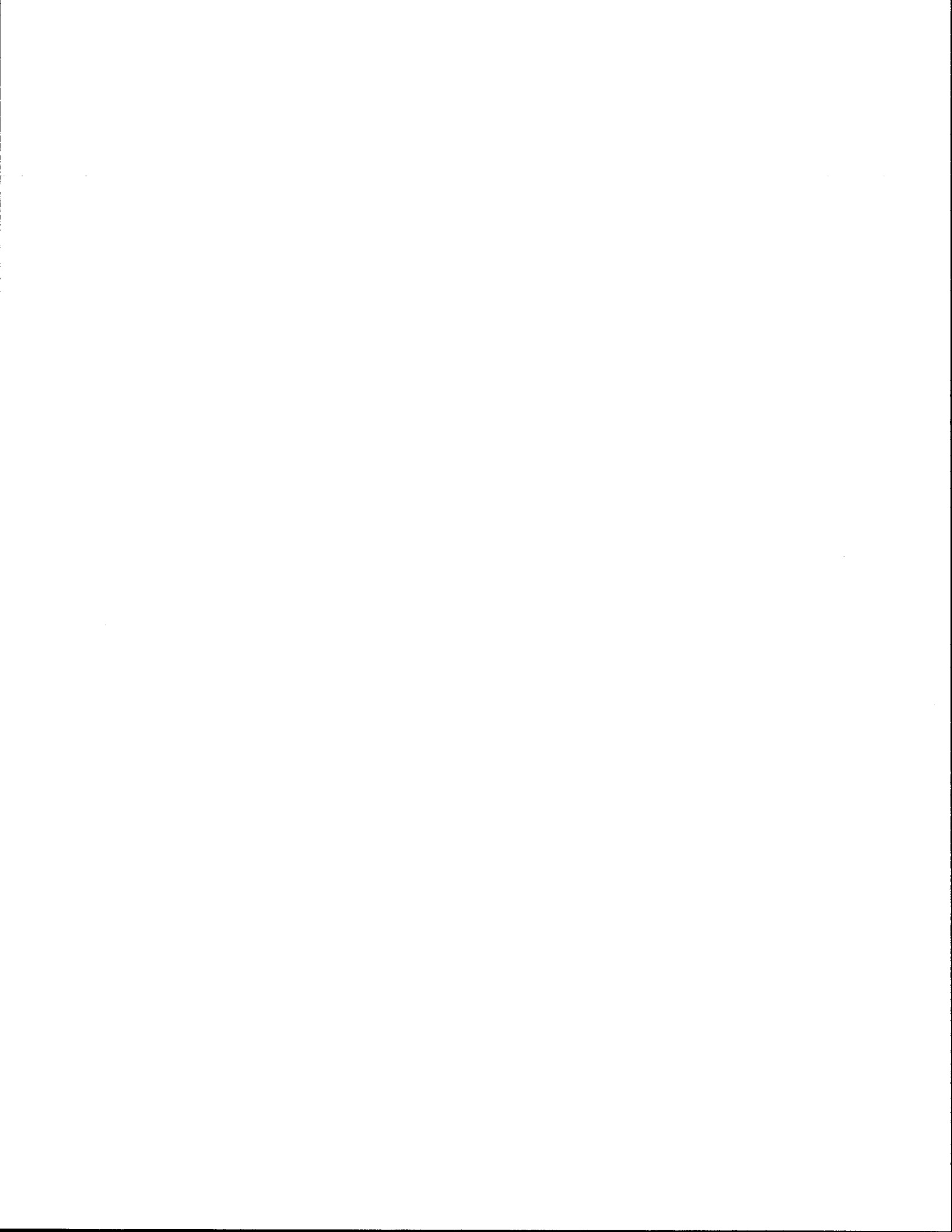


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TCM ANALYST 1.0 AND USER'S GUIDE

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and

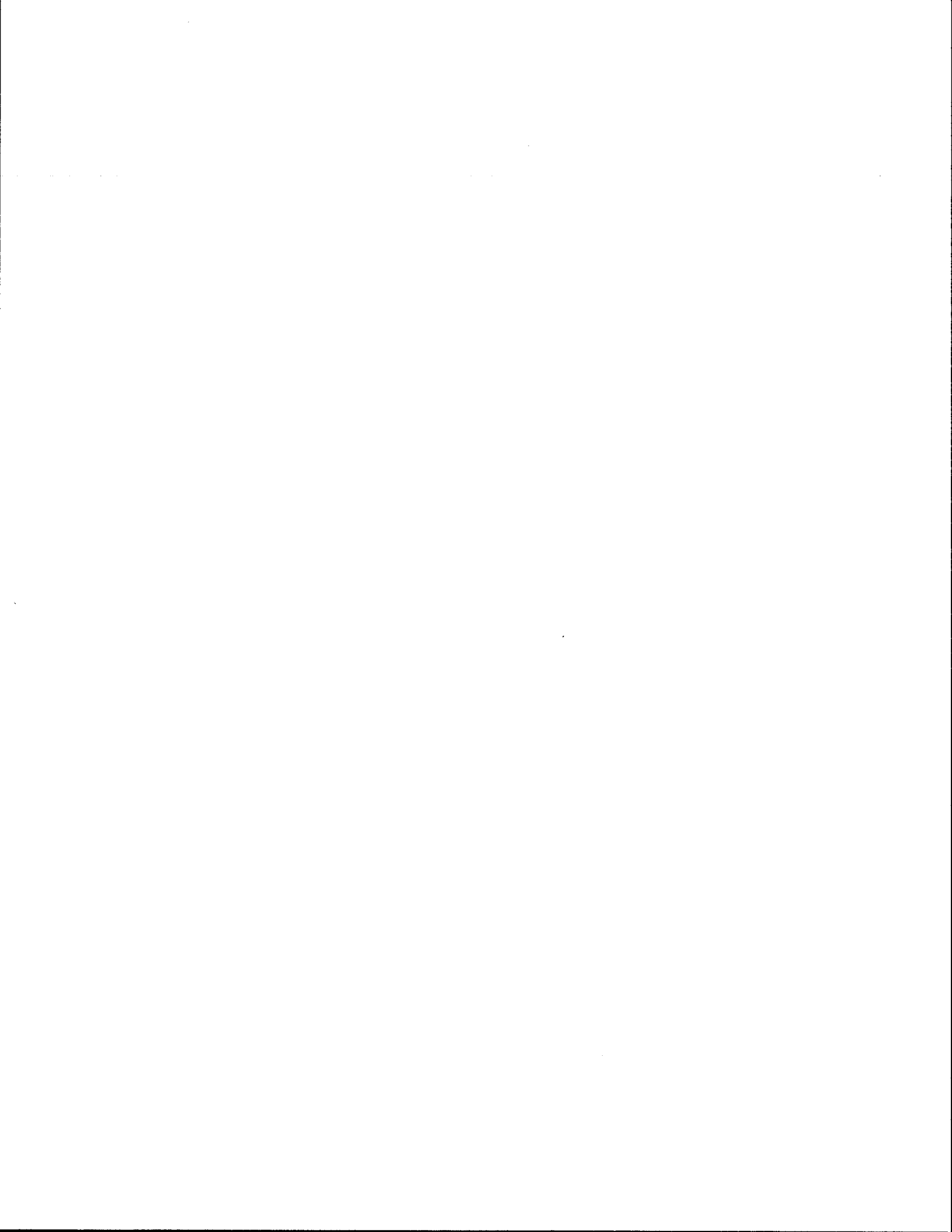
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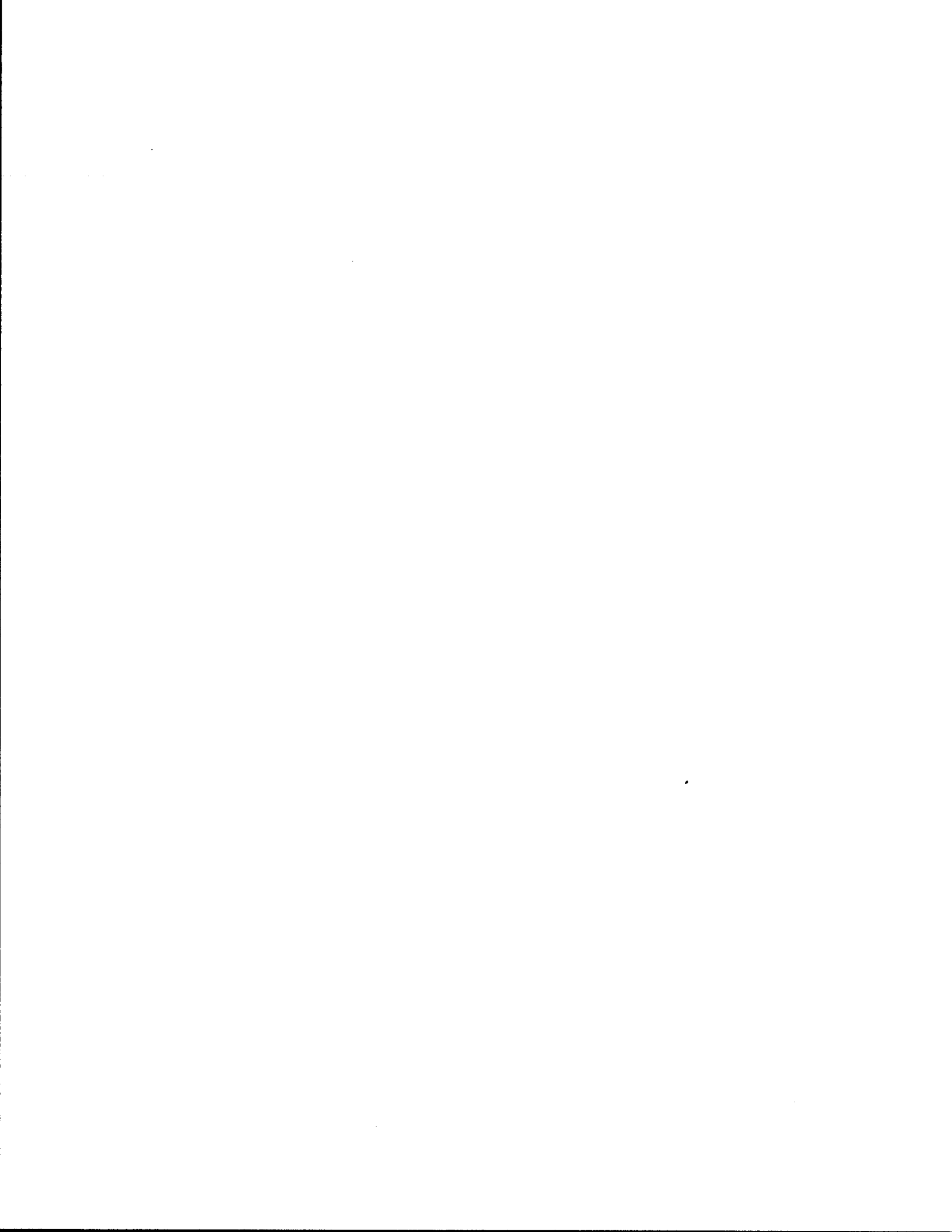
TEXAS TRANSPORTATION INSTITUTE
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IMPLEMENTATION STATEMENT

The TCM Analyst 1.0 and User's Guide can be implemented immediately. The software runs through the Microsoft Excel environment and has several analysis tools and features to assist the user with the software. The software can be used to evaluate selected transportation control measures on a regional basis by metropolitan planning organization and TxDOT district staff. The software was designed to reflect the needs in mobile source emission analysis of transportation control measures for nonattainment areas.

This report and accompanying software have not been converted to metric units because the software relies on input to and output from the Environmental Protection Agency's MOBILE emission factor model. As of the publication of this report, English inputs are required for MOBILE, and inclusion of metric equivalents could cause some user input error.



DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation. Additionally, this report is not intended for construction, bidding, or permit purposes. Raymond A. Krammes, P.E. (Registration Number 66413), was the Principal Investigator for the project.

