MI.	PASS-MI.
TOTAL TRAVEL DISTANCE	193078.	256794.
DIVERSION TRAVEL DISTANCE	12284.	16338.

APPENDIX C

ECOANA SAMPLE OUTPUT

```
EEEEEEEEEEE      CCCCCCC       CCCCCC      AAAAAAAAA    NNNN     NNN    AAAAAAAAA
EEEEEEEEEEE     CCCCCCCCC     CCCCCCCCOO  AAAAAAAAAAA   NNNNN    NNN   AAAAAAAAAAA
EEE            CCCC    CCC   CCC     CCO  AAA     AAA   NNNNNN   NNN   AAA     AAA
EEE           CCCC           CCC     COO  AAA     AAA   NNNNNNN  NNN   AAA     AAA
EEEEEEEEE     CCCC           COO     OOO  AAAAAAAAAAA   NNN NNNNNNN    AAAAAAAAAAA
EEEEEEEEE     CCC            CCC     CCO  AAAAAAAAAAA   NNN NNNNNNN    AAAAAAAAAAA
EEE           CCC            COC     CCC  AAAAAAAAAAA   NNN   NNNNNN   AAAAAAAAAAA
EEE            CCCC    CCC   CCCC    CCO  AAA     AAA   NNN    NNNNN   AAA     AAA
EEEEEEEEEEE     CCCCCCCCCC    CCCCCCCCCO  AAA     AAA   NNN    NNNNN   AAA     AAA
EEEEEEEEEEE      CCCCCCCC      COOOCCO    AAA     AAA   NNN     NNNN   AAA     AAA
```

*** U.S. 59 (SOUTHWEST FREEWAY - HOUSTON,TEXAS INBOUND DIRECTION) ****

FREQ3CP ANALYSIS FROM 6:00 AM TO 9:30 AM BEFORE CONTROL

THE FOLLOWING DATA WAS STORED BY FREQ3CP

	VEH-HRS	PASS-HRS
FREEWAY TRAVEL TIME	7146.	9504.
INPUT DELAY	386.	513.
OUTPUT DELAY	17.	23.
TOTAL TRAVEL TIME	7549.	10041.

	VEH-MI.	PASS-MI.
TOTAL TRAVEL DISTANCE	207660.	276188.
DIVERSION TRAVEL DISTANCE	0.	0.

VEHICLE TYPES AND PERCENTAGES USED IN THIS CONTROL PERIOD

VEHICLE TYPE	PERCENTAGE	DESCRIPTION
1	0.915	AUTOS,PU (2-AXLES,4-TIRES)
2	0.070	SU TRUCKS (OTHER THAN ABOVE)
3	0.010	SEMI AND T.T. TRUCKS
4	0.005	BUSES

*** U.S. 59 (SOUTHWEST FREEWAY - HOUSTON,TEXAS INBOUND DIRECTION) ****

FREQ3CP ANALYSIS FROM 6:00 AM TO 9:30 AM   BEFORE CONTROL

TRAVEL TIME DELAY AND COSTS

	DELAY		VEHICLE & DRIVER	PASS. ONLY	TOTAL COST
	VEH-HRS	PASS-HRS	COST (DOLLARS)	COST (DOLLARS)	(DOLLARS)
ON FREEWAY	7145	2358	$ 48920	$ 14879	$ 63799
ON RAMP	386	127	3982	13	3995
OFF RAMP	17	5	179	47	226
DIVERSION	0	0	0	0	0
TOTALS	7548	2490	$ 53081	$ 14939	$ 68020

*** U.S. 59 (SOUTHWEST FREEWAY - HOUSTON,TEXAS INBOUND DIRECTION) ****

FREQ3CP ANALYSIS FROM 6:00 AM TO 9:30 AM BEFORE CONTROL

VEHICLE OPERATING COSTS
(DOLLARS)

	VEHICLE TYPE 1	VEHICLES 2 & 4	VEHICLE TYPE 3	TOTALS
ON FREEWAY	$ 20948	$ 4046	$ 1021	$ 26015
ON RAMP	$ 132	$ 22	$ 3	$ 157
OFF RAMP	$ 5	$ 1	$ 0	$ 6
DIVERSION - UNIFORM SPEED	$ 0	$ 0	$ 0	$ 0
DIVERSION - SPEED CHANGES	$ 0	$ 0	$ 0	$ 0
DIVERSION - IDLING	$ 0	$ 0	$ 0	$ 0
*** TOTALS ***	$ 21085	$ 4069	$ 1024	$ 26178

*** U.S. 59 (SOUTHWEST FREEWAY - HOUSTON,TEXAS INBOUND DIRECTION) ****

FREQ3CP ANALYSIS FROM 6:00 AM TO 9:30 AM BEFORE CONTROL

FUEL CONSUMPTION

(GALLONS)

	VEHICLE TYPE 1	VEHICLES 2 & 4	VEHICLE TYPE 3	TOTALS
ON FREEWAY	11118 GALS	2674 GALS	604 GALS	14396 GALS
ON RAMP	130 GALS	18 GALS	1 GALS	149 GALS
OFF RAMP	5 GALS	0 GALS	0 GALS	5 GALS
DIVERSION - UNIFORM SPEED	0 GALS	0 GALS	0 GALS	0 GALS
DIVERSION - SPEED CHANGES	0 GALS	0 GALS	0 GALS	0 GALS
DIVERSION - IDLING	0 GALS	0 GALS	0 GALS	0 GALS
*** TOTALS ***	11253 GALS	2692 GALS	605 GALS	14550 GALS

*** U.S. 59 (SOUTHWEST FREEWAY - HOUSTON,TEXAS INBOUND DIRECTION) ****

FREQ3CP ANALYSIS FROM 6:00 AM TO 9:30 AM BEFORE CONTROL

POLLUTION EMISSIONS

(KILOGRAMS)

	VEHICLE TYPE 1					VEHICLE TYPES 2 & 4					VEHICLE TYPE 3					TOTALS				
	CO	HC	NO	PR	SO	CO	HC	NO	PR	SO	CO	HC	NO	PR	SO	CO	HC	NO	PR	SO
ON FREEWAY	6261	642	870	68	24	2252	228	193	20	5	28	6	53	4	5	8541	876	1116	92	34
ON RAMP	312	17	2	0	0	107	6	0	0	0	0	0	0	0	0	419	23	2	0	0
OFF RAMP	14	0	0	0	0	4	0	0	0	0	0	0	0	0	0	18	0	0	0	0
DIVERSION	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	6587	659	872	68	24	2363	234	193	20	5	28	6	53	4	5	8978	899	1118	92	34

CO - CARBON MONOXIDE
HC - HYDROCARBONS
NO - NITROGEN OXIDES
PR - PARTICULATES
SO - SULFUR OXIDES

*** U.S. 59 (SOUTHWEST FREEWAY - HOUSTON,TEXAS INBOUND DIRECTION) ****

FREQ3CP ANALYSIS FROM 6:00 AM TO 9:30 AM BEFORE CONTROL

ACCIDENTS AND COSTS

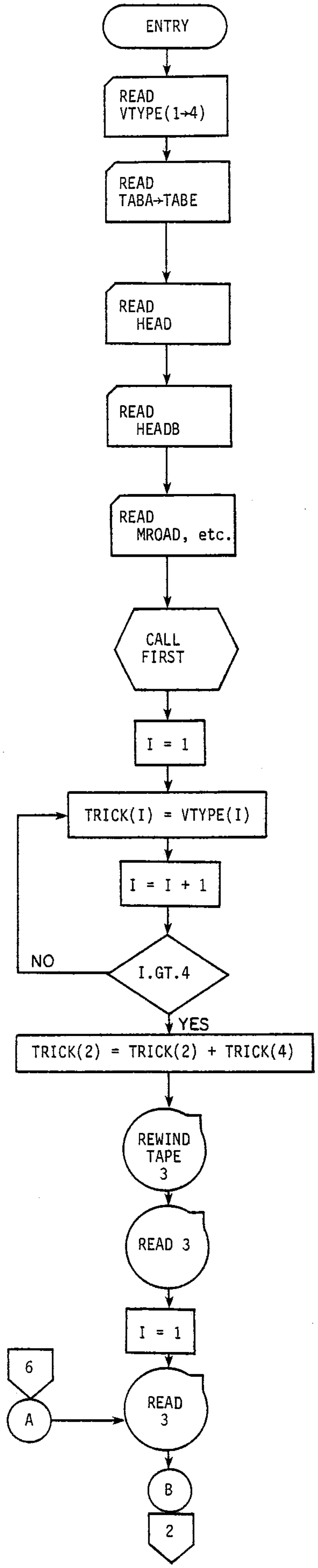
(DOLLARS)

	FATALITIES		INJURIES		PROPERTY DAMAGE		TOTALS
	NUMBER	$ COST	NUMBER	$ COST	NUMBER	$ COST	$ COSTS
ON FREEWAY	0.0051	$ 2259.	0.1672	$ 4035.	0.2677	$ 242.	$ 6537.
DIVERSION	0.0	$ 0.	0.0	$ 0.	0.0	$ 0.	$ 0.
TOTALS	0.0051	$ 2259.	0.1872	$ 4035.	0.2677	$ 242.	$ 6537.

APPENDIX D

ECOANA PROGRAM FLOWCHART

ECOANA



VTYPE(1→4) - Fractional parts of 4 vehicle types.