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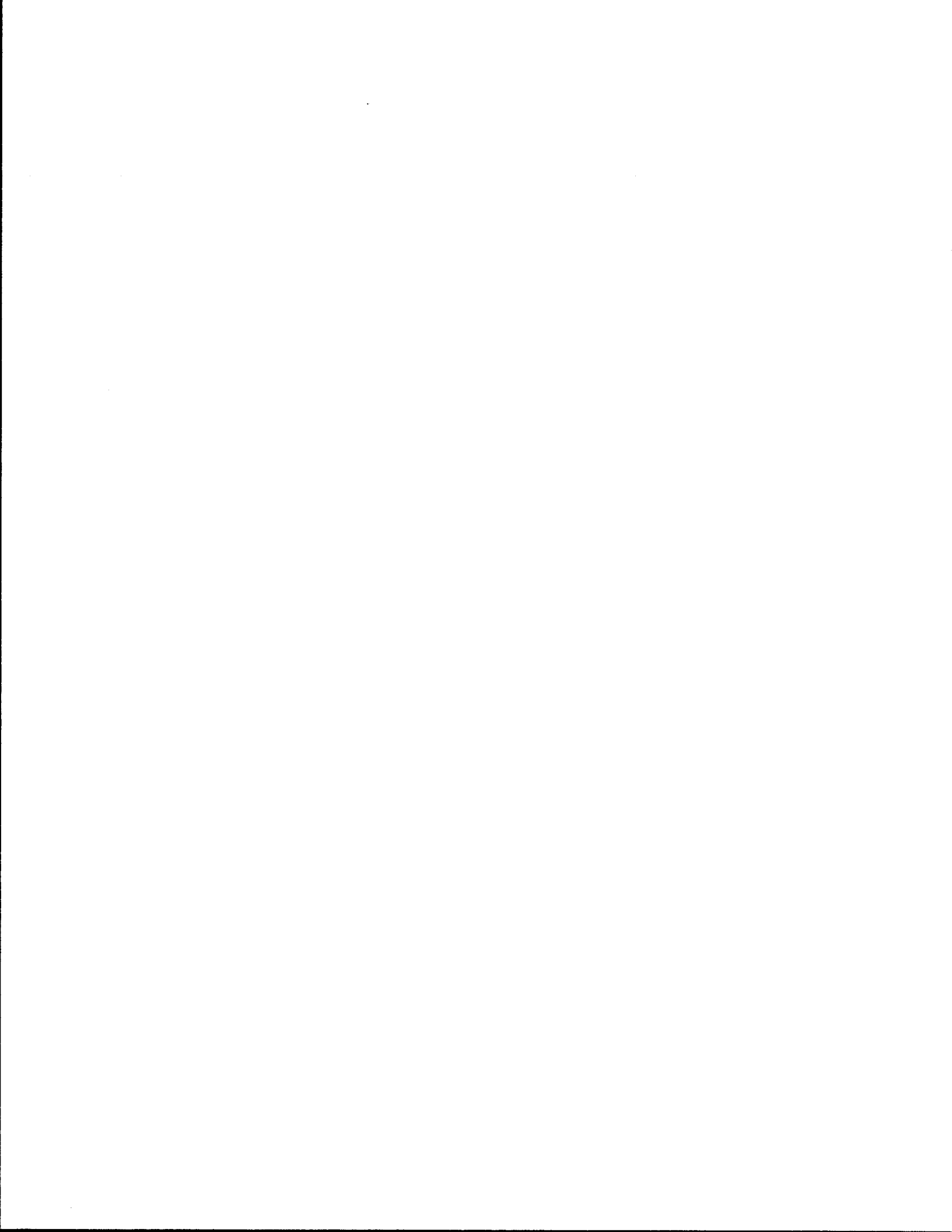
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SUMMARY

Since the passage of the 1990 Clean Air Act Amendments (CAAA), transportation planning has increased its focus on the air quality impacts of transportation improvement projects. Transportation control measures (TCMs) are possible tools for improving regional air quality as defined in the CAAA. TCMs are a collection of actions previously grouped into two categories: transportation system management (TSM) and transportation demand management (TDM). The TCM Analyst computer package was prepared to provide a tool for evaluating the effectiveness of TCMs on a regionwide basis and is intended to be used by transportation engineers and planners.

Traditionally, three broad categories of methodologies have been employed for TCM analysis: comparison with other areas, computer-based modeling, and sketch-planning tools. Comparison with other areas involves a simple application of the observed changes in travel activity due to TCM implementation in another area to a local scenario. Computer-based modeling involves using complex simulation tools traditionally employed in transportation planning and traffic engineering. Sketch-planning tools involve simple manual or computerized methods and fall between the two previously described methods in complexity and formality.

The TCM Analyst is a sketch-planning tool that combines elements of the methodologies developed by Systems Applications International (SAI) for the U.S. Environmental Protection Agency (EPA) and the San Diego Association of Governments' (SANDAG) TCM Tools program into one spreadsheet-based evaluation tool. The software uses the Microsoft Excel spreadsheet environment as a platform for TCM analysis.

The TCM Analyst can be used to estimate the travel and emission effects of selected TCMs and can also evaluate their cost-effectiveness. Eleven TCMs are included for evaluation in the TCM Analyst: (1) telecommuting, (2) flextime, (3) compressed work week, (4) ridesharing, (5) transit fare decrease, (6) transit service increase, (7) transit plazas, (8) parking management, (9) HOV lanes, (10) traffic signalization, and (11) intersection improvements. Emission changes are evaluated for both the carbon monoxide (CO) and ozone emission seasons.

Additionally, three analysis tools are included to help determine the effects that specific inputs have on the estimated benefits of a TCM.

CHAPTER I. INTRODUCTION

Transportation control measures (TCMs) are a collection of actions previously grouped into two categories: transportation system management (TSM) and transportation demand management (TDM). TSM actions influence the supply side of the transportation system: capacities, traffic flow, and traffic movement. TDM actions influence the requirements put on the transportation system: increasing vehicle occupancy, reducing trips, and reducing vehicle miles traveled (VMT). The TCM Analyst computer package was prepared to provide a tool for the evaluation of the effectiveness of TCMs on a regionwide basis.

The TCM Analyst is a sketch-planning tool that combines elements of the methodologies developed by Systems Applications International (SAI) for the U.S. Environmental Protection Agency (EPA) and the San Diego Association of Governments' (SANDAG) TCM Tools program into one spreadsheet-based evaluation tool. The TCM Analyst can be used to estimate the travel and emission effects of selected TCMs and can also evaluate their cost-effectiveness. Eleven TCMs are included for evaluation in the TCM Analyst: (1) telecommuting, (2) flextime, (3) compressed work week, (4) ridesharing, (5) transit fare decrease, (6) transit service increase, (7) transit plazas, (8) parking management, (9) HOV lanes, (10) traffic signalization, and (11) intersection improvements. Additionally, there are three analysis tools included to help determine the effects specific inputs have on the estimated benefits of a TCM.

The TCM Analyst is intended to be used by transportation engineers and planners who need to assess the potential effectiveness of TCM implementation within their jurisdiction. It is important to note that this program evaluates the effects of TCMs on a regional, rather than microscale, level. The TCM Analyst is also limited to the evaluation of isolated TCMs; it is not designed to evaluate the effects of TCM programs. Although the TCM Analyst cannot evaluate the effects of TCM programs, guidance is provided for the engineer/planner to perform their own program analysis.

NEED FOR ANALYSIS TOOLS

TCMs became an integral part of the air quality improvement process with the passage of the 1990 Clean Air Act Amendments (CAAA). The TCMs that are specifically designated in Section 108(f) of the CAAA are:

- Programs for improved public transit;
- Restriction of certain roads or lanes to, or construction of such roads or lanes for use by, passenger buses or high-occupancy vehicles;
- Employer-based transportation management plans, including incentives;
- Trip-reduction ordinances;
- Traffic flow improvement programs that achieve emission reductions;
- Fringe and transportation corridor parking facilities serving multiple occupancy vehicle programs or transit service;
- Programs to limit or restrict vehicle use in downtown areas or other area of emission concentration particularly during periods of peak use;
- Programs to limit portions of road surfaces or certain sections of the metropolitan area to the use of non-motorized vehicle or pedestrian use, both as to time and place;
- Programs for secure bicycle storage facilities and other facilities, including bicycle lanes, for the convenience and protection of bicyclists, in both public and private areas;
- Programs to control the extended idling of vehicles;
- Programs to reduce motor vehicle emissions which are caused by extreme cold start emissions;
- Employer-sponsored programs to permit flexible work schedules;
- Programs and ordinances to facilitate non-automobile travel, provision and utilization of mass transit, and to generally reduce the need for single-occupant vehicle travel, as part of transportation planning and development efforts of a locality, including programs and ordinances applicable to new shopping centers, special events, and other centers of vehicle activity;

- Programs for new construction and major reconstruction of paths, tracks or areas solely of the use by pedestrian or other non-motorized means of transportation when economically feasible and in the public interest; and
- Programs to encourage the voluntary removal from use and the marketplace of pre-1980 model year light duty vehicles and pre-1980 model light duty trucks.

TCMs, like other transportation projects, must be evaluated before being adopted into the transportation improvement program (TIP) of a nonattainment area. The evaluation of TCMs requires some form of technical screening process; and when the CAAAs were adopted, very few analysis tools were available for this purpose.

ROLE OF ANALYSIS TOOLS IN THE TECHNICAL SCREENING PROCESS

Traditionally, three broad categories of methodologies have been employed for TCM analysis: comparison with other areas, computer-based modeling, and sketch-planning tools. Comparison with other areas involves a simple application of the observed changes in travel activity due to TCM implementation in another area to a local scenario. Computer-based modeling involves using complex simulation tools that are traditionally employed in transportation planning and traffic engineering. Sketch-planning tools involve simple manual or computerized methods and fall between the two previously described methods in complexity and formality. These categories are examined and discussed in more detail in TTI Research Report 1279-6, entitled "The Use and Evaluation of Transportation Control Measures" (1).

Sketch-planning tools can be used in the TCM screening process. The analysis of potential TCMs is only one part of the technical screening and evaluation process required for their inclusion into the State Implementation Plan (SIP).

Loudon and Dagang (2) identified four phases of TCM implementation: (1) identify potential TCMs, (2) assess feasibility of candidate TCMs, (3) implement TCMs, and (4) monitor the TCM program. Figure 1 shows these steps. Sketch-planning tools are used in the second step of this process.

A similar process developed by Eisinger, et al (3) for the EPA is shown in Figure 2. This figure shows the technical analyses that need to be performed to include TCMs in the SIP. After

candidate TCMs are selected for a region (Step 1), a more thorough analysis should be undertaken to better estimate the impacts of the TCM. Sketch-planning tools can be used to analyze the regional traffic and emissions effects of TCMs as part of Steps 2 and 3.

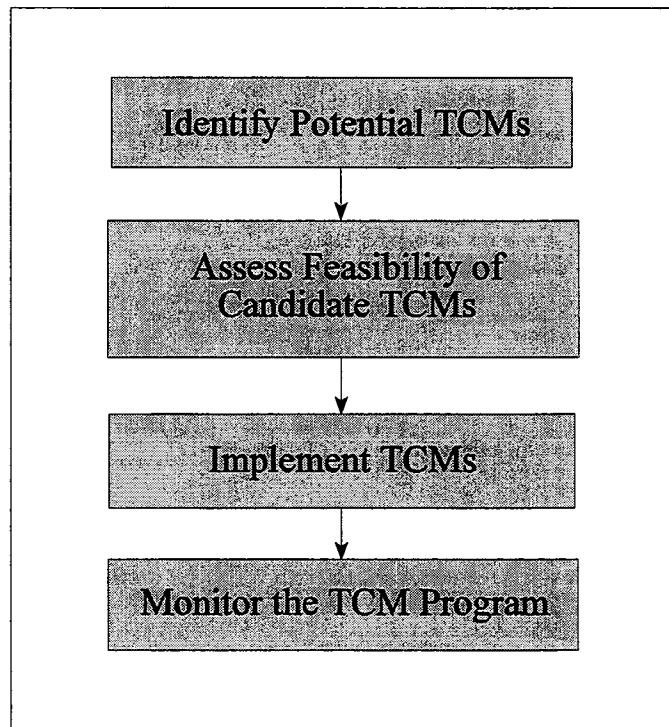


Figure 1. TCM implementation phases

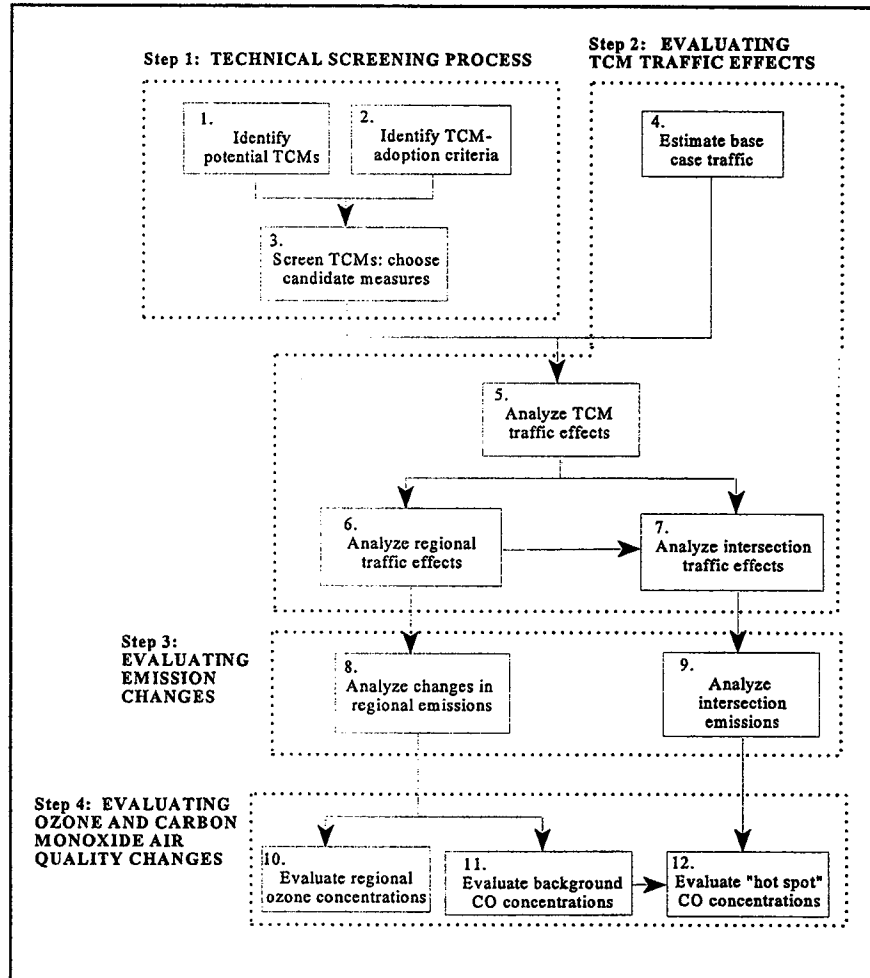
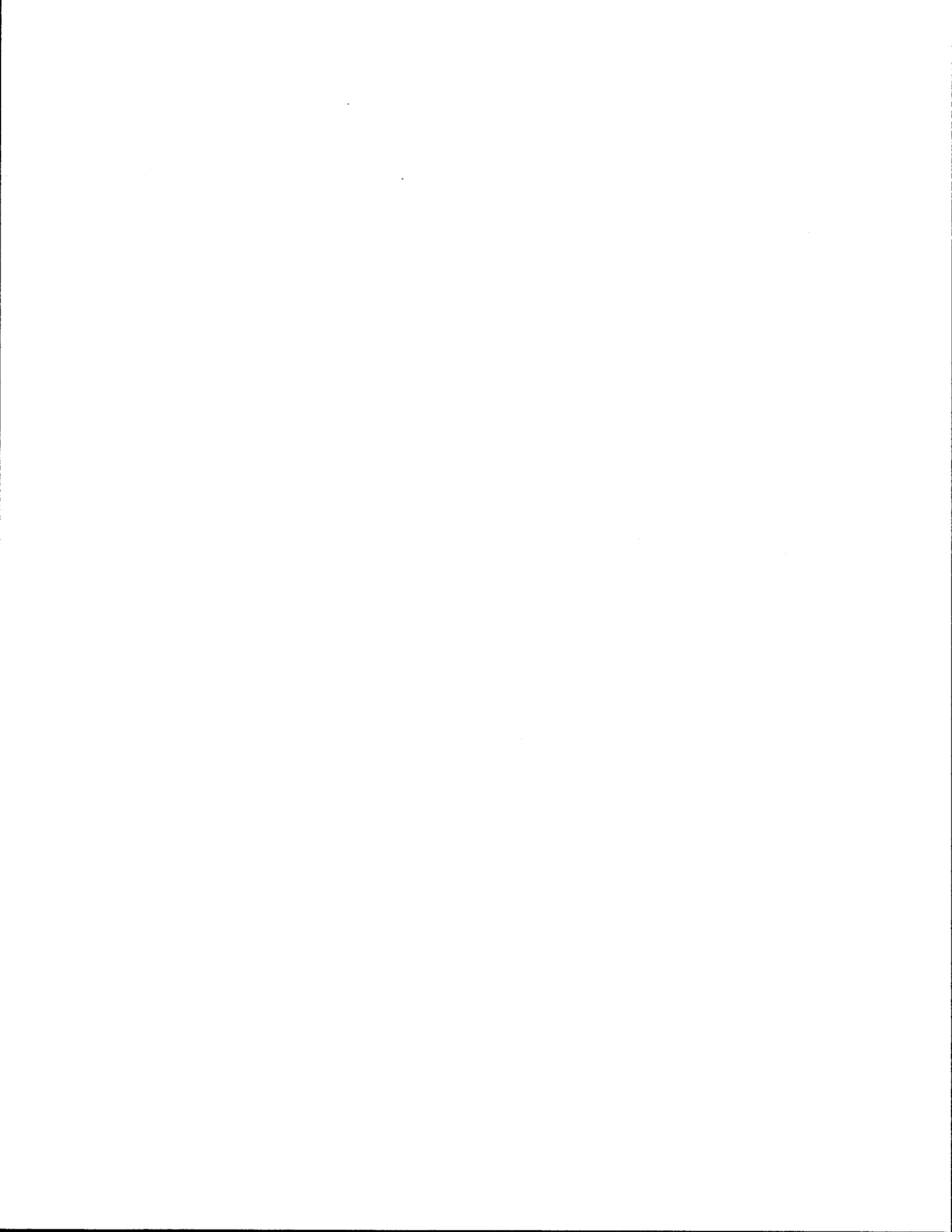


Figure 2. Overview of technical analyses to be performed (4)

ORGANIZATION OF REPORT

This report is organized into eight chapters. Chapters II through IV describe the functional aspects of the TCM Analyst and its data requirements. Chapters V through VII briefly describe the technical background of the model by referencing the original SAI and SANDAG methodologies. Sample applications are provided in Chapter VIII. Appendices are also provided which include sample templates, selected default data, and documentation of new TCMs included in the TCM Analyst.



CHAPTER II. INSTALLING AND STARTING TCM ANALYST

SYSTEM REQUIREMENTS

The following hardware and software is required to run TCM Analyst 1.0:

- Any IBM®-compatible computer with an 80286 (or higher) microprocessor,
- 4 MB (or more) of memory,
- A hard disk with 1 MB (or more) of available storage,
- Microsoft Excel version 5.0 or later,
- Microsoft Windows operating environment version 3.1 or later in standard or enhanced mode,
- MS-DOS® version 3.1 or later, and
- A printer (recommended).

INSTALLATION

Microsoft Excel 5.0 or later must be installed before installing the TCM Analyst. Initially, Excel establishes associations for the TCM Analyst files and makes them ready for immediate use.

To install TCM Analyst, do the following:

1. Start Windows.
2. Insert disk into drive A: or B:.
2. Select the File menu in Program Manager and choose Run.
3. Depending on the computer settings, type B:SETUP or A:SETUP.
4. Press ENTER.

NOTE The TCM Analyst 1.0 setup program copies all TCM Analyst files to the hard disk in a directory called C:\ANALYST and creates a Windows group in the Program Manager with the necessary icons for the application's use in Windows. Dynamic links within the TCM Analyst are defined with this directory location. The program will not function if the directory is modified or renamed.

STARTING TCM ANALYST

After Microsoft Excel and the TCM Analyst have been properly installed, the program can be run. Regional data may be entered into the emission factor files and into the main program itself. The program's data requirements are discussed in the next chapter.

Figure 3 shows the TCM Analyst group and its icons after installation. The list below describes the purpose of each icon:

Icon Name	Description
TCM Analyst 1.0	Main program
CO Season Emission Factors	Input MOBILE5a factors for CO season
O3 Season Emission Factors	Input MOBILE5a factors for ozone season
Sample Data Inputs	Examples of Emission and Data Input Screens

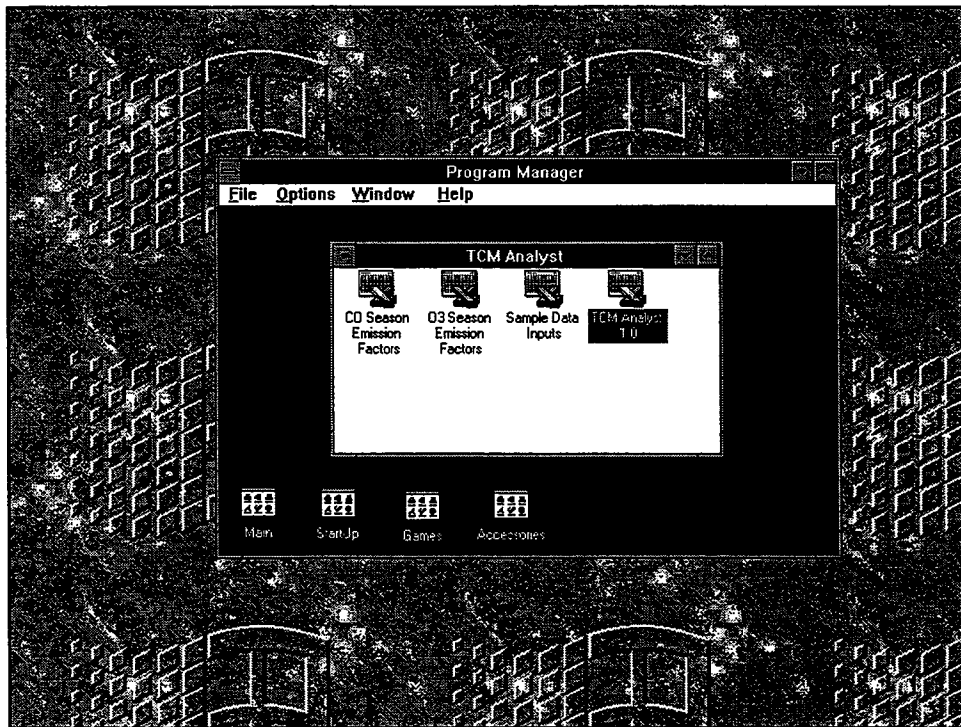


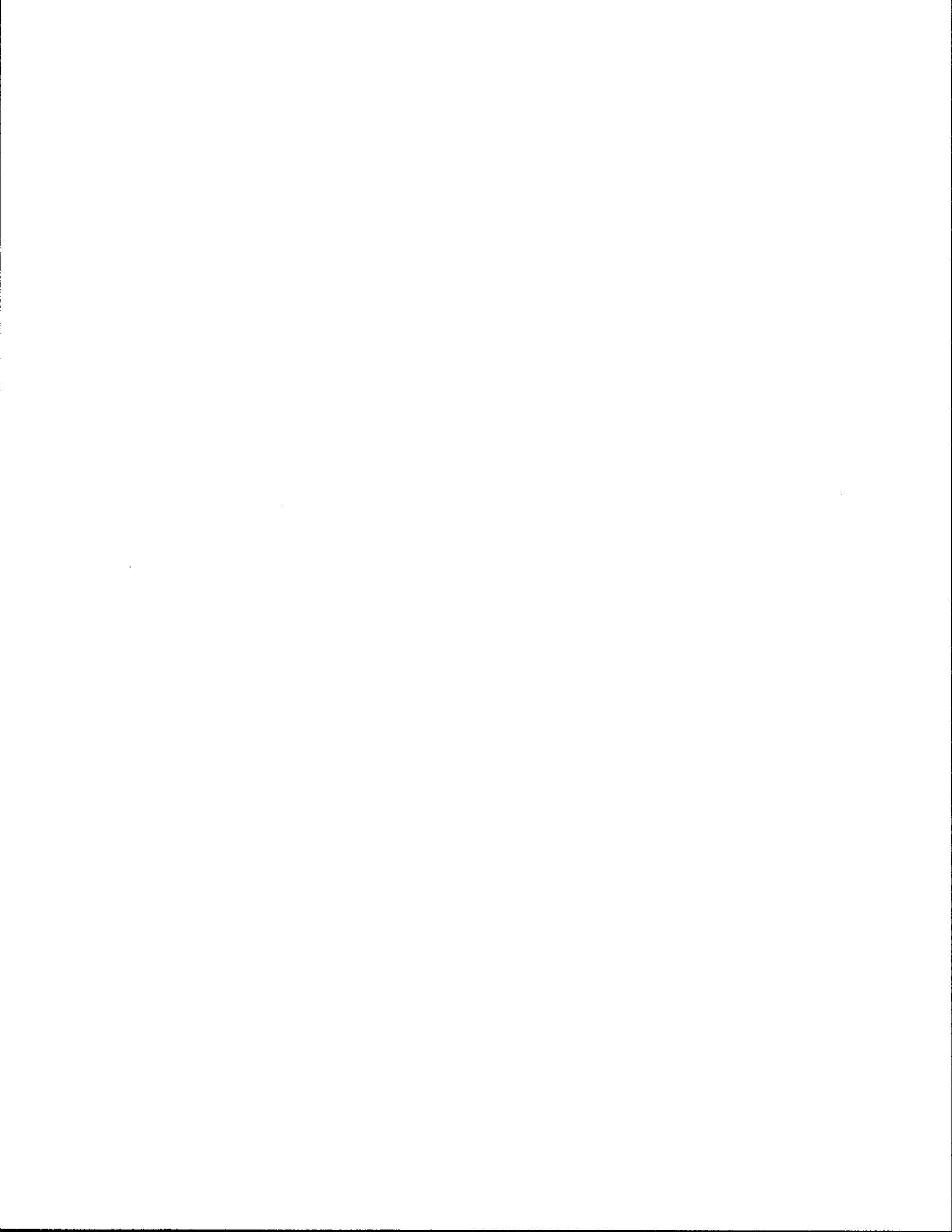
Figure 3. TCM Analyst group in Windows

To start TCM Analyst 1.0, do the following:

1. Open the TCM Analyst program group in the Program Manager.
2. Double-click on the TCM Analyst 1.0 program icon.

To enter data in the emission factor files, do the following:

1. Open the TCM Analyst program group in the Program Manager.
2. Double-click on the appropriate emission factor program icons.



CHAPTER III. DATA REQUIREMENTS

The data inputs to the TCM Analyst range from travel characteristics and travel behavior to the associated project costs and emission factor data. A Data Input Module in the TCM Analyst organizes the different data types to streamline data collection efforts. This chapter provides information for obtaining the required data.

DATA SOURCES

Table 1 shows some different types of data required by the TCM Analyst and their possible sources. The regional data sources include:

- Federal census
- Local and state transportation departments
- Local transit agencies
- Local metropolitan planning agencies/organizations (MPOs)
- Local and state ridesharing agencies
- Travel demand models
- Travel surveys

DEFAULT VALUES

In most cases, some of the data required for the study region may not be available. In these cases, default values may be used.

Care should be taken in using default values in the analysis. Default values were developed in varying geographies and urban transportation systems and may not represent the study region. For instance, the travel characteristics in Los Angeles, California, may not apply to smaller urbanized areas like Austin, Texas. The use of a default value that is inappropriate for the study region may cause errors in the estimates of TCM effectiveness. A list of default values is provided in Appendix A.

Table 1
Data Used in TCM Methodologies

Data Type		Census	State DOT	Transit Agency	MPO	Rideshare Agency
Travel data	Single occupant vehicle work and non-work trips per day				X	
	Shared vehicle work and non-work trips per day				X	
	Percent of work and non-work trips occurring in peak period of day				X	
	VMT by trip type in peak and off-peak periods		X		X	
	Average work trip distances	X	X		X	X
	Average non-work trip distances				X	
	Average speeds for peak and off-peak periods		X		X	
	Relative costs of different modes as well as cost ranges			X	X	
	Elasticity of mode choice with respect to cost		X		X	
	Elasticity of speed with respect to volume		X		X	
	Length of peak period				X	
Average vehicle occupancy			X	X		
Project data	Average number of people per carpool					X
	Fraction of carpoolers who do not drive to park-and-ride lots					X
	Fraction of carpoolers who join existing carpools					X
	Fraction of carpoolers who form new carpools					X
	Average distance to park-and-ride lots					X
	Frequency of ridesharing, telecommuting					X
	Fraction of telecommuters who work from satellite centers				X	X
Average distance to satellite centers				X	X	
Census data	Number of individuals over 16	X				
	Number of employed persons	X				
	Total population in study regions	X				
	Number of people per household	X				
	Percent of population of driving age that does not own a vehicle	X				

Source: Adapted from (4)

ELASTICITIES

The TCM Analyst uses several elasticities to estimate TCM participation and their trip/traffic effects. These elasticities include:

- Elasticity of peak speed with respect to volume
- Elasticity of off-peak speed with respect to volume
- Elasticity of mode choice with respect to cost
- Elasticity of transit ridership with respect to fare
- Elasticity of parking demand with respect to cost
- Elasticity of travel time with respect to cost
- Elasticity of HOV demand with respect to travel time

Elasticities can be developed for specific regions. Data must be collected for several projects in order to derive these elasticities. Three methods can be used to estimate elasticities: the point, arc, and shrinkage factor methods. These methods are illustrated in Table 2.