By Vehicle Types

TABA(1→4) - Uniform approach speed
TABB(1→4) - Number stops per veh-mi
TABC(1→4) - Average vehicle-hrs per stop
TABD(1→4) - Number speed changes per veh-mi
TABE(1→4) - Average Speed reduction

HEAD - 1st line of page heading
HEADB - 2nd line of page heading
MROAD - Accident location (TAB 28)
NTYPE - Highway type (TAB 28)
MHIGHT - Highway type (TAB 29)
LSEVER - Accident location (TAB 27)
IDVER - Diversion route (TAB 28)

Subroutine first brings economic tables from storage file to dimensioned ARRAYES.

Vehicle percentages into working file.

All vehicle types 4 are included in economic tables for type 2.

TAPE 3 has data stored by FREQ3CP.

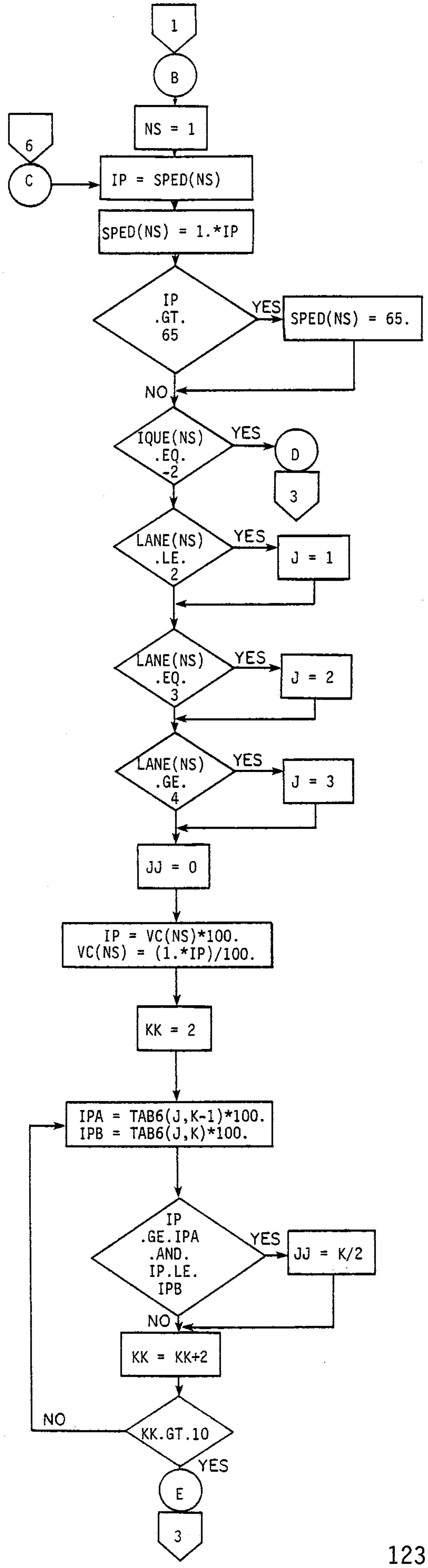
Record 1 has

LANE(1→40) - Number of lanes per subsection
DVM(1→40)- Diverted veh-mi travel by Time Slice
NSEC - Number of subsections
NTS - Number of Time Slices
FAC - Persons per vehicle

Begin Time Slice processing.

Record 2 through record NTS has

SPED(1→40) - Speed (MPH)
VC (1→40) - Volume to capacity ratio
FVM(1→40) - Veh-mi travel on freeway
IQUE(1→40) - Freeway queue status
CUM(1→40) - Cumulative measures



NS = Present subsection number

Drop all decimal points of speed.

Maximum speed limit 65. MPH.

No queue = 0, partial queue = 1, total queue = -2

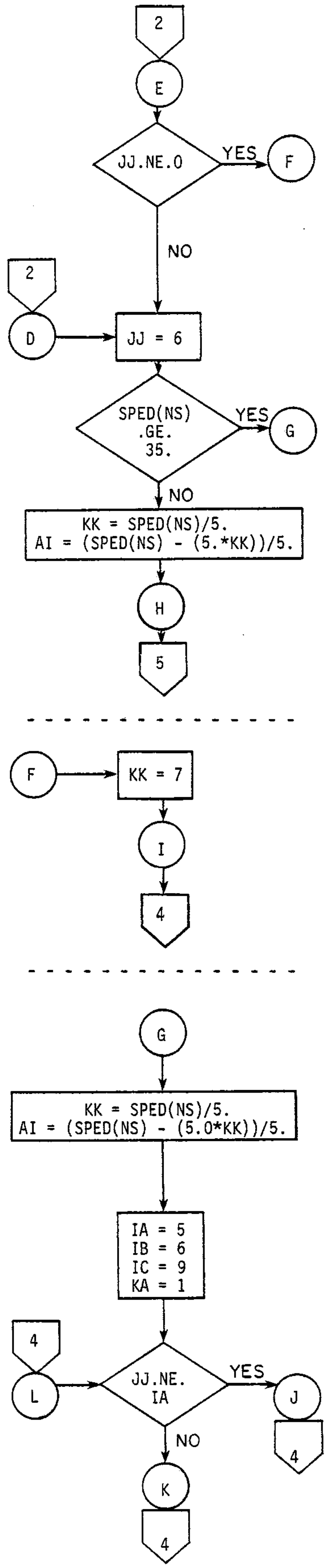
Determine number of lanes in this subsection (TAB 6 has V/C and Level of Service by number of lanes).

Drop all decimal places smaller than hundredth for V/C.

Convert real to integer for limit check.

Object of this DO-LOOP is to place VC in Table 6. JJ is Level of Service. (1 - 5)

Limit is L/S F(5)



JJ should have some value 1-5. If not, force to L/S F(6).

If for some reason the level of service is not found, the level of service will be set at F (or 6).

In L/S F, speed must be .LE. to 35 MPH and not greater than 35 MPH.

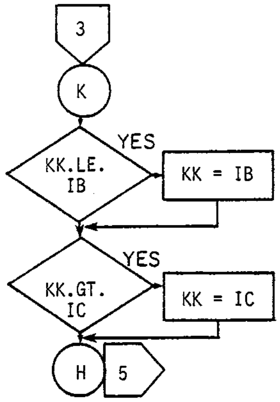
L/S F means a total queue in subsection and speed .LE. 35 MPH.

L/S F(6) and speed set at MAX 35 MPH.

L/S A - E.
Speed ranged from 35 MPH and greater.

In Tables 3, 4, 5 (or 12, 13, 14) a check must be made to insure that the L/S chosen (JJ) and speed range (KK) fall into a range of valid rate data.

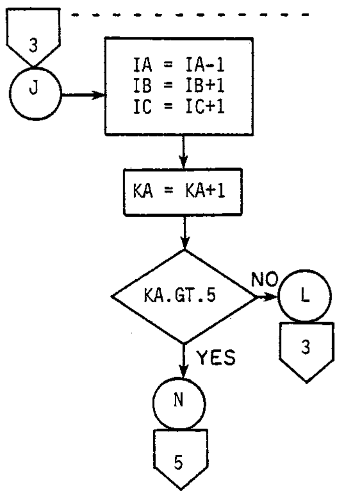
ECOANA (cont.)



The correct L/S column (JJ) is reached.

If speed ranged (KK) is .LT. the lowest valid rate (IB) - set ranged value to IB.

Likewise, if KK .GT. upper valid rate (IC), set ranged value to IC.

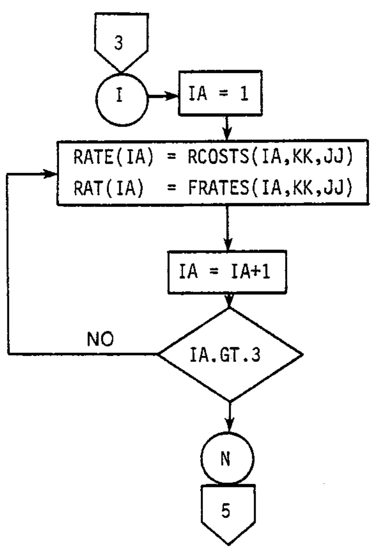


L/S column (IA) is changed and valid rate data limits changed.

L/S is checked for L/S E(5) to L/S A(1).

End of DO-LOOP.

All 5 L/S columns have been checked and no JJ/KK meeting - something wrong - by pass further processing.