USE OF EPA'S MOBILE EMISSION FACTOR MODEL

MOBILE is the EPA-approved emission factor model for the United States, except California. The model uses inputs to characterize the region (i.e., VMT mix, vehicle registration information, vehicle speeds, etc.) in developing emission factors to represent the study region. The inputs to the MOBILE model are important to the estimated changes in emissions because incorrect MOBILE input files will yield inaccurate results and misrepresent the study region.

For users who are unfamiliar with the MOBILE emission factor model the *MOBILE5a User's Guide* (EPA, March 1993) provides the reader with a working knowledge of MOBILE's inputs and formats. It is important to note that MOBILE5a will produce emission factors for nine vehicle categories and a composite factor for all vehicles. These vehicle types are listed in Table 3.

Table 2
Elasticity Methods (4)

Method	Formula
Point Elasticity	$\epsilon_p = \frac{dQ}{dP} \times \frac{P}{Q}$ <p> ϵ_p = point elasticity P = price Q = quantity demanded at price P </p>
Arc Elasticity	$\epsilon_a = \frac{\Delta \log Q}{\Delta \log P} = \frac{\log Q_2 - \log Q_1}{\log P_2 - \log P_1}$ <p> ϵ_a = point elasticity Q_1, Q_2 = demand before and after P_1, P_2 = price or service before and after </p>
Shrinkage Factor (Shrinkage Ratio)	$\epsilon_s = \frac{\Delta \frac{Q}{Q_1}}{\Delta \frac{P}{P_1}} = \frac{\frac{(Q_2 - Q_1)}{Q_1}}{\frac{(P_2 - P_1)}{P_1}}$ <p> ϵ_s = point elasticity </p>

Table 3
MOBILE5a Vehicle Categories

Category	Description
LDGV	Light-duty gasoline vehicle
LDGT1	Light-duty gasoline truck under 6,000 lbs. GVW
LDGT2	Light-duty gasoline truck over 6,000 lbs. GVW
LDGT	Composite of light-duty gasoline trucks
HDGV	Heavy-duty gasoline vehicles
HDDV	Heavy-duty diesel vehicles
LDDV	Light-duty diesel vehicles
LDDT	Light-duty diesel trucks
MC	Motorcycles

After a MOBILE5a run is made, specific emission factors can be extracted and input into the two emission factor files used by the TCM Analyst. These two files are denoted by their emission season (CO or ozone). Files for both emission seasons are provided for the user to evaluate potential TCMs for specific times of the year and for the type of pollutant an area is in nonattainment. The analysis of only one or both emission seasons is available in the TCM Analyst.

Control Flag Settings for the TCM Analyst

Several control flag settings must be used when running MOBILE5a for TCM Analyst purposes. These flags are identified in Table 4. An example input file is provided in Figure 4. It is important that the formats are followed exactly for MOBILE5a to run correctly.

Table 4
Critical Control Flag Setting for MOBILE5a

Field	Variable Name	Description
5	VMFLAG	1=MOBILE5a VMT mix or 3=User supplies a single VMT mix for all scenarios
12	LOCFLAG	2=One Local Area Parameter record input for all scenarios
14	OUTFMT	3=112 column descriptive format
15	PRTFLAG	4=Calculate and output emission factors for all three pollutants
16	IDLFLAG	2=Idle emission factors calculated and printed (in addition to exhaust emission rates)
17	NMHFLAG	1=Total hydrocarbon (THC) emission factors
18	HCFLAG	3=Print sum and component emission factors for THC

1		BEGIN CONTROL SECTION
Example Input File for MOBILE5a		
1		
1		
3		
3		
1		
2		
1		
2		
1		
2		
1		
3		
4		
2		
1		
3		
.679.195.053.019.010.003.037.004	BEGIN VMT MIX SECTION	
.042 .077 .074 .069 .065 .068 .070 .051 .055 .058	BEGIN ANNUAL MILEAGE	
.054 .060 .053 .042 .031 .019 .020 .019 .014 .010	ACCUMULATION RATES	
.015 .010 .009 .008 .007		
.038 .066 .077 .068 .082 .070 .068 .048 .050 .049		
.036 .048 .044 .039 .031 .021 .026 .024 .019 .013		
.025 .016 .016 .013 .012		
.037 .062 .059 .037 .065 .052 .055 .042 .051 .040		
.037 .075 .062 .064 .051 .045 .045 .035 .018 .011		
.017 .011 .011 .009 .009		
.021 .031 .027 .033 .047 .052 .048 .034 .043 .040		
.053 .073 .057 .046 .036 .048 .047 .042 .034 .026		
.049 .032 .031 .026 .025		
.042 .077 .074 .069 .065 .068 .070 .051 .055 .058		
.054 .060 .053 .042 .031 .019 .020 .019 .014 .010		
.015 .010 .009 .008 .007		
.038 .066 .077 .068 .082 .070 .068 .048 .050 .049		
.036 .048 .044 .039 .031 .021 .026 .024 .019 .013		
.025 .016 .016 .013 .012		
.028 .024 .028 .046 .059 .087 .066 .042 .057 .075		
.095 .054 .069 .050 .019 .023 .028 .032 .026 .015		
.022 .015 .014 .012 .014		
.024 .063 .044 .053 .102 .094 .068 .086 .103 .090		
.074 .196 .000 .000 .000 .000 .000 .000 .000 .000		
.000 .000 .000 .000 .000		
87 18 75 20 0. 0. 073 2 1 2221 1 11	BEGIN I/M PROGRAM SECTION	
86 80 20 2221 21 073. 22222222	BEGIN ANTI-TAMPERING SECTION	
Test-----TEST. 26.0 63.0 11.6 11.6 90	BEGIN LAP RECORD	
1 90 35.0 50.7 00.0 00.0 00.0 1	BEGIN SCENARIO RECORD	

Figure 4. Example Input File for MOBILE5a

TCM Analyst Emission Factor Needs

The TCM Analyst uses two emission factor files for analysis: one for the CO season and the second for the ozone season. In each emission factor file, emission factors are developed from MOBILE5a. Figure 5 shows the locations of the emission tables in the two TCM Analyst emission factor files. The emission tables in the TCM Analyst include: (1) composite exhaust emission factors for speeds ranging from 10.0 miles per hour (mph) to 50.0 mph at 0.1 mph increments, (2) exhaust emission factors by vehicle type for speeds ranging from 20 mph to 60 mph at 5 mph increments, (3) evaporative emission factors by vehicle type for speeds ranging from 20 mph to 60 mph at 5 mph increments, (4) trip start emission factors, (5) hot soak emission factors, (6) diurnal emission factors, and (7) idle emission factors. Each of these seven emission factor groups are discussed in more detail below.

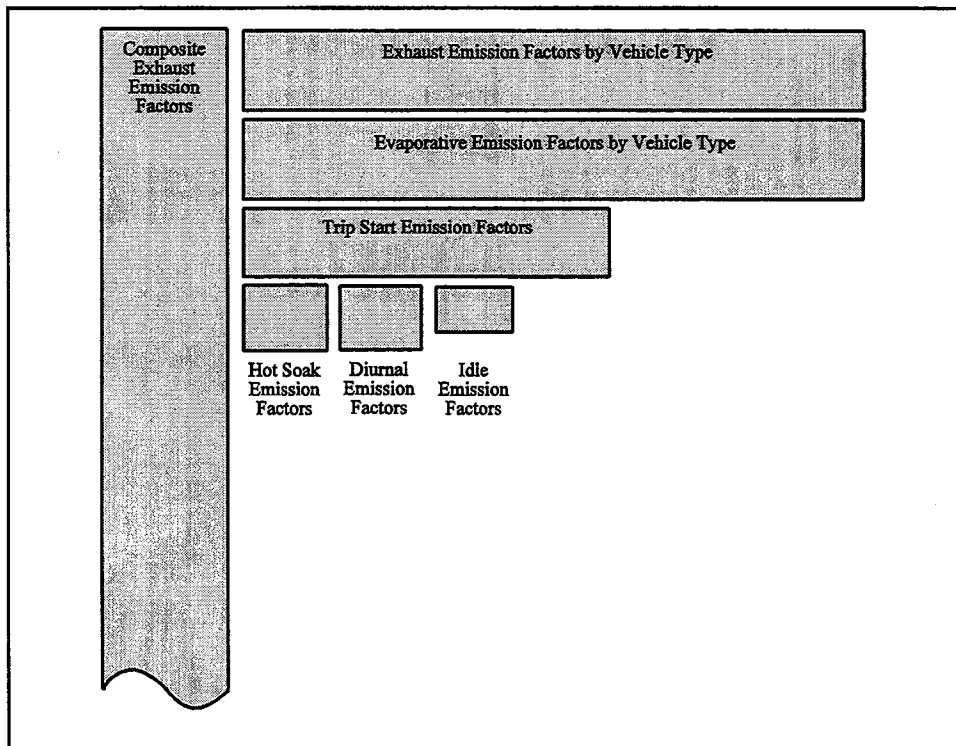


Figure 5. Representation of TCM Analyst emission factor file

To complete the TCM Analyst emission factor input files, five specific MOBILE5a scenario record types are required. These scenario records may be appended to the MOBILE5a input file or run independently. Output from these MOBILE5a runs are used in the TCM Analyst's emission factor files. Figure 6 shows an example of a MOBILE5a output file from which the emission factors required by the TCM Analyst can be extracted. The required emission factors are extracted from many parts of the output to create the TCM Analyst emission factor files.

```

0Emission factors are as of Jan. 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 1990      I/M Program: Yes      Ambient Temp: 51.1 / 51.1 / 51.1 (F) Region: Low
                    Anti-tam. Program: Yes Operating Mode: 0.0 / 0.0 / 0.0 Altitude: 500. Ft.
                    Reformulated Gas: No
0 Veh. Type:      LDGV      LDGT1      LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV      MC      All Veh
+
Veh. Speeds:      2.5        2.5        2.5        2.5        2.5        2.5        2.5        2.5        2.5
VMT Mix:          0.679      0.195      0.053      0.019      0.010      0.003      0.037      0.004
0Composite Emission Factors (Gm/Mile)
Total HC:         29.01      29.26      52.23      34.17      77.78      1.39      1.89      7.87      20.13      30.044
Exhaust HC:      14.30      15.90      26.83      18.24      35.01      1.39      1.89      7.87      15.91      15.270
Evaporat HC:     0.53       0.70       1.04       0.78       2.00       4.02      0.609
Refuel L HC:     0.19       0.24       0.26       0.25       0.41
Running L HC:    14.14      12.62      24.33      15.12      40.73      14.128
Rsting L HC:     0.04       0.04       0.03       0.03       0.06
Exhaust CO:      194.41     204.36     350.16     235.52     536.94     4.05      4.68      46.50     160.18     203.029
Exhaust NOX:     2.52       2.60       3.12       2.71       5.93       2.88      3.08      39.14     0.90       3.988
0Evaporative Emissions by Component      Weathered RVP: 11.6      Hot Soak Temp: 59.3 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr)      Running Loss Temp: 60.7 (F)
Resting Loss Temp: 48.4 (F)
Hot Soak      1.32      1.30      2.09      1.55      3.49
WtDiurnal    8.97      13.42     22.65     16.36     39.33
Multiple     17.38     22.78     26.86     24.08     40.81
Crankcase    0.02      0.04      0.12      0.06      0.20
Refuel       3.77      3.77      3.77      3.77      3.77
Resting      0.04      0.04      0.04      0.04      0.06
  
```

Figure 6. Example Output from MOBILE5a

Start Emissions

The location of the trip start emission factors in the TCM Analyst emission factor files is shown in Figure 5. The first, second, and third MOBILE5a scenario records characterize the study region for 100 percent cold starts, 100 percent hot starts, and 100 percent hot stabilized, respectively.

To run MOBILE5a for these vehicle states, three MOBILE5a input fields in the scenario records (5, 6, and 7) must be set as shown in Table 5. Each of these MOBILE5a scenario records should be run at a speed of 26 mph. The 26 mph represents the average speed during the trip-start

portion of the Federal Test Procedure (FTP) used to develop emission rates. After these MOBILE5a scenario records are created, MOBILE5a can be run or the MOBILE5a input file may be appended for additional scenario records.

Table 5
Vehicle State Inputs for MOBILE5a Scenario Records

Vehicle State	Field 5, PCCN (non-catalyst, cold-start mode)	Field 6, PCHC (catalyst-equipped, hot-start mode)	Field 7, PCCC (catalyst-equipped, cold-start mode)
100% Cold Starts	100.	00.0	100.
100% Hot Starts	00.0	100.	00.0
100% Hot Stabilized	00.0	00.0	00.0

From the MOBILE5a output file, the exhaust emission factors for all pollutants by vehicle type are extracted and used them in the TCM Analyst emission factor files.

The following summarize how to obtain the trip start emission factors:

- Create 3 MOBILE5a scenario records
- Set speed to 26 mph in each MOBILE5a scenario record
- Vary Fields 5, 6, and 7 in the MOBILE5a scenario records for each of the vehicle states
- Run MOBILE5a or append MOBILE5a input file
- Extract exhaust emission factors by vehicle type for CO, NOx, and HC

Exhaust and Evaporative Emissions

Exhaust and evaporative emissions require a fourth type of scenario record in MOBILE5a. Exhaust emissions are created when the vehicle is operating. Evaporative emissions occur as the fuel passes into the engine and turns into gases due to the heat of the engine. To obtain these factors, 400 scenario records ranging from 10.0 mph to 50.0 mph at increments of 0.1 mph must be created.

The composite exhaust emission factors, on the far left of the TCM Analyst emission factor file, require the following data to be input: NOx exhaust, CO exhaust, and HC exhaust and

running loss at speeds ranging from 10.0 mph to 50.0 mph in increments of 0.1 mph in a 100 percent hot stabilized mode. The exhaust factors by vehicle type, at the top right of the file, require the same inputs but for speeds ranging from 20 mph to 60 mph in increments of 5 mph. The evaporative emission factors require the running loss, crankcase, and refueling factors on a grams per mile basis for a 100 percent hot stabilized mode. These factors are located in the Composite Emission Factors section of the MOBILE5a output record.

To summarize how to obtain the exhaust and evaporative emission factors:

- Create 400 MOBILE5a scenario records
- Set the vehicle state to 100 percent hot stabilized
- Set speeds from 10.0 mph to 50.0 mph in 0.1 mph increments
- Run MOBILE5a or append input file
- Extract exhaust emission factors by vehicle type and composite for CO, NO_x, and HC
- Extract running loss, crankcase, and refueling factors for HC on a grams per mile basis by vehicle type and composite for running loss

Hot Soak and Diurnal Emissions

Figure 5 shows the location of the hot soak and diurnal emission factors in the TCM Analyst emission files. These emission factors are independent of speed but are dependent on environmental factors including ambient temperature. The information extracted from the MOBILE5a output file is the hot soak emission factor by vehicle type and the weighted diurnal (WtDiurnal) and multiday diurnal (Multiple) emission factors by vehicle type. These factors are taken from output of previous scenario records and do not require the creation of new scenario records.

To summarize how to obtain the hot soak and diurnal emission factors:

- Use results from evaporative and exhaust scenario records
- Extract hot soak, weighted diurnal, and multiday diurnal emission factors by vehicle type

Idle Emissions

The location of the idle emission factors in the TCM Analyst emission factor files is shown in Figure 5. The fifth scenario record type should be set at a speed of 2.5 mph and should represent a 100 percent hot stabilized vehicle state. Only the exhaust emission factors for HC, CO, and NO_x by vehicle type are used from this run. Before inputting the idle emission rates into the TCM Analyst, multiply the MOBILE5a exhaust emission factors are multiplied by 2.5 to convert the units of the emission rate from grams per mile to grams per hour ($EF_{idle} = EF_{2.5MPH} * 2.5$).

Obtaining the idle emission factors can be summarized as follows:

- Create one MOBILE5a scenario record
- Set speed to 2.5 mph
- Set the vehicle state to 100 percent hot stabilized
- Run MOBILE5a
- Extract exhaust emission factors for CO, NO_x, and HC by vehicle type
- Multiply 2.5 by each emission factor to convert from grams per mile to grams per hour

CHAPTER IV. USING THE TCM ANALYST

The TCM Analyst uses Microsoft Excel (Excel) as its operating environment. Users new to the Excel environment are encouraged to go through the tutorial provided with the Excel software before continuing with the TCM Analyst. The Excel tutorial will familiarize the user with the basic functions of Excel and allow the user to take full advantage of both software packages.

The TCM Analyst is comprised of seven modules:

1. Data Input Module
2. Travel Module
3. Emissions - CO Season Module
4. Emissions - Ozone Season Module
5. Cost-Effectiveness Module
6. Results Module
7. TCM Summary Module

In addition to these modules, several features are included with the TCM Analyst. These features include analysis tools for determining the effect of specific variables on the program's results, a view manager to help move around the Data Input Module, and a menu item on the Excel menu bar as an alternative to the traditional control keys that are provided with the TCM Analyst. The modules and features used in the TCM Analyst are explained in detail below.

NOTE: Due to differences in monitor resolution, the example screens provided here may not be sized as the user's particular monitor may display. Either the zoom function in Excel or the resolution used in Windows may be changed to the user's preference for sizing the screens in the model. To adjust the screens in Excel, select View, Zoom, set the screen to the user's preference, and save the file. To adjust the resolution of the user's monitor in Windows, run Windows Setup from the command line or select the Windows Setup icon in the Main program group.

MAIN SCREEN

Figure 7 shows the Main screen. This screen is activated by double-clicking the TCM Analyst 1.0 icon. The functions of the Main screen are:

To	Do The Following
Load the TCM Analyst for use	Click on the <i>Begin Analysis</i> button.
Access the Quick Keys screen	Click on the <i>Quick Keys</i> button or select it from the TCM Analyst menu. To return to the previous screen from the Quick Keys screen, click on the <i>Return to Previous Screen</i> button
Exit the TCM Analyst	Click on the <i>Quit</i> button

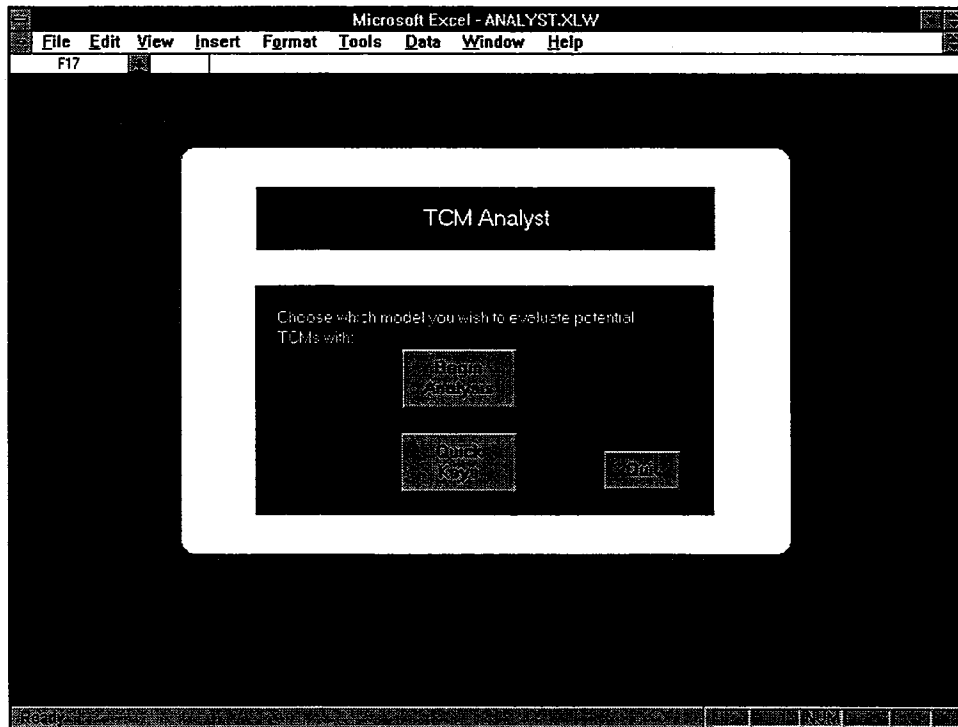


Figure 7. TCM Analyst Main screen

TCM ANALYST MODULES

The TCM Analyst has six modules which are reviewed below. The Data Input Module is the only module that can be edited in the TCM Analyst. The user may edit any of the input values in this module. The remaining modules are provided for the user's reference and cannot be modified in any way.

Data Input Module

The Data Input Module shown in Figure 8 is used to input most of the data required to run the TCM Analyst, with the exception of the emission factor data discussed in Chapter III. The module is divided into several sections (e.g., General Data Inputs, Work Schedule Changes) and subsections (e.g., Census, Trip & Travel Information) to simplify data input. When changes are made to the Data Input Module, save the file to prevent the loss of any new data.

Action	Data Description	Anywhere, USA
	Average household size	3.31
	Fraction of population that does not own a vehicle	38%
	Fraction of population that is employed (16+ years)	51%
	Fraction of population that is unemployed (16+ years)	6%
	Total registered vehicles in region	227,000
	Regional hourly wage	\$6.50
	Total number of person trips per day	1,975,822
	Total number of vehicle trips per day	1,337,658
	Total vehicle trips in peak period	535,063
	Total vehicle trips in off-peak period	802,595
	Total work vehicle trips in peak period	240,138
	Total work vehicle trips in off-peak period	60,034
	Percent of non-work travel that occurs in the peak periods	28.8%
	Percent of work travel that occurs in the peak periods	60.8%
	Fraction of person trips made via shared mode	20.0%
	Average passenger vehicle occupancy	1.95
	Number of work trips per vehicle commute day	2
	Number of non-work trips per day per vehicle	5
	Work trip generation rate for SOV users (trips per day)	1.71
	Non-work trip generation rate for SOV users (trips per day)	3.25
	Total trips per day affected by the speed increase	529,712

Figure 8. TCM Analyst Data Input screen

One row in each of the TCM action sections is labeled "Evaluate TCM?". To evaluate the TCM, enter a "1" in the data cell. This will activate the evaluation process and present the estimated benefits in the Results Module.

To input original data:

1. Enter the study area (e.g., Houston, TX)
2. Enter the study year
3. Enter a run description
4. Enter the name of the analyst
5. Enter current date
6. Enter data values to right of Data Description column
7. Save changes to file

Travel Module

Figure 9 shows the Travel Module screen. This module estimates the effects of the selected TCM on vehicle trips, VMT, and regional speeds. Chapter V provides more detail on how these effects are calculated.

The module is available only for reference and is structured so that each step in the evaluation process can be examined. The contents of each cell can also be viewed to study the intermediate results of the TCM Analyst procedure.

Emission Modules

The Emissions - CO Season Module, shown in Figure 10, and Emissions - Ozone Season module are also available for reference. These modules estimate the changes in vehicle emissions based on travel changes estimated from the Travel Module. Chapter VI provides more detail on the steps used to estimate the vehicle emissions in the emission modules.

These modules are linked to the emission factor files in the TCM Analyst group in the Program Manager of Windows. The data in the emission factor files are shared with the Emission Modules to estimate various emission impacts of a TCM action.

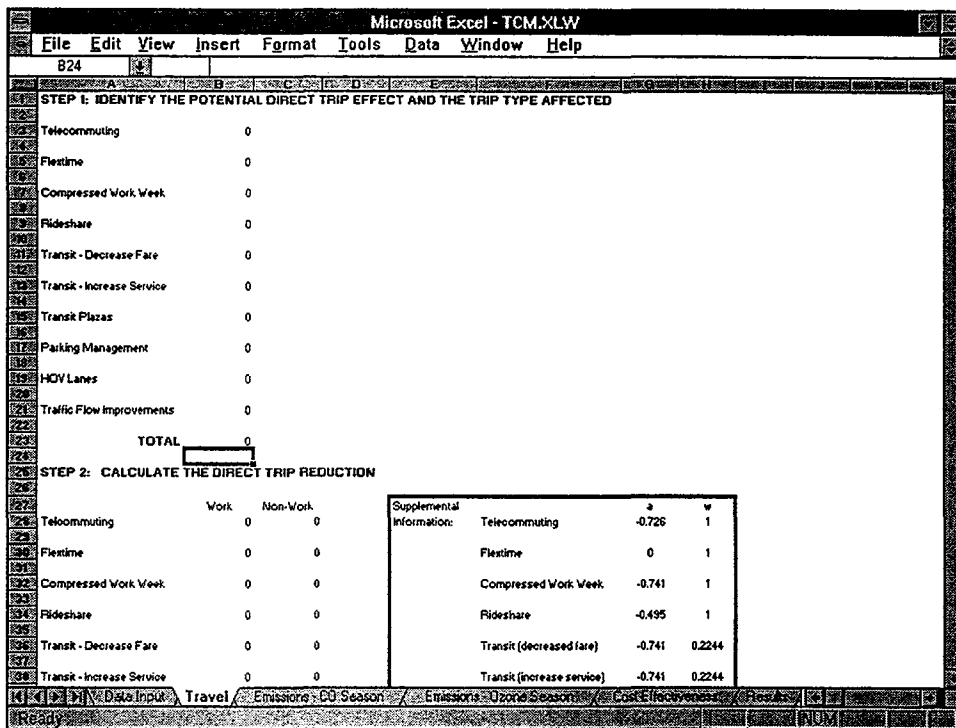


Figure 9. TCM Analyst Travel Module screen

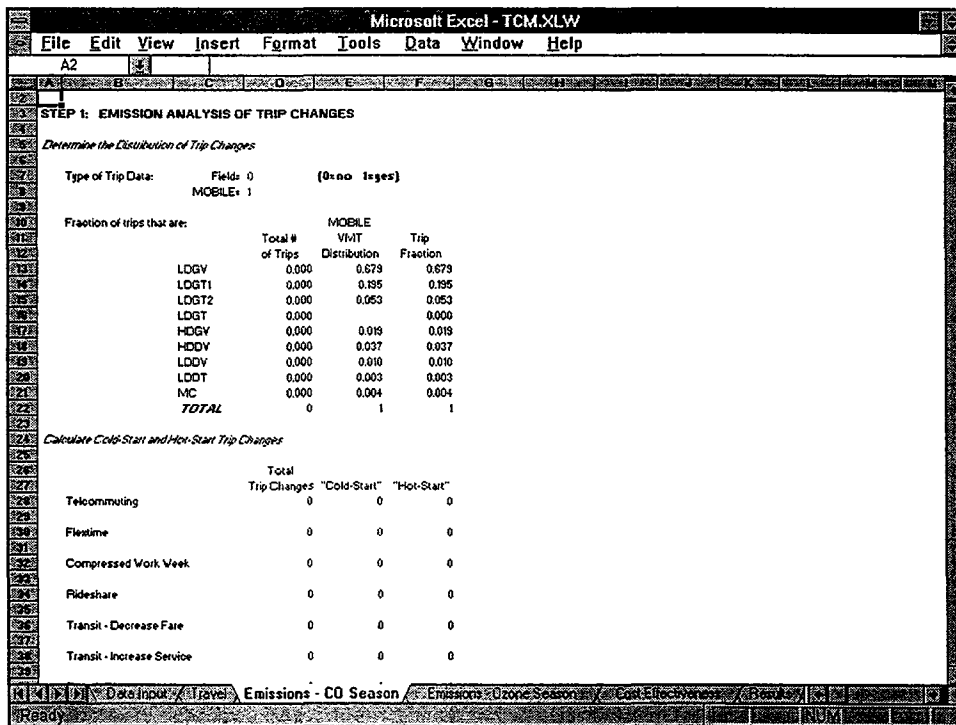


Figure 10. TCM Analyst Emissions Module screen

Cost-Effectiveness Module

Figure 11 shows the Cost-Effectiveness Module. This module calculates the costs associated with the implementation of TCMs. Discussion of each step in this module is provided in Chapter VII.