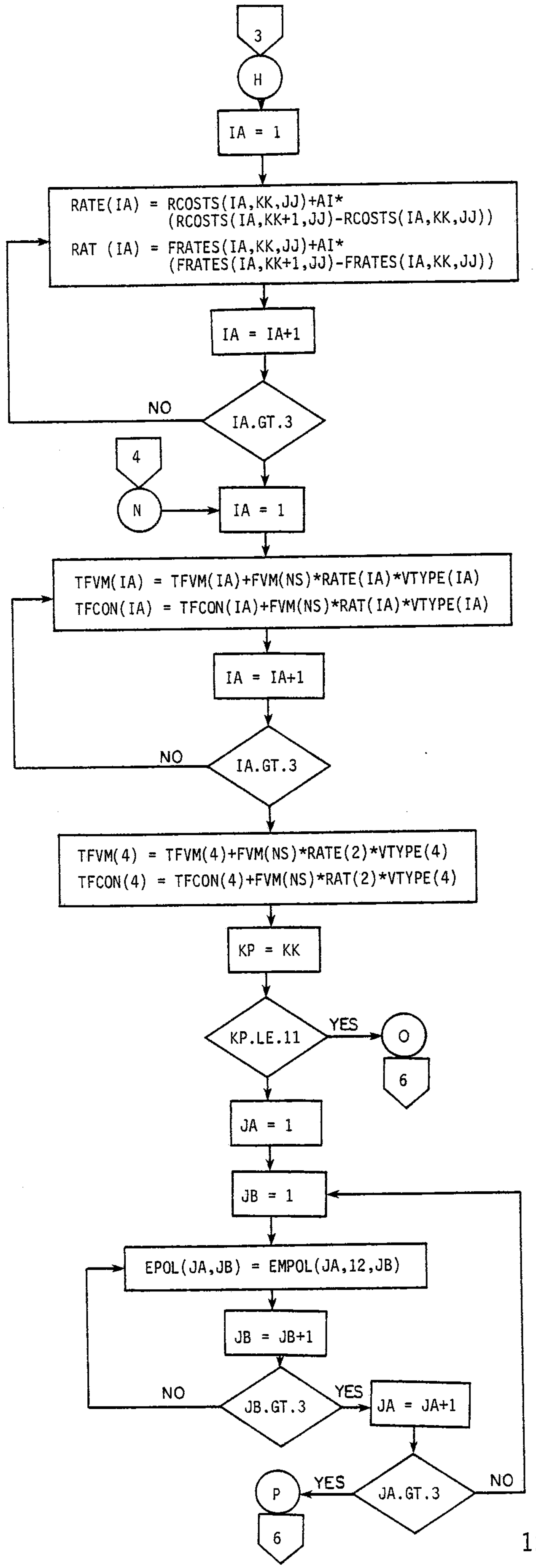
Entry due to KK set to 7 and JJ = 6

RATE(vehicle type) = Running Cost Rate

RAT (vehicle type) = Fuel Consumption Rate

3 vehicle types

End of DO LOOP.



Entry for JJ = 1→6 and KK = 1→6 or 6→12 where AI has non-zero value.

RATE(vehicle type) = Running Cost Rate

RAT (vehicle type) = Fuel Consumption Rate

Began Veh-Miles of travel summation

TFVM(vehicle type) = Total Freeway Vehicle Miles
FVM = Freeway Veh-Mi
RATE = ¢/V-M
VTYPE = #Type/Vehicle

TFCON(vehicle type) = Total Freeway Fuel Consumption
RAT = Gals/V-M

TFVM & TFCON for Buses

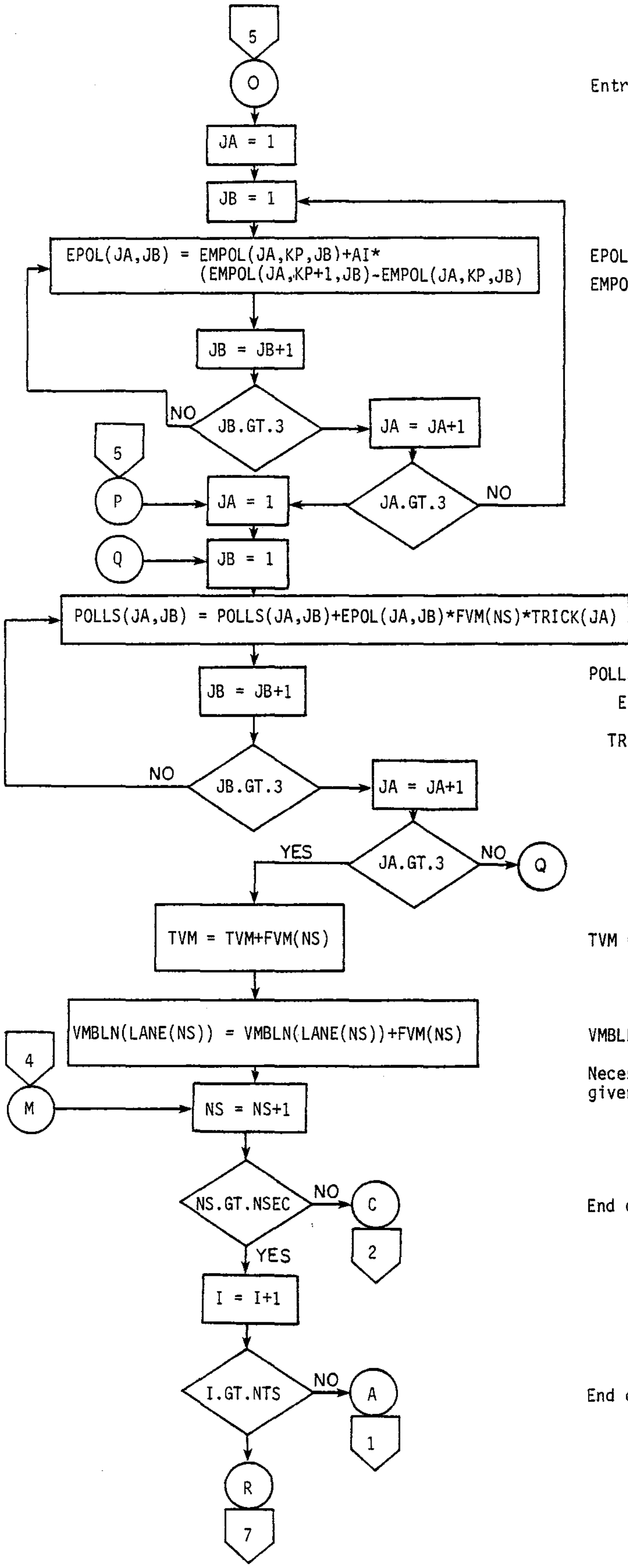
Rename of speed ranged.

Pollution tables have only maximum 60 MPH
(60÷5)=12

Every speed above 60 set to 60

EPOL(vehicle type, emission type) = Grams/Mile
EMPOL(vehicle type, speed ranged, emission type)

ECOANA (cont.)



Entry for speed .LT. 60 MPH and AI non-zero.

EPOL(vehicle type, emission type)

EMPOL(vehicle type, speed ranged, emission type)

POLLS(vehicle type, emission) = Grams
EPOL = Grams/Mile
FVM = Veh-Mi
TRICK = #/Veh

TVM = Total Vehicle Miles of Travel

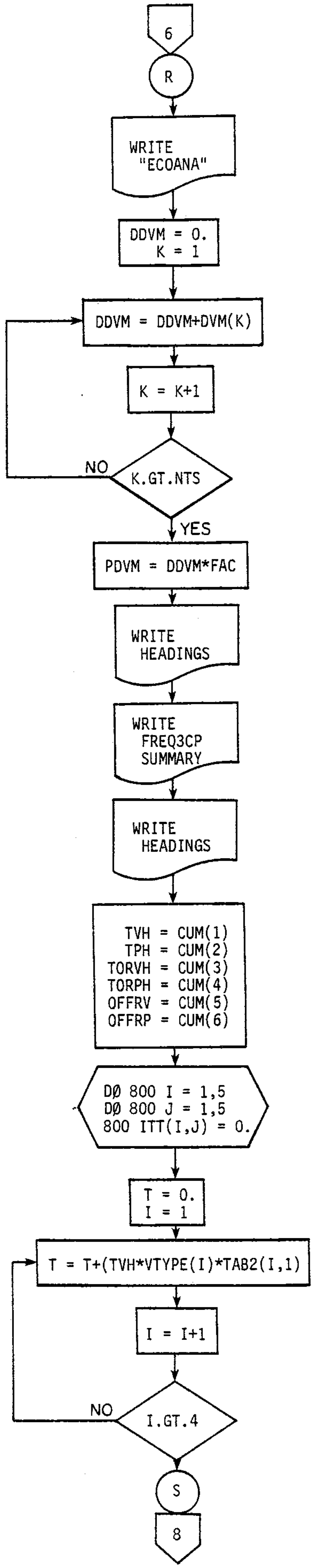
VMBLN(#lanes) = Veh-Mi Travel by # lanes

Necessary because of accident analysis rate given in # lanes.

End of processing for the subsections.

End of processing for the Time Slice.

ECOANA (cont.)



Entry after all Time Slices have been analyzed.

Put large ECOANA HEADING

Sum up all diverted veh-mi of travel from all Time Slices.

PDVM = Number pass-mi of travel on diversion route

Page HEADINGS information.

All SUMMARY information contained in last Time Slice record in variable (CUM) is printed.

Bring up new page and put heading information.