The Cost-Effectiveness Module, like the three previous modules, is provided for reference. Once again, the module is structured to enable the user to examine each step of the TCM evaluation process.

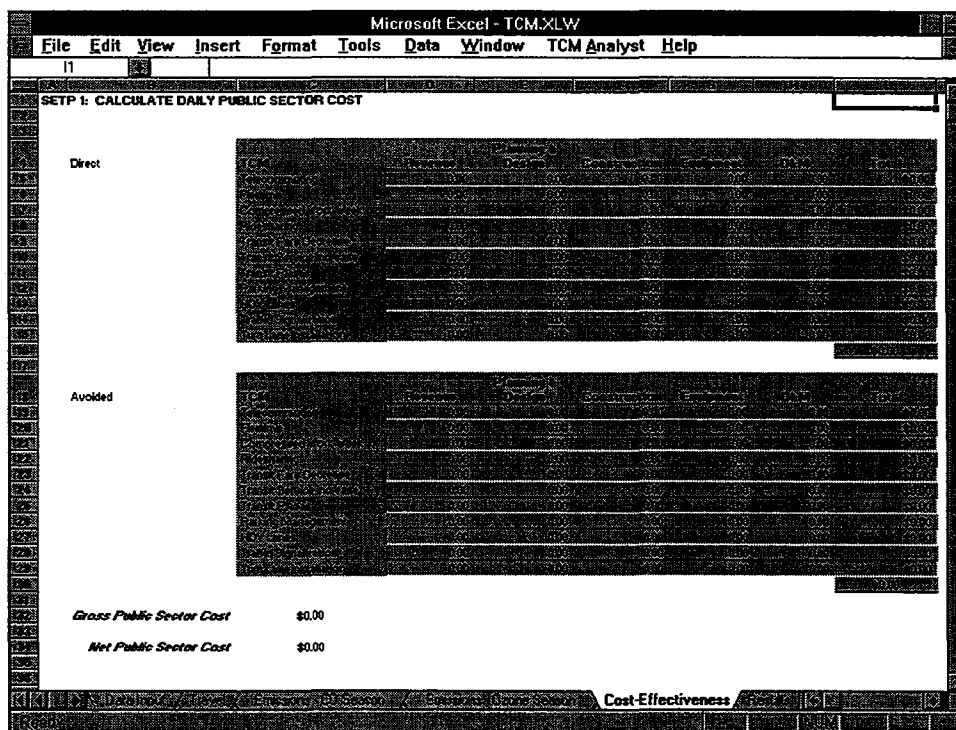


Figure 11. TCM Analyst Cost-Effectiveness Module screen

Results Module

The results reported by the TCM Analyst include the travel and emission impacts and cost-effectiveness of the TCM evaluated. A sample of the Results Module screen is provided in Figure 12.

Microsoft Excel - TCM.XLW

File Edit View Insert Format Tools Data Window Help

J2

Region: Anywhere, USA
Year: 1990
Run Title: Generic
Analyst: John J. Doe
Date: 1-Jan-90

PAGE 1 of 2

Region: Anywhere, USA
Year: 1990
Run Title: Generic
Analyst: John J. Doe
Date: 1-Jan-90

Travel Changes				
	D	Peak	Off-Peak	Total
All Vehicle Trips	0	0	0	0
Work Vehicle Trips	0	0	0	0
VMT	0	0	0	0
Speed	0.0%	0.0%		N/A

Emission Changes (kilograms/day)				
CO Season				
	Trip Changes	VMT Changes	Fleet Speed Changes	Total
HC	0	0	0	0
CO	0	0	0	0
NOx	0	0	0	0

Ozone Season				
	Trip Changes	VMT Changes	Fleet Speed Changes	Total
HC	0	0	0	0
CO	0	0	0	0
NOx	0	0	0	0

Relative Changes Travel	
	Peak
All Vehicle Trips	0.00%
Work Vehicle Trips	0.00%
VMT	0.00%

Emissions	
	Emissions
HC	N/A
CO	N/A
NOx	N/A

Ready

Figure 12. TCM Analyst Results screen

Travel impacts are reported in terms of absolute changes in total and work-related vehicle trips, VMT, and regional speed for the peak and off-peak periods. Relative changes in these measures are also presented.

The emission impacts are presented for both emission seasons for three pollutants (CO, HC, and NOx) according to the cause of change (trip changes, VMT changes, fleet speed changes). The total reduction or increase in each type of pollutant for each emission season is reported. Relative changes in the emission impacts are also presented.

The cost-effectiveness results are presented in terms of gross and net cost to the public sector, the private sector, and the individual. The results are presented in terms of dollars per kilogram per day to allow for the comparison between potential TCMs.

If the user experiences problems printing the results screen, adjust the page setup so that the information prints on two pages. To do this, select the File menu and then select Page Setup. Adjust the percentage enlarge/reduce accordingly.

TCM Summary Module

This module presents the same information as presented in the Results Module, but for each TCM processed. A sample of this module is shown in Figure 13. The results presented in this module are to be used in a TCM program analysis or to compare benefits between different TCMs. TCM program analysis is discussed further in this chapter.

Microsoft Excel - TCM.XLW

File Edit View Insert Format Tools Data Window Help

TCM Analyst: TCM Summary

Region..... Anywhere, USA
 Year..... 1990
 Run Title..... Generic
 Analyst..... John J. Doe
 Date..... 1-Jan-90

Travel Changes

TCM	All Vehicle Trips			Work Vehicle Trips			VMT			Speed		
	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total
Telecommuting	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%
Flextime	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%
Compressed Work Week	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%
Ridesharing	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%
Transit Fare Decrease	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%
Transit Service Increase	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%
Transit Plaza	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%
Parking Management	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%
HOV Lanes	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%
Traffic Signalization	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%
Turn Lane Installation	0	0	0	0	0	0	0	0	0	0.00%	0.00%	0.00%

Emission Changes: CO Season (kg/day)

TCM	Trip Changes			VMT Changes			Fleet Speed Changes			Total		
	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
Telecommuting	0	0	0	0	0	0	0	0	0	0	0	0
Flextime	0	0	0	0	0	0	0	0	0	0	0	0
Compressed Work Week	0	0	0	0	0	0	0	0	0	0	0	0
Ridesharing	0	0	0	0	0	0	0	0	0	0	0	0
Transit Fare Decrease	0	0	0	0	0	0	0	0	0	0	0	0
Transit Service Increase	0	0	0	0	0	0	0	0	0	0	0	0
Transit Plaza	0	0	0	0	0	0	0	0	0	0	0	0
Parking Management	0	0	0	0	0	0	0	0	0	0	0	0
HOV Lanes	0	0	0	0	0	0	0	0	0	0	0	0
Traffic Signalization	0	0	0	0	0	0	0	0	0	0	0	0
Turn Lane Installation	0	0	0	0	0	0	0	0	0	0	0	0

TCM Summary

Figure 13. TCM Analyst TCM Summary screen

TCM ANALYST FEATURES

TCM Analyst Menu

The TCM Analyst includes a menu item (TCM Analyst) on the Excel menu bar shown in Figure 14. From this menu item, the user can access all of the features that the TCM Analyst offers. To access the TCM Analyst menu, type ALT + a, or click on TCM Analyst.

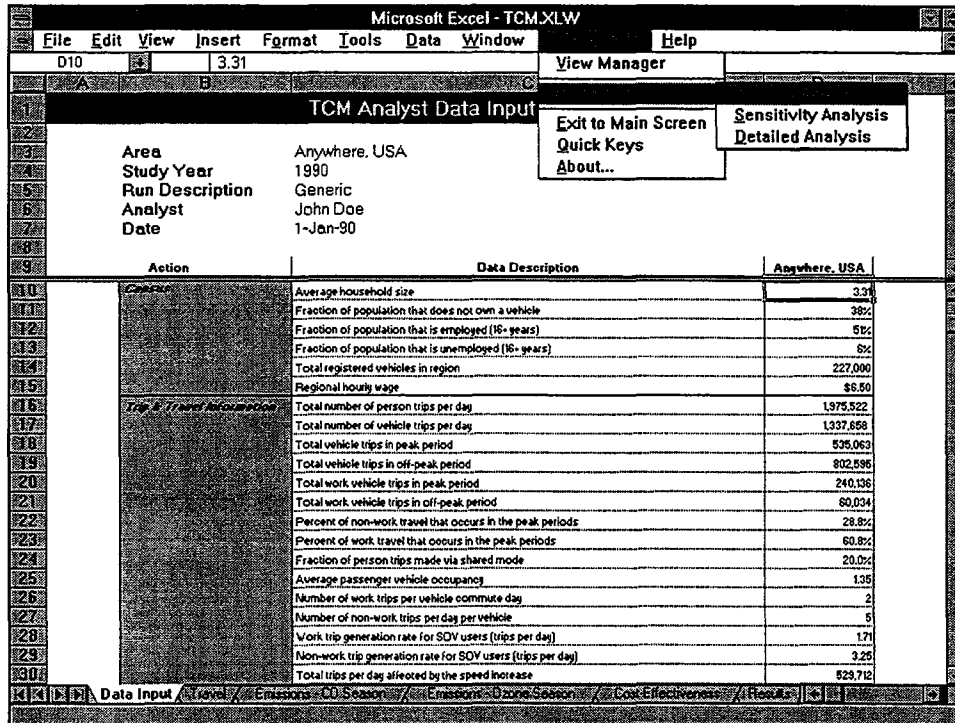


Figure 14. TCM Analyst customized menu

If preferred, the TCM Analyst Quick Keys can be used to access the TCM Analyst features. These Quick Keys are described in the following section.

Quick Keys

Several Quick Keys are provided to access program features. These keys invoke the same commands that can be selected from the TCM Analyst menu bar. Table 6 shows the key combinations to run the TCM Analyst features.

The control (CTRL) key and a lowercase letter must be pressed to run a specific program feature.

Table 6
List of Quick Key Functions

CTRL + Key	Program Feature
b	Begin TCM Analysis
a	About this Program
i	Returns the Quick Keys Screen
e	Closes the model and returns to the main screen
q	Exits the TCM Analyst from the Excel environment
v	Runs the TCM Analyst View Manager
t	Runs the Trend Analysis Tool
s	Runs the Sensitivity Analysis Tool
d	Runs the Detailed Analysis Tool
r	Returns to the previous screen from the Quick Keys screen

View Manager

Figure 15 shows the TCM Analyst View Manager ready for selection. The View Manager is used to adjust the Data Input Module for the TCM category of interest. These views are defined by TCM category in the Data Input Module. For instance, if transit improvements were selected, the View Manager would adjust the screen to begin at the top of the transit improvements category. The View Manager feature is available only in the Data Input Module. The views listed in the View Manager are shown in Table 7.

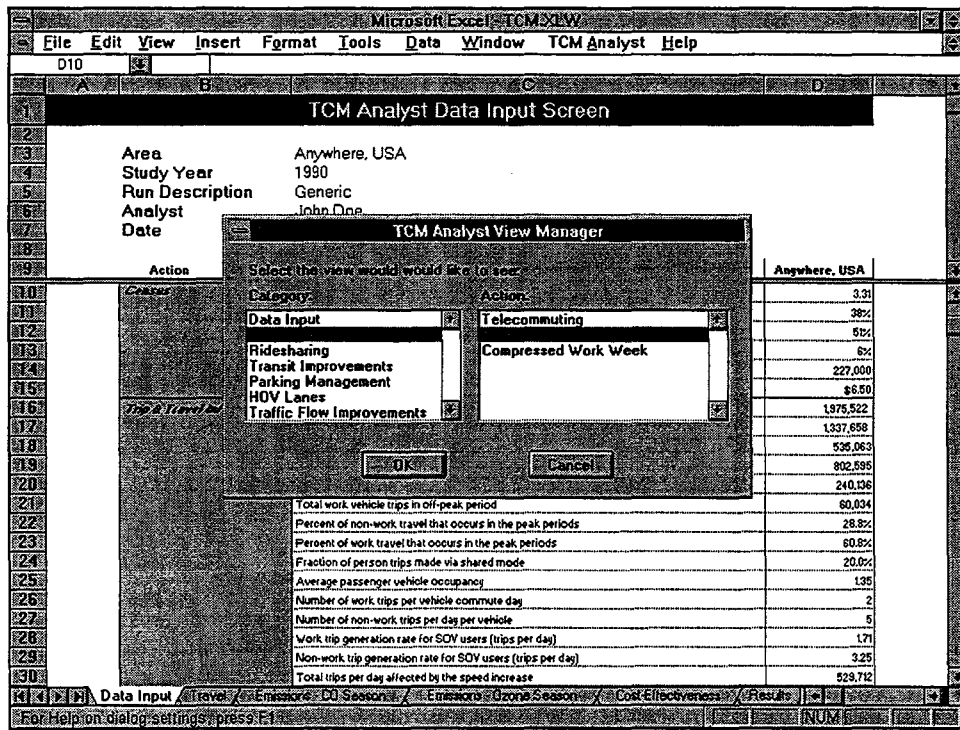


Figure 15. TCM Analyst View Manager

Table 7
Hierarchy of the TCM Analyst View Manager

TCM	Category
Data Inputs	Census Trip & Travel Information Vehicle Trip Distribution VMT Distribution Regional Emission Information Cost Information
Work Schedule Changes	Telecommuting Flextime Compressed Work Week
Ridesharing	
Transit Improvements	Transit Fare Decrease Transit Service Increase Transit Plazas
Parking Management	
HOV Lanes	
Traffic Flow Improvements	Signal Improvements Turn Lane Installation

To access the View Manager, do the following:

- Activate the Data Input Module
- Press CTRL + v or Select TCM Analyst, View Manager from the menu.
- Highlight a TCM item
- Highlight a Category item (see note below)

NOTE For TCMs without a category to choose from, the user must highlight the *** Select This *** item in the category box for the View Manager to operate correctly.

ANALYSIS TOOLS

Evaluating potential TCMs for a specific region is difficult without a historical basis to estimate the expected participation rates in new programs. Historical participation data help to focus the TCM scope descriptors to reasonable values for evaluation.

To ease the burden of TCM analysis, three analysis tools are included within the TCM Analyst: (1) trend analysis, (2) sensitivity analysis, and (3) detailed analysis. The analysis tools are helpful in testing inputs, including participation, that define the TCM program.

The differences between these analysis tools are described below, and examples of each analysis tool's output are included for reference in Appendix B. The output files created by these analysis tools may need the print scale changed to print correctly for the user's specific printer. To modify the print scale, select File, Page Setup from the main menu. Adjust the percentage accordingly, and check the output by previewing the print job.

Trend Analysis

The trend analysis tool is used to evaluate travel and emission effects for a particular variable over a range of values. For example, a user may want to test the participation rate in a flextime program or a change in parking prices under a parking management scheme. This tool requires the user to set a minimum and maximum value and a step size. By stepping through the

intermediate values, trends produced by the specific TCM scope descriptor can be evaluated and assessed.

The maximum number of allowed observations for this analysis tool is 300. If more than 300 observations are required for analysis, the user will need to make more than one file. The model will prompt the user to modify their inputs if they exceed the maximum number of observations. An example of this analysis tool in use is shown in Figure 16.

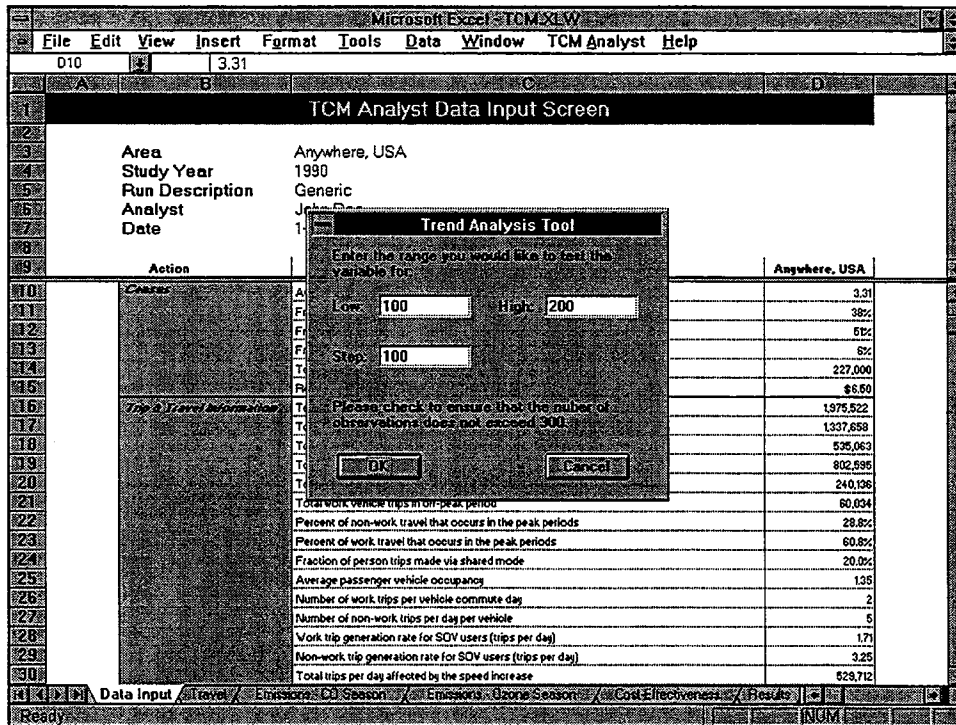


Figure 16. Example of trend analysis tool use

To use the trend analysis tool, do the following:

- Select the value cell to the right of the variable to be evaluated
- Select TCM Analyst, Analysis Tools, Trend Analysis from the menu or press CTRL + t
- Follow the prompts provided by the TCM Analyst for the data values and to save the newly created results file

Seven X-Y charts are created to examine the relationships between the analysis results and the variable being tested . These X-Y charts are: (1) Emissions Reductions (for HC, CO, and NOx by emission season), (2) HC Changes (by emission season), (3) CO Changes (by emission season), (4) NOx Changes (by emission season), (5) Vehicle Trip Changes (by peak or off-peak periods), (6) VMT Changes (by peak or off-peak periods), and (7) Speed Changes (by peak or off-peak periods).

Sensitivity Analysis

The sensitivity analysis tool allows the user to compare results from three input values for one specific variable. Each of the values should be greater than the previous value. If the values do not increase, the TCM Analyst prompts the user to modify the input values. Figure 17 shows an example of this tool being used in the TCM Analyst.

To use the sensitivity analysis tool, do the following:

- Select the value cell to the right of the variable to be evaluated
- Select TCM Analyst, Analysis Tools, Sensitivity Analysis from the menu, or press CTRL + s
- Follow the prompts provided by the TCM Analyst for each of the values and to save the newly created results file

Summary tables created by the sensitivity analysis tool display the emission reductions in kilograms per day and tons per day. Travel changes are also reported in terms of vehicle trips, VMT, and regional average vehicle speed for the peak and off-peak periods. Accompanying the tables are seven bar charts that display the information provided in the summary tables: (1) change in emissions in kilograms per day (kg/day) for the CO season, (2) change in emissions in kg/day for the ozone season, (3) change in emissions in English tons per day (tons/day) for the CO season, (4) change in emissions in tons/day for the ozone season, (5) change in trips for the peak and off-peak periods, (6) change in VMT for the peak and off-peak periods, and (7) change in regional average vehicle speed for the peak and off-peak periods.

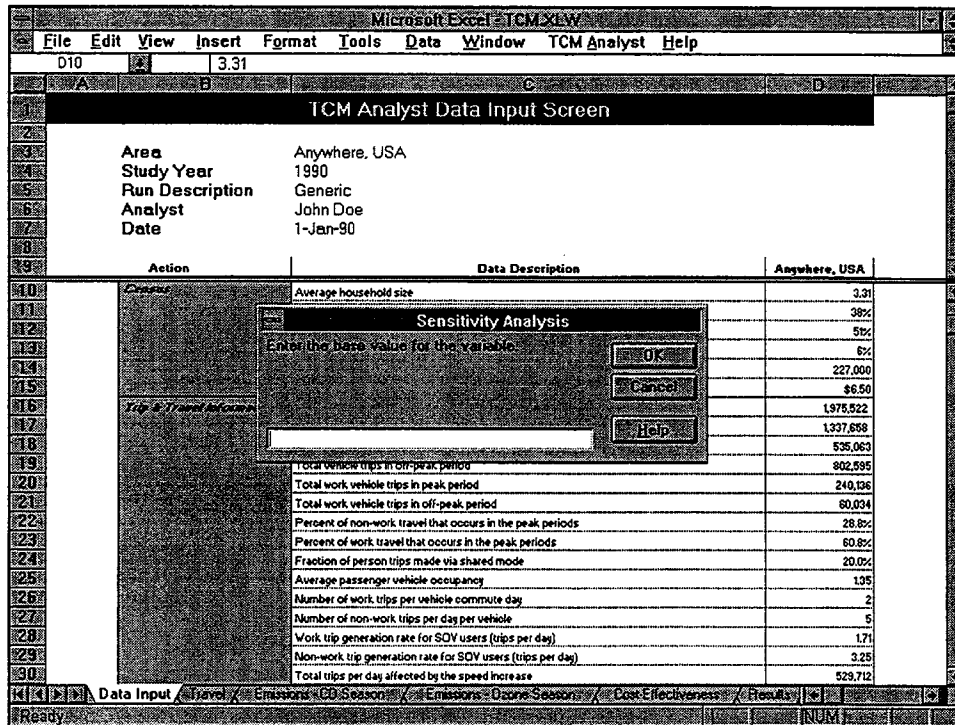


Figure 17. Example of sensitivity analysis tool use

Detailed Analysis

The detailed analysis tool allows the user to output several input values for a particular variable and to obtain the intermediate, step-by-step results for a particular variable. These intermediate results are extracted from each step in the analysis process for travel and emission changes. The maximum number of observations per detailed analysis file is six.

This analysis tool may be useful in determining the specific effects a TCM may impose once implemented. To use the detailed analysis tool:

- Select the value cell to the right of the variable to be evaluated
- Select TCM Analyst, Analysis Tools, Detailed Analysis from the menu or press CTRL + d
- Follow the prompts provided by the TCM Analyst for each of the values and to save the newly created results file

TCM PROGRAM ANALYSIS

A strategic implementation of TCM projects, as a program, is needed to maximize a region's travel and emission benefits. TCM projects implemented with no regard to other TCM projects, existing or planned, can sometimes have negative effects on travel and emissions. Currently, TCMs are evaluated independently and selected for implementation based upon their individual performance. Little analysis is performed to evaluate the effects of TCM programs.

Recognizing that TCMs are not evaluated as programs, an analysis methodology was developed based on existing literature about TCM relationships. This procedure was not programmed into the TCM Analyst 1.0 software, because although it provides a good first attempt at TCM program analysis, it did produce some counter-intuitive results in tests which necessitates further analysis before implementation. Thus, engineering judgement will continue to be the principal basis for making decisions on TCM interaction.

TCM relationships can be defined by three categories: negative, additive, and synergistic. Negative relationships occur between TCMs that compete for market share such as transit and rideharing. Additive TCM relationships occur when two TCMs have no effect on one another and operate independently, thus allowing the analyst to add the effects of the two independently acting projects. The last category is a synergistic relationship between TCMs. This relationship produces results that are more than an additive process. In these cases, one TCM may enhance the participation in another, thus producing a greater combined effect than each TCM would produce independently (e.g., guaranteed ride home and ridesharing).

The analysis procedure described here is based on a matrix developed from two sources: EPA's Transportation Control Measure: State Implementation Plan Guidance (5) and Rosenbloom (6). These matrices define relationships as positive, negative, or neutral. Based on the discussion in the previous paragraph, these would be equivalent to synergistic, negative, and additive. The resulting TCM interaction matrix, shown in Figure 18, required few assumptions to complete.

Legend												
+ Positive												
0 Neutral												
- Negative												
		Telecommuting	Flextime	Compressed Work Week	Ridesharing	Transit Fare Decrease	Transit Service Increase	Transit Plazas	Parking Management	HOV Lanes	Traffic Signalization	Intersection Improvements
Telecommuting												
Flextime	-											
Compressed Work Week	-	-										
Ridesharing	-	-	-									
Transit Fare Decrease	-	+	+	-								
Transit Service Increase	-	+	+	-	+							
Transit Plazas	-	+	+	-	+	+						
Parking Management	-	0	0	+	+	+	+					
HOV Lanes	-	-	-	+	+	+	+	+				
Traffic Signalization	-	0	0	-	-	-	-	-	-			
Intersection Improvements	-	0	0	-	-	-	-	-	-	-		+

Figure 18. TCM interaction matrix

A common problem identified in TCM program analysis is double-counting the participants. A reduction in work trip VMT can be claimed by each project independently; however, in conjunction, the projects cannot claim the same reduction in work trip VMT. One project must concede this benefit, partially or in full, because the projects do not act independently but rather as a system.

Effects from individual TCMs that naturally have a neutral effect are considered to have an additive characteristic in this analysis procedure. If projects interact neutrally, they neither compete for market share and detract from one another nor enhance the other projects' attractiveness or capabilities.

The procedure described here accounts for the interaction of one TCM with all other TCMs in a program. It does this by taking the relationships between TCMs and determining if

there is an overall positive or negative effect for a TCM if it were implemented with the other TCMs in a program. If the effect is negative, the results of the TCM are subtracted from the travel and emission analysis. If the affect is positive, the individual TCM results are added in the travel and emission analysis. Should a TCM be estimated to have no effect, or neutral, the results are added to the TCM program's estimated benefits.

Two examples of this procedure are provided below. The first example shows a small TCM program and how the analysis would proceed past the individual project analysis. The second example shows how counter-intuitive results are obtained from this process. The legend for the examples is shown below:

<u>Effect</u>	<u>Symbol</u>
Additive (positive)	+
Neutral	0
Negative (conflicting)	-

Example 1: Flextime, Ridesharing, and Parking Management

This example TCM program represents a set of strategies that could reasonably be implemented at a large employment center. Flextime is a work schedule change that is frequently used by employers to spread out the arrival and departure time of employees. Ridesharing is used to increase the Average Passenger Occupancy (APO) levels as defined in the Employer Trip Reduction program under the Clean Air Act Amendments of 1990. Parking management can sometimes be used where employers are able to control visitor and employee parking to encourage other modes of transportation.

The results of the relationship analysis are shown in Tables 8 through 10. As discussed previously, the relationship that flextime has with ridesharing and parking management is equivalent to a neutral position. This neutral position is then used to add the effects from the independent flextime project to the TCM program benefits. The same is true for ridesharing, shown in Table 9.

Table 8
TCM Program Example 1
TCM 1: Flextime

TCM Combination	Relationship
Flextime - Ridesharing	-
Flextime - Parking Management	+
Overall	0 ➡ +

Table 9
TCM Program Example 1
TCM 2: Ridesharing

TCM Combination	Relationship
Ridesharing - Flextime	-
Ridesharing - Parking Management	+
Overall	0 ➡ +

Table 10
TCM Program Example 1
TCM 3: Parking Management

TCM Combination	Relationship
Parking Management - Flextime	+
Parking Management - Ridesharing	+
Overall	+

TCM Program

TCM Program = Flextime + Ridesharing + Parking Management

Note that two of the TCMs initially have neutral effects after the relationship analysis; however, because they have a neutral effect, their benefits are added to the total program benefits.