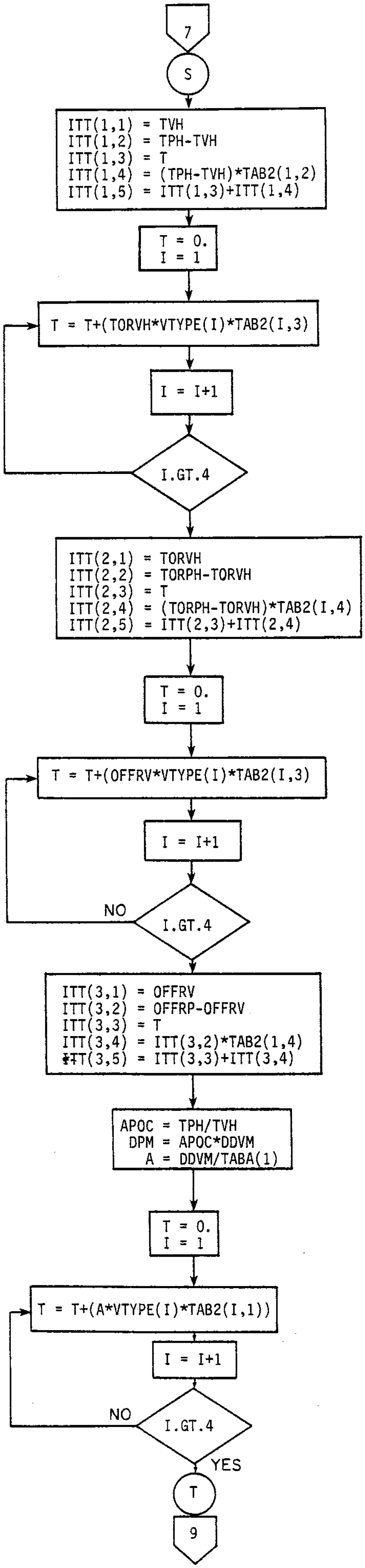
Begin processing for Travel Time calculations

TVH = Total Vehicle Hours Delay
TPH = Total Passenger Hours Delay
TORVH = Total Vehicle Hours Delay at On-Ramps
TORPH = Total Passenger Hours Delay at On-Ramps
OFFRV = Total Vehicle Hours Delay at Off-Ramps
OFFRP = Total Passenger Hours Delay at Off-Ramps

ITT arrays used to hold printout information.

T = Total Cost of Time-Freeway
TVH = Total Vehicle Hours on Freeway
VTYPE = #/Vehicle
TAB2(vehicle type, 1) = Time Cost - Driver and Vehicle

ECOANA (cont.)



Filling printout array - Freeway.

TAB2(1,2) = Pass. Time Cost Moving Vehicle

TAB2(vehicle type, 3) = Cost Delay for Stopped Vehicle

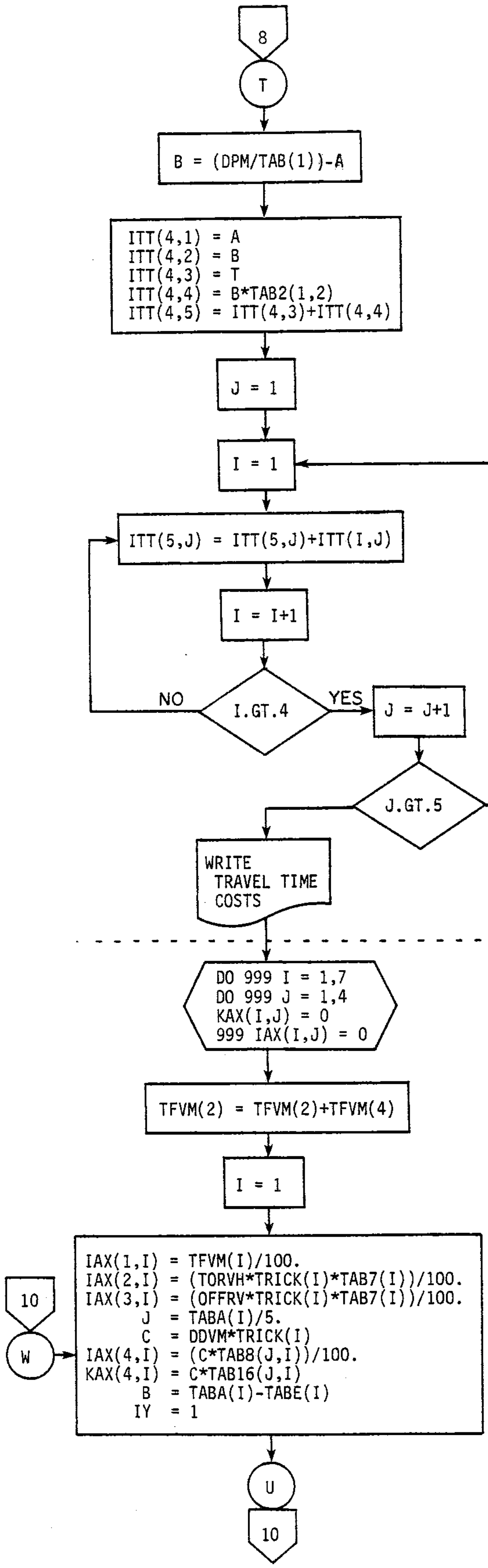
Filling printout array - On-Ramp
-TAB 2 (VEH TYPE, 4) - Cost of Pass. Time in Stopped Vehicle
(40D)

Filling printout array - Off-Ramp

APOC = Average Pass-Occupancy per Vehicle
DPM = Diverted Pass-Mile of Travel
A = Diverted Vehicle-Hours of Delay
TABA = Approach Speed (MPH)

T = Total Cost of Delay on Diversion Route

ECOANA (cont.)



B = Pass Hours of Delay on Diversion Route

Filling printout array - Diversion

Creating vertical sums.

Printing Travel Time Summary information.
End of Travel Time Costs Analysis.

Beginning of Operating Cost Analysis.

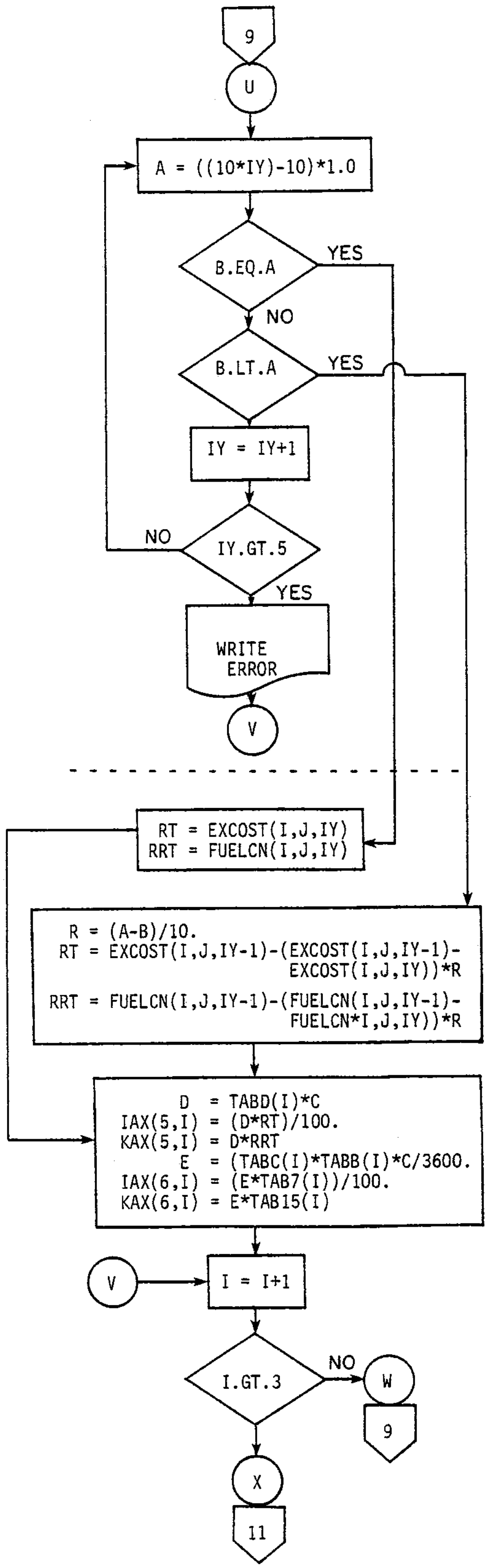
IAX(7,4) used as printout array for Operating Costs
KAX(7,4) used as printout array for Fuel Usage

Combine veh type 4 with veh type 2 veh miles travel.

Beginning of DO-LOOP.

IAX(1,veh type) = Cost ($/veh mi) Freeway
TAB7(veh type) = Cost Idling ¢/veh-hr
IAX(2,veh type) = Cost $ for Stopped - On-Ramp
IAX(3,veh type) = Cost $ for Stopped - Off-Ramp
TABA = Apparoch Speed Diversion Route
C = Diverted veh mi by type
IAX(4,veh type) = Cost $Uniform Speed - Diversion
(KAX(4,veh type)= Grams Fuel Used - Uniform Speed Diversion
B = Speed (MPH) Due to Change

ECOANA (cont.)



Tables 9, 10, 11 have speed changes in 10 MPH increments.

If speed change other than 10 MPH find fractional part there of.

Is speed changed to equal to speed in Tables 9, 10,11.

Is speed changed to .LT. speed in Table

Keep moving speed search to right in Tables 9, 10 11 until find speed range.

Initial speed and/or speed changed to greater than 50 MPH - error caused by improper Tables TABA→TABE definitions

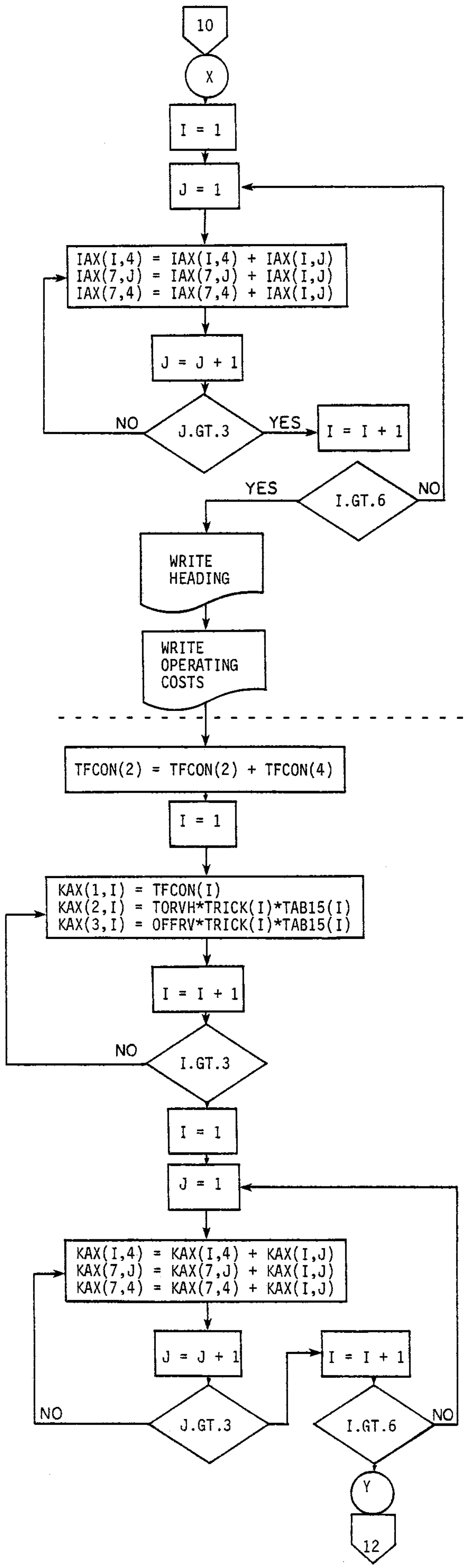
Speed changed to equals exactly that in Tables 9, 10, 11

RT = Cost (¢) for this vehicle type - Excess Running
RRT = Fuel used (grams) for this vehicle type - Excess Running
EXCOST(veh type, speeds, speed change) = ¢/cycle
FUELCN(veh type, speeds, speed change) = gals/cycle
Speed changed <u>not</u> on 10 MPH increments

TABD(veh type) = # speed changes/mile
IAX(5,veh type) = Cost ($) due to speed changes - Diversion
(KAX(5,veh type) = Gals fuel used - speed changes - Diversion
(IAX(6,veh type) = Cost ($) due to idling - Diversion
(KAX(6,veh type) = Gals fuel used - idling - Diversion

End of DO-LOOP.

ECOANA (cont.)



Creating horizontal and vertical sums.

Bring up new page and print heading information.

Write Operating Costs Summaries.

End Operating Cost Analysis.

Begin Fuel Consumption Analysis.

Combine Veh-Type 4 with type 2.

Begin DO-LOOP.

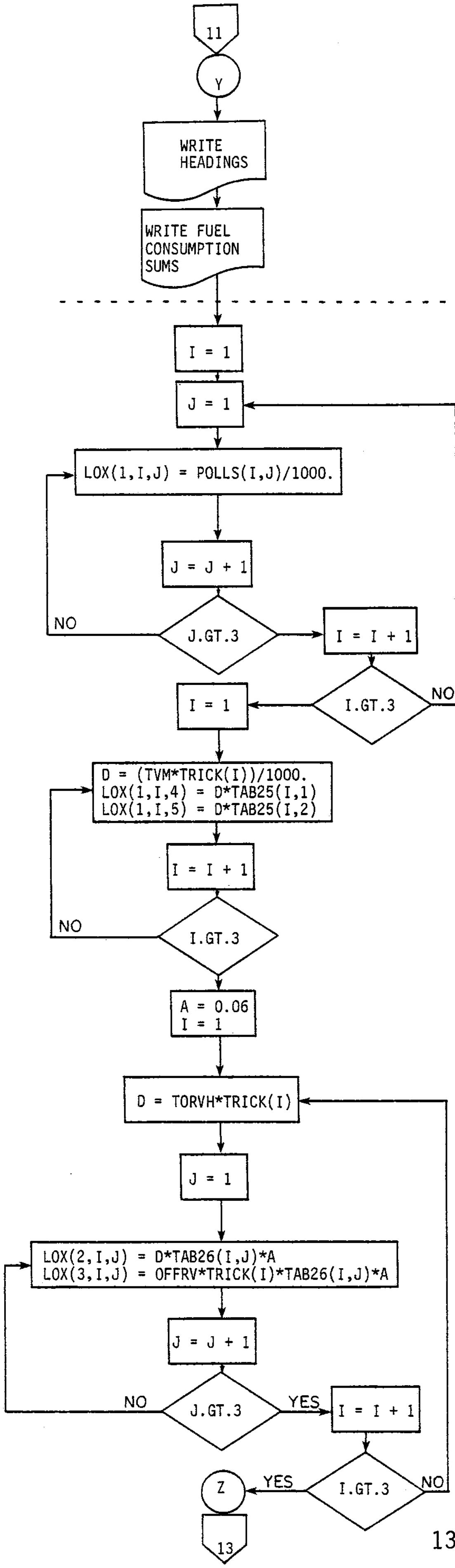
KAX(1,Veh-Type) = Gal fuel used on freeway
KAX(2,Veh-Type) = Gal fuel used on ON Ramp
KAX(3,Veh-Type) = Gal fuel used on OFF Ramp
TAB15(Veh-Type) = Idling fuel consumption

2nd DO-LOOP.

The majority of KAX array created during operating cost analysis.

Create horizontal and vertical summaries.

ECOANA (cont.)



Bring up new page and write heading information.

Printout Fuel Consumption Summaries.

End of Fuel Consumption Analysis.

Start of Emissions Analysis

LOX(1,veh-type,pollutants) = Kilograms ON FREEWAY

Pollutant = 1 Carbon Monoxides
= 2 Hydrocarbons
= 3 Nitrogen

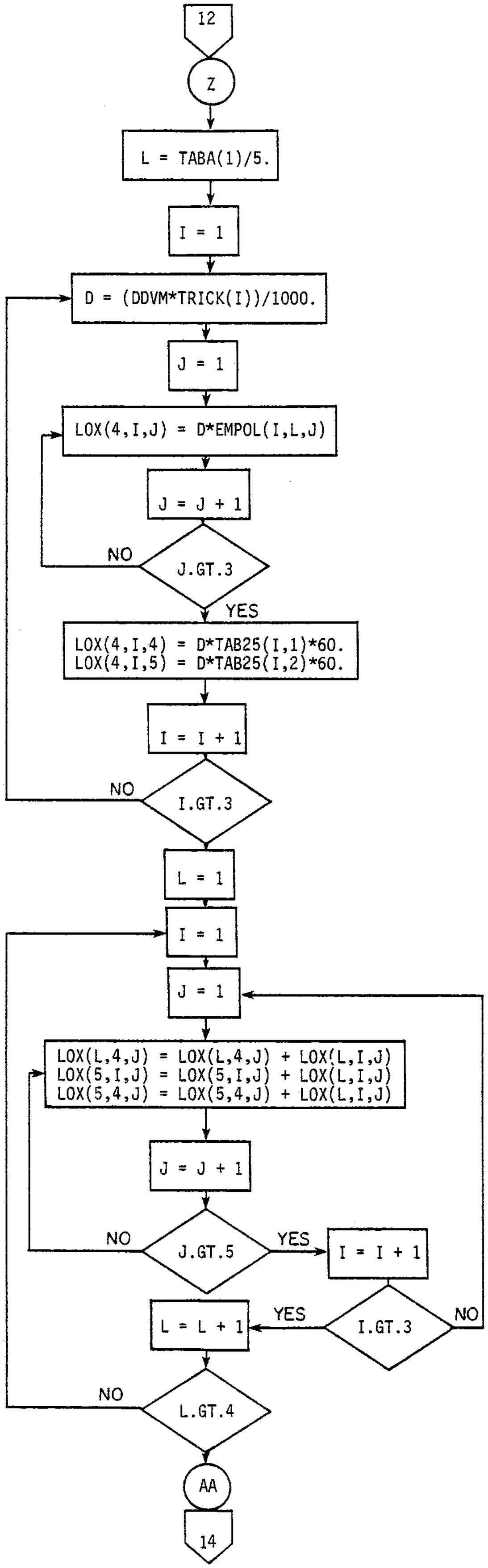
I = Veh-Type
J = Pollutants

Pollutant = 4 Particulates
Pollutant = 5 Sulfur Oxides

A = conversion factor $\frac{60 \text{ min}}{1 \text{ hr}} * \frac{1 \text{ kg.}}{1000 \text{ g.}}$

LOX(2,Veh-Type,Pollutant) = Kilograms ON RAMP
TAB26(Veh-Type,Pollutant) = Grams/Minute Idling Rates
LOX(3,Veh-Type,Pollutant) = Kilograms OFF RAMP

ECOANA (cont.)



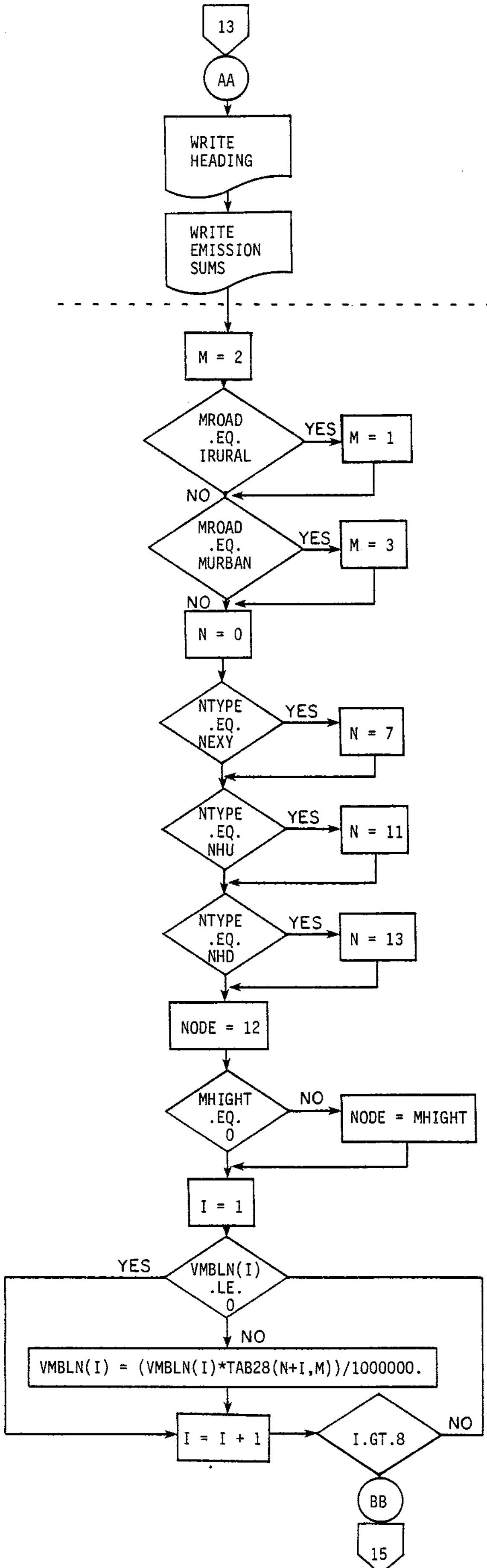
Range the approach speed on Diversion Route into 5 MPH increment.

LOX(4,Veh-Type,Pollutant) = Kg. due to Uniform Speed-Diversion Route

Same as above except for Pollutants 4 & 5.

Create vertical and horizontal sums in output array LOX.

ECOANA (cont.)



Bring up new page and print heading information

Write the Pollution Emissions Summaries

End of Pollution Analysis

Start of Accident Analysis

MROAD = 1 Rural
= 2 Urban
= 3 Urban Metered
TABLE 28

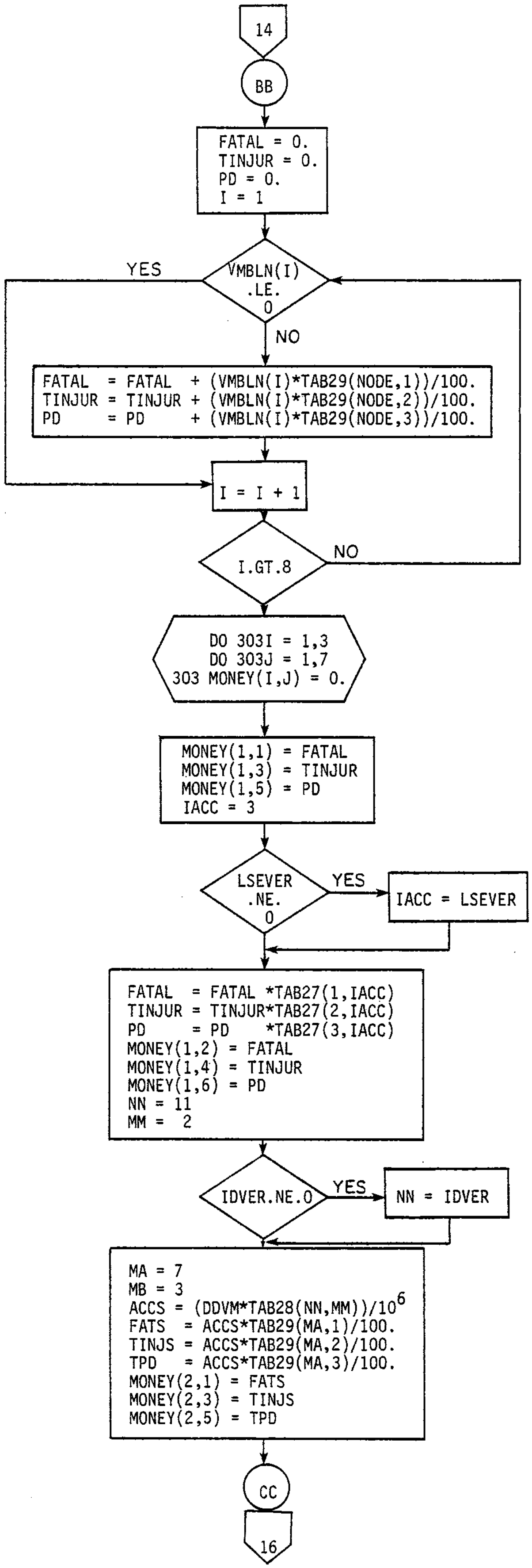
NTYPE = 0 Freeways
= 7 Expressways
= 11 Undivided
= 13 Divided
TABLE 28

MHIGHT = 1 - 12 for Highway Type TABLE 29

VMBLN = Veh-Miles by # lanes ON Freeway

TAB28(Highway-Type,Location) = Accident rate per million veh-miles.

ECOANA (cont.)



FATAL = Total # of Fatalities
TINJUR = Total # of Injuries
PD = Total # of Property Damage

MONEY(1,1) = Total # of Deaths
(1,3) = Total # of Injuries
(1,5) = Total # of Property Damage Acc } ON FREEWAY

LSEVER = 1 Rural
= 2 Suburban } TABLE 27
= 3 Urban

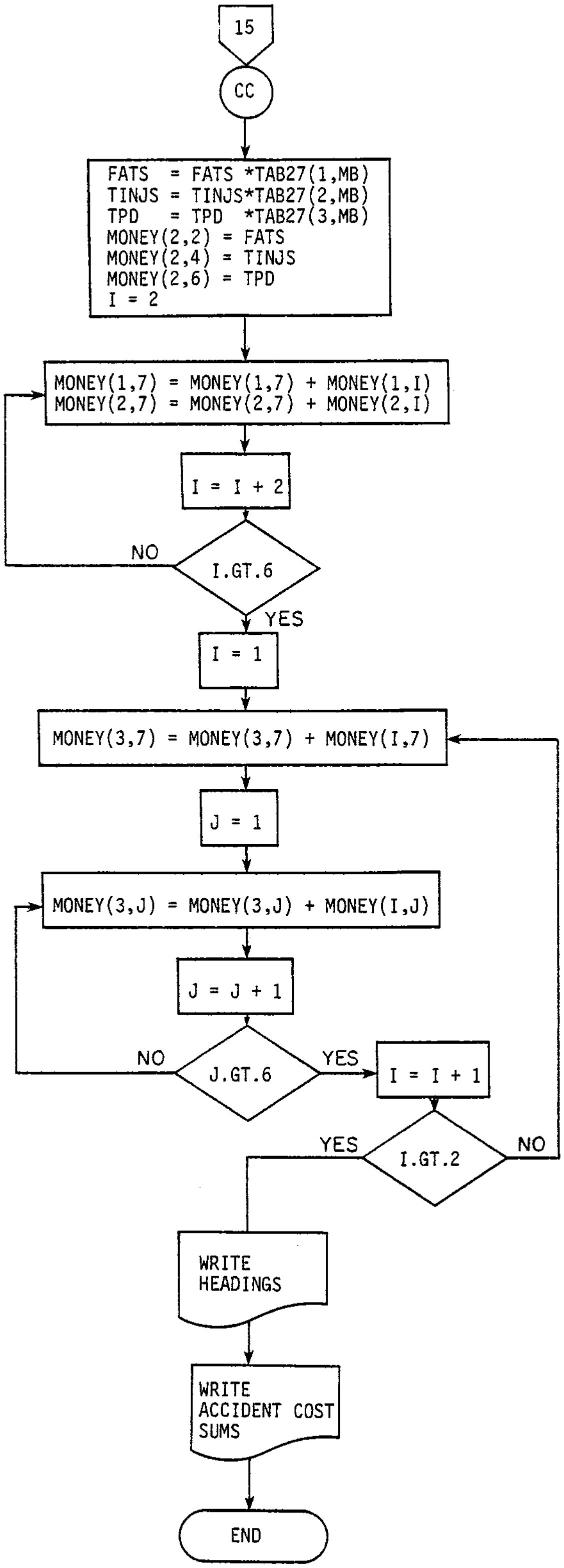
MONEY(1,2) = Cost for Fatal Accidents
(1,4) = Cost for Injury Accidents
(1,6) = Cost for Property Damage Acc } ON FREEWAY

IDVER = Highway-Type in Table 28 for Diversion Route.

MA chosen for Urban 2 lane roadway Table 29 for Diversion.
MB chosen for Urban Table 27 for Diversion

MONEY(2,1) = Total # of deaths on Diversion Routes
(2,3) = Total # of injuries on Diversion Routes
(2,5) = Total # of property damage on diversion Routes

ECOANA (cont.)



MONEY(2,2) = Cost Deaths on Diversion
(2,4) = Cost Injuries on Diversion
(2,6) = Cost Property Damage on Diversion

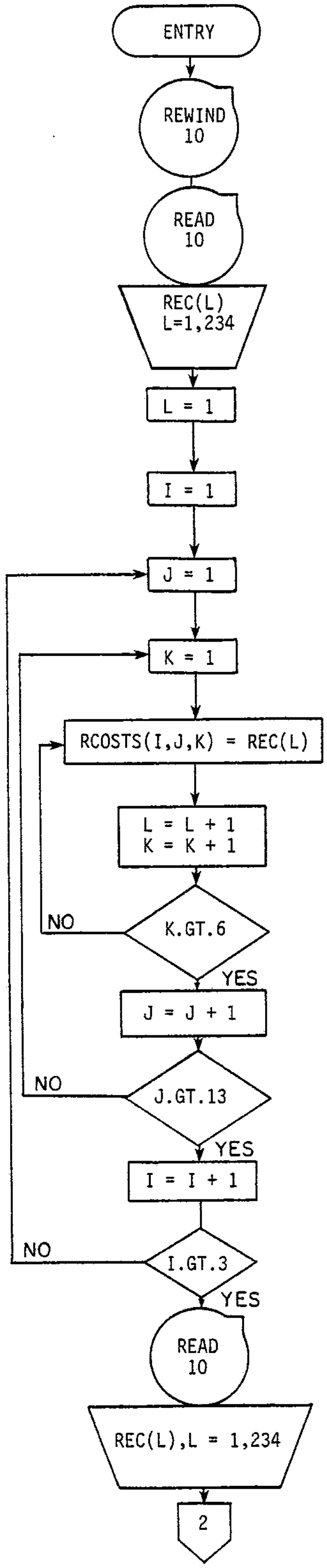
Creating Horizontal and Vertical Sums.

Bring up new page and print heading information.

Write the Accident Costs Summaries.

End of Accident Analysis and Program

SUBROUTINE FIRST

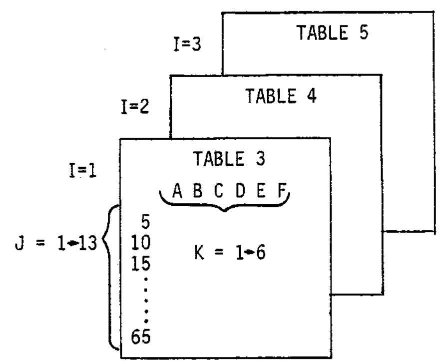


Subroutine Entry.

Rewind Tape.

Read Record 1,234 units long into array REC

Start DO-LOOP where RCOSTS(3,13,6) is filled.

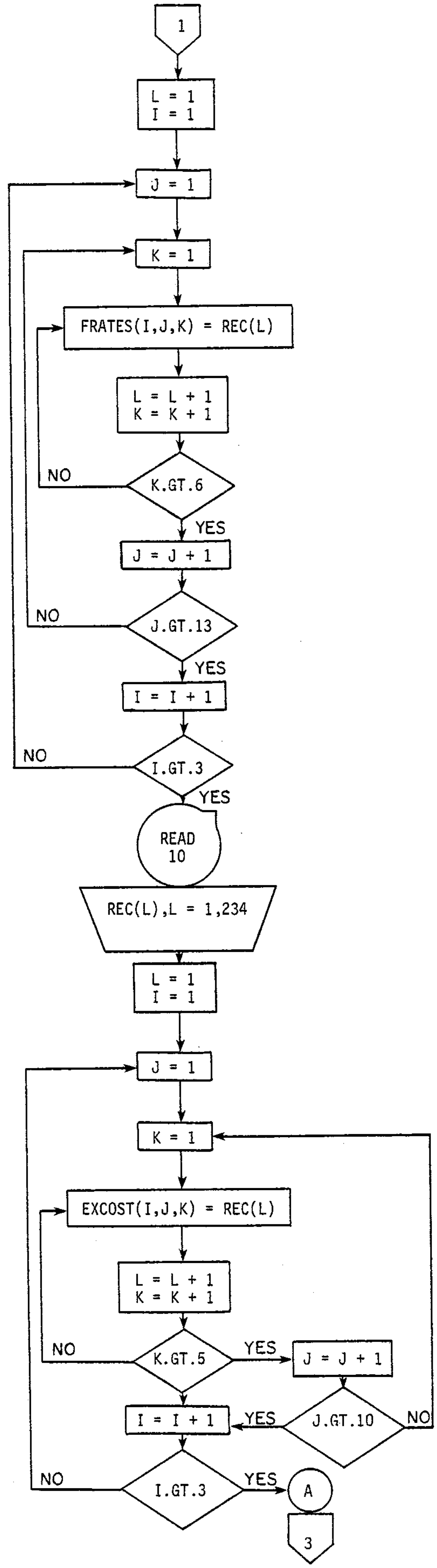


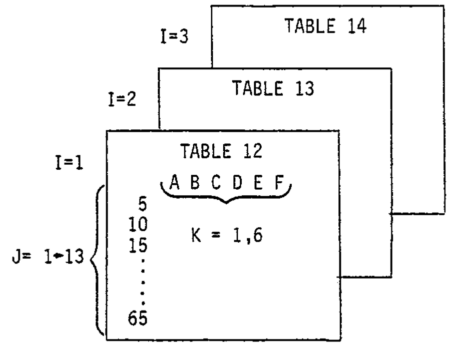
RCOSTS (I,J,K) filled with Tables 3, 4, 5 (Operating Costs)

Read Tape.

Record 2 has tables 12, 13, 14 (fuel consumption)

Subroutine First (Cont.)

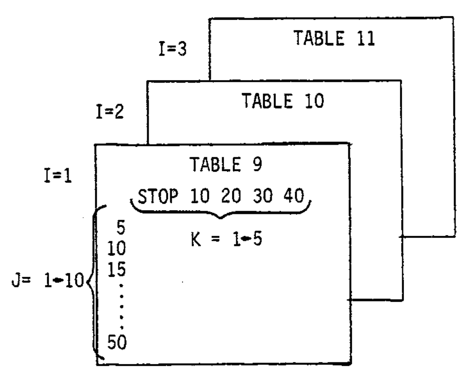




FRATES(I,J,K) filled with Tables 12, 13, 14
(fuel consumption rates)

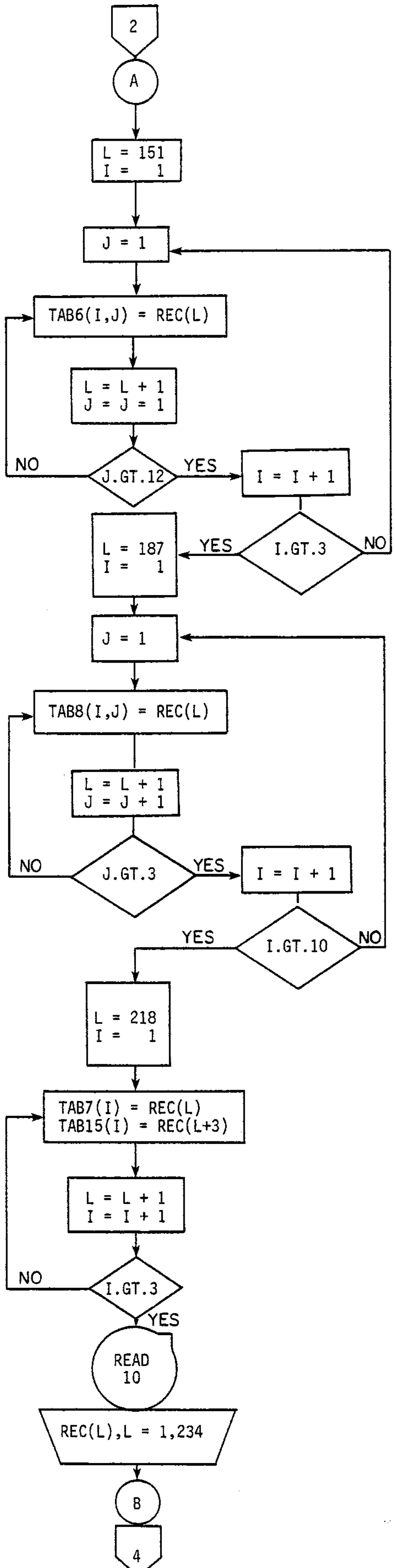
Read Tape.

Record 3 has Tables 9, 10, 11, 6, 8, 7, 15.



EXCOST(I,J,K) filled with Tables 9, 10, 11
(Excess Running Costs of Speed Cycle Changes)

Subroutine First (Cont.)



TAB6(3,12)
(Freeway volume to cpaacity ratios, by lanes
and level of service)

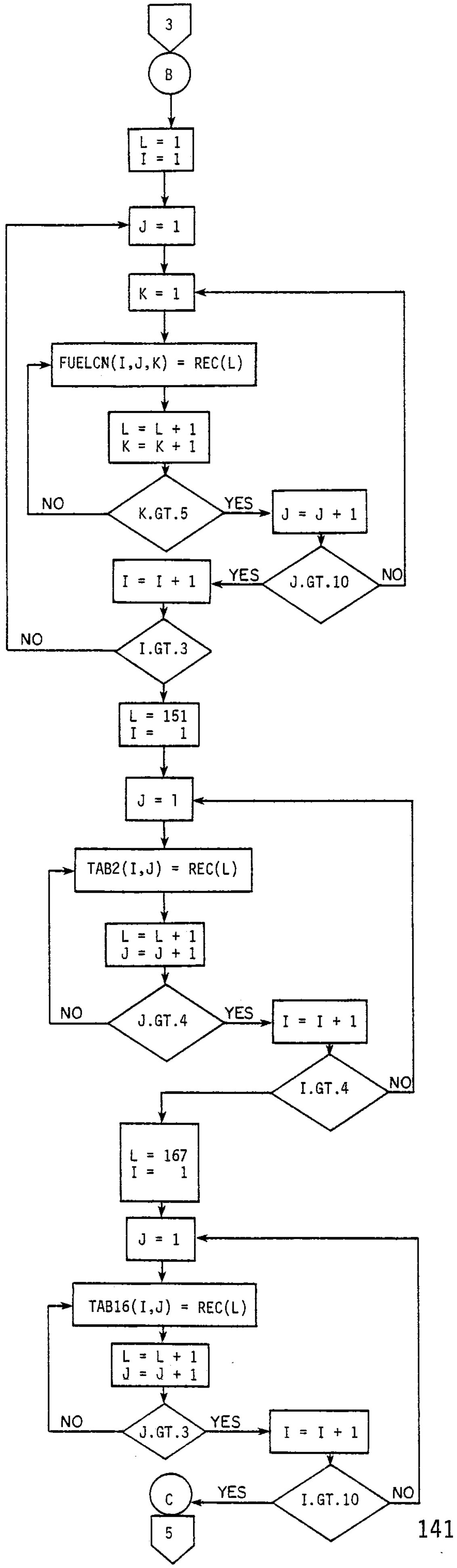
TAB8(10,3)
(Running costs on city streets, by vehicle-type
and uniform speed)

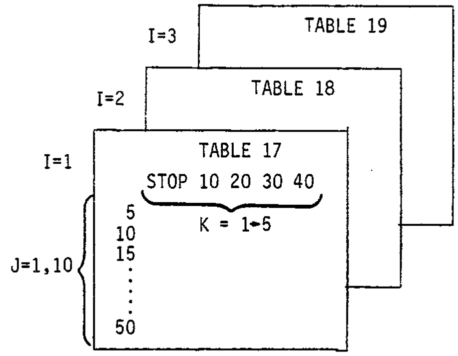
TAB7(3) (Idling cost by Vehicle-Type)
TAB15(3) (Idling fuel consumption by vehicle-type)

Read Tape.

Record 4 has Tables 17, 18, 19, 2, 16, 29.

Subroutine First (Cont.)



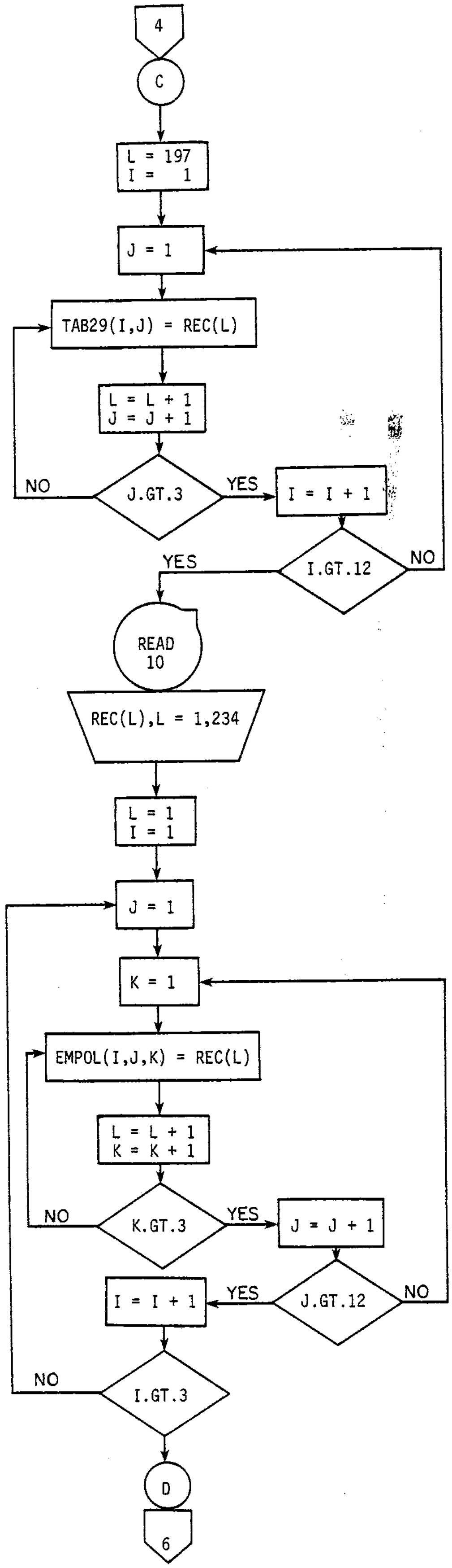


FUELCN(3,10,5) (Excess fuel consumption rates for speed cycle changes by vehicle-types)

TAB2(4,4) (Value of time by vehicle-type and driving mode)

TAB16(10,3) (Fuel consumption rates on city streets, by vehicle-type and uniform speed)

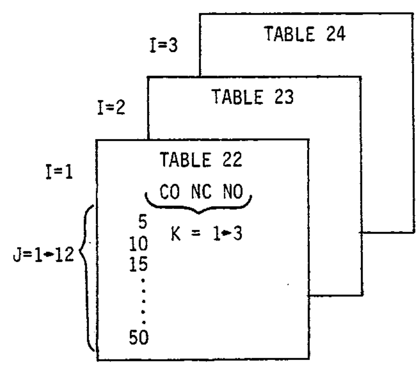
Subroutine First (Cont.)



TAB29(12,3) (Percentage distribution by Accident Severity).

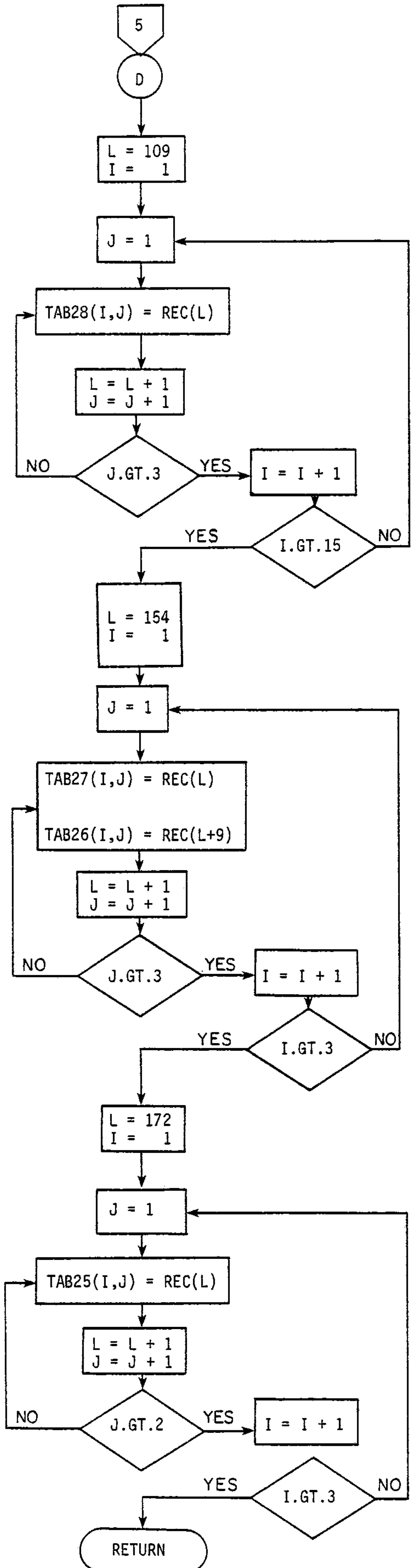
Read Tape.

Record 5 has Tables 22, 23, 24, 28, 27, 26, 25



EMPOL(3,12,3) (Pollution emissions of vehicle-types, by pollutant and average speed)

Subroutine First (Cont.)



TAB28(15,3) (Motor vehicle accident rates; by highway-type and location of accident)

TAB27(3,3) (Motor vehicle accidnet unit costs per reported accident by severity and location)

TAB26(3,3) (Idling pollution rates by vehicle type and type of pollutant)

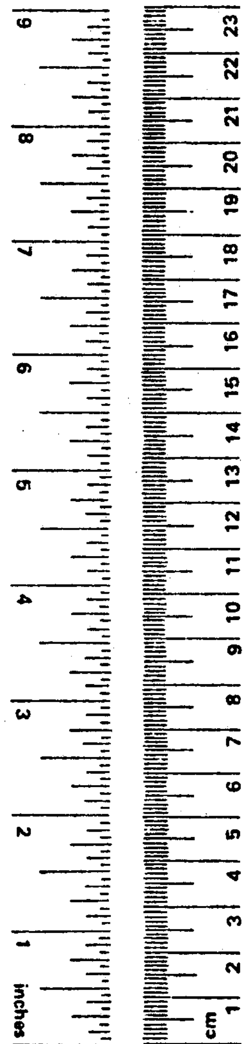
TAB25(3,2) (Particulates and sulfur oxides pollution rates by vehicle types)

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F