Example 2: Transit Service Increase, HOV Lanes, Ridesharing, and Telecommuting

This example may characterize a regional partnership between employers, the state department of transportation, and the local transit agency. HOV lanes could be constructed with no additional programs to boost average vehicle occupancy; however, by starting a ridesharing program and increasing the service area of the transit service in conjunction with the HOV lane corridor, significant benefits may be gained. If telecommuting were implemented near the HOV lane corridor, some of the benefits gained by increases in AVO may be detracted.

The results of the TCM relationship analysis are shown in Tables 11 through 14. Interesting relationships can be seen as the number of TCMs in a program increase. Note in Table 11 that although transit service is complementary to the construction of HOV lanes, it competes for market share with ridesharing programs and telecommuting. Closer inspection also shows that rideharing has a similar relationship with the other TCMs in the program. Of particular interest is the negative effect of telecommuting on the three other TCMs. Telecommuting competes against all other TCMs in this program for market share.

Table 11
TCM Program Example 2
TCM 1: Transit Service Increase

TCM Combination	Relationship
Transit Service Increase - HOV Lanes	+
Transit Service Increase - Ridesharing	-
Transit Service Increase - Telecommuting	-
Overall	-

Table 12
TCM Program Example 2
TCM 2: HOV Lanes

TCM Combination	Relationship
HOV Lanes - Transit Service Increase	+
HOV Lanes - Ridesharing	+
HOV Lanes - Telecommuting	-
Overall	+

Table 13
TCM Program Example 2
TCM 3: Ridesharing

TCM Combination	Relationship
Ridesharing - Transit Service Increase	-
Ridesharing - HOV Lanes	+
Ridesharing - Telecommuting	-
Overall	-

Table 14
TCM Program Example 2
TCM 4: Telecommuting

TCM Combination	Relationship
Telecommuting - Transit Service Increase	-
Telecommuting - HOV Lanes	-
Telecommuting - Ridesharing	-
Overall	-

TCM Program

$$\text{TCM Program} = \text{HOV Lanes} - \text{Transit Service Increase} - \text{Ridesharing} - \text{Telecommuting}$$

Observations on TCM Program Analysis Procedure

Two distinct observations can be made about the analysis procedure described above. First, the analysis procedure lacks the ability to accurately define relationships between two TCMs. At the current time, the profession's knowledge about TCM relationships remains limited. The research community is unaware of the full effects when two TCMs are implemented as a program. In question is the level of positive or negative effects between TCMs. For example, it is not known if a TCM has a completely positive effect (100%) on a TCM or only a moderate effect (50%). The same is true for TCMs with conflicting relationships. Research has not begun to investigate the synergistic relationships between TCMs. The level of effort required to conduct such quality studies on synergistic effects is unavailable due to scope and resources of such a study. This analysis procedure assumes that all effects are either 100% positive or 100% negative. The developers understand that this is not always the case; however, with such

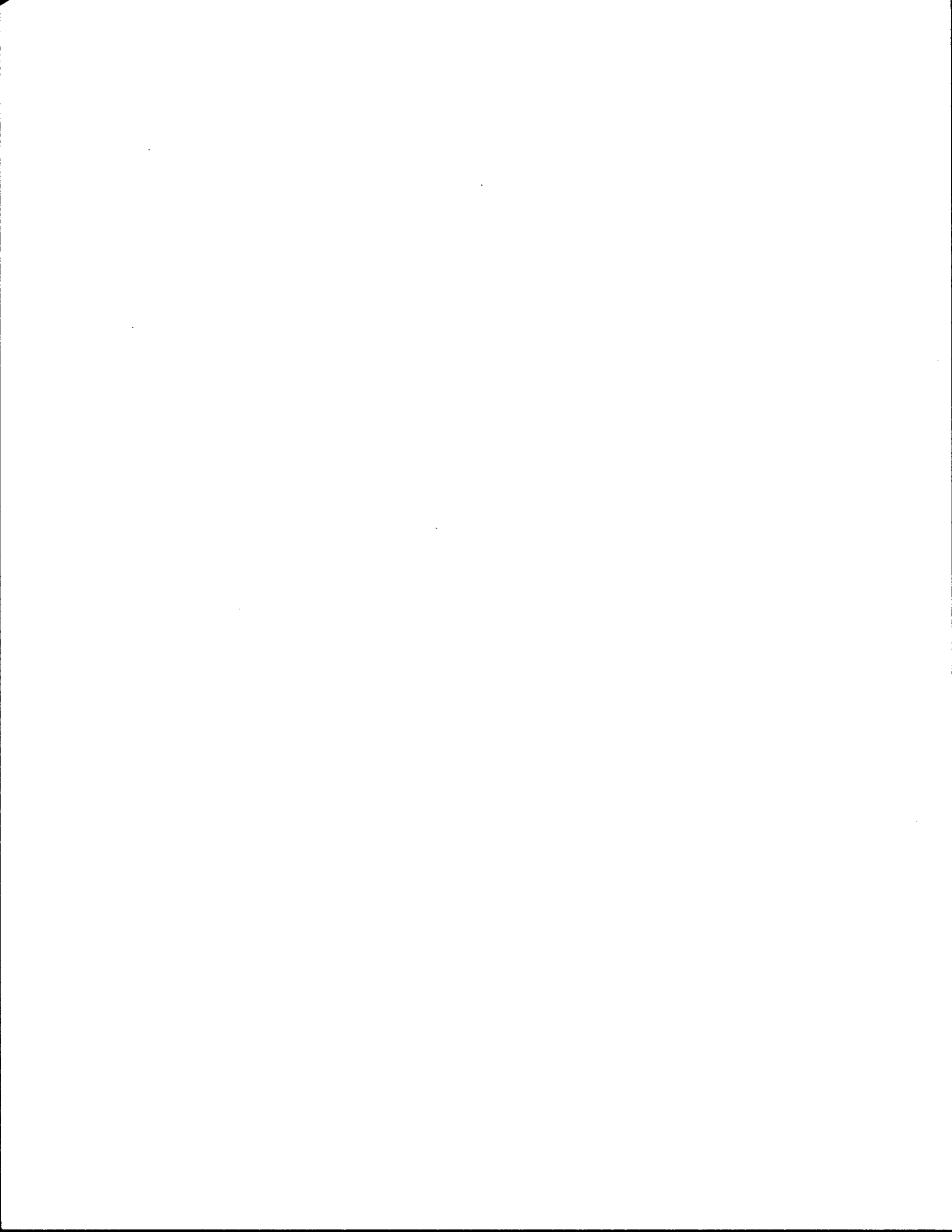
a limited understanding of TCM relationships, it is the first proposed methodology for estimating TCM program effects.

Second, the procedure tends to produce more TCMs with an overall negative effect as the number of TCMs in the program increases. This is due to the relationships between the available TCMs in the TCM Analyst 1.0 which was the basis for the matrix used in this analysis procedure. As seen in Figure 18, the interaction matrix has 55% conflicting relationships, 11% neutral relationships, and 34% positive relationships. More than half of the relationships for TCMs included in the TCM Analyst 1.0 are conflicting.

SUMMARY OF STEPS IN TCM ANALYSIS

These are the general steps needed to perform a TCM analysis with this software:

1. Run MOBILE5a to obtain emission factors for the region
2. Input the MOBILE5a emission factors in the appropriate emission season file
3. Start the TCM Analyst from the Program Manager in Windows
4. Click on the Begin Analysis button once the TCM Analyst has started
5. Enter/modify regional information which is applicable to all TCMs (Census, Trip & Travel Information, Vehicle Trip Distribution, VMT Distribution, Emission Information, and Cost Information)
6. Go to the section containing the TCM to analyze and enter "1" for "EVALUATE TCM?"
7. Enter all data under the individual TCM section
8. Print TCM results or use the analysis tools provided with the TCM Analyst to evaluate individual variables within the TCM section
9. Perform TCM program analysis, when applicable



CHAPTER V. TRAVEL MODULE

The methodology for the travel module is taken from the work performed for the EPA by SAI (4). Travel effects are determined through a nine-step process:

1. Identify the potential direct trip effect and trip type affected
2. Calculate the direct trip reductions
3. Calculate the indirect trip increase
4. Determine direct peak/off-peak period trip shifts
5. Calculate the total trip changes
6. Calculate the VMT changes due to trip changes
7. Calculate the VMT changes due to trip length changes
8. Determine the total VMT changes
9. Calculate speed changes

Each of the steps is briefly described below. For further explanation of each step, it is recommended that the original methodology be studied (1).

STEP 1: IDENTIFY THE POTENTIAL DIRECT TRIP EFFECT AND TRIP TYPE AFFECTED

Identify the total number of person trips that may be reduced from a TCM.

STEP 2: CALCULATE THE DIRECT TRIP REDUCTIONS

This step estimates the vehicle trip reduction from TCM participation. The TCM participation is converted from person trips to vehicle trips through two factors, α and ω . The α factor is the TCM adjustment factor and converts the person-trip changes into vehicle-trip changes. The ω factor defines the fraction of the affected trip changes assumed to be work related.

The α and ω factors are calculated from data provided to the TCM Analyst. For a better understanding of the α factor, these three conditional cases may help:

1. When $\alpha > 0$, there is an increase in vehicle trips due to a TCM, (e.g., capacity increase);
2. When $\alpha = 0$, there is no net direct vehicle trip effects, (e.g., flextime); and
3. When $\alpha < 0$, there is a vehicle trip reduction due to TCM, (e.g., parking management).

The ω factor describes the potential trip market of the TCM. For example, work schedule changes focus on modifying the trip behavior of work trips and $\omega = 1$. For cases where there is a mixture of trip types, the work trip fraction defined by work trips/total trips is used. HOV lanes are a special case because they affect only work trips in the peak periods and are closed during off-peak hours. Because of their specific market, the work trip fraction definition for HOV lanes is defined by work vehicle trips divided by the total peak vehicle trips.

STEP 3: CALCULATE THE INDIRECT TRIP INCREASE

This step accounts for the travel activity of vehicles being left at home by a TCM participant. For example, the commute vehicle may be used by other family members, for work or non-work purposes, who were not able to use the vehicle before it was left at home.

Although latent demand is shown in this step, the results are not used in the analysis. The latent demand algorithm is provided as a first cut analytical process for estimating latent demand. A greater understanding of latent demand is needed before induced trips can be classified as work or non-work trips occurring during the peak or off-peak periods.

STEP 4: DETERMINE DIRECT PEAK/OFF-PEAK PERIOD TRIP SHIFTS

This step is used to determine the number of vehicle trips that will shift to a less congested time period thus relieving some of the congestion during the peak periods. This step is used exclusively by the work schedule changes TCM. The purpose of work schedule changes is to spread the travel demand over a larger time period, thus reducing the peak period travel demand.

STEP 5: CALCULATE THE TOTAL TRIP CHANGES

This step determines the net vehicle trip changes from Steps 2 and 4. The trip changes are split into four categories defined by trip purpose and time the trip occurs: (1) work, peak, (2) work, off-peak, (3) non-work, peak, and (4) non-work, off-peak. The variables PK_w and PK_{NW} are important to the estimation of total trip changes and are shown in the equations below. These variables represent the fraction of work trips and non-work trips to the total trips in the region. It is important that the TCM modeler obtain region-specific values of PK_w and PK_{NW} (1).

$$PK_w = \frac{\text{vehicle work trips}}{\text{total vehicle work trips}}$$

$$PK_{NW} = \frac{\text{vehicle non-work trips}}{\text{total vehicle non-work trips}}$$

STEP 6: CALCULATE THE VMT CHANGES DUE TO TRIP CHANGES

This step determines the amount of VMT reduced due to the reduction of vehicle trips estimated in Step 5.

STEP 7: CALCULATE THE VMT CHANGES DUE TO TRIP LENGTH CHANGES

This step is used to estimate the VMT reduction due to actions such as telecommuting or ridesharing. These actions change the trip behavior of participants by shifting their destinations to new locations closer to their residence. These new locations may include park-and-ride lots for ridesharing participants or satellite work stations for telecommuters. In addition, the new work trip length should be shorter than the original work trip length to produce positive air quality results.

The β factor in this step represents the fraction of those participants who change their trip length rather than eliminate the trip. These β values are contained in the Travel Module and are derived from values in the Data Input Module.

STEP 8: DETERMINE THE TOTAL VMT CHANGES

This step totals the results from Steps 6 and 7 to provide an estimate of the total VMT changes due to the TCM implementation.

STEP 9: CALCULATE SPEED CHANGES

This step estimates changes in regional average vehicle speeds in the peak and off-peak periods due to the implementation of the TCM. These estimates are based on changes in VMT and elasticities of speed with respect to volume.

Care should be taken since there are several sources for obtaining these elasticity values. Efforts should be made to derive a region-specific elasticity for use in the model. The elasticities used in the model are only suggestions and do not reflect the individual characteristics of each study region.

CHAPTER VI. EMISSION MODULES

The TCM Analyst provides the user with the capability of analyzing TCM effects in the CO and ozone season simultaneously. These emission modules are based on the methodology developed by SAI for the EPA (4). The basic approach to the methodology is a four-step process:

1. Emission analysis of trip changes
2. Emission analysis of VMT changes
3. Emission analysis of idle and local speed changes
4. Emission analysis of fleet speed changes
5. Total emission changes due to TCM implementation.

STEP 1: EMISSION ANALYSIS OF TRIP CHANGES

This step estimates the emission reduction due to trip changes from TCM implementation. Several emission categories are used: cold and hot starts, hot soaks, and diurnals.

The number of cold- and hot-start trip changes are calculated based on results obtained from Step 4 in the Travel Module and data entered for the percentages of cold- and hot-start trips for work and non-work trips. For instance, most work trips will begin in a cold-start mode and a value of 100 percent would be entered for percent of cold starts for work trips. Cold- and hot-start emission factors are determined based on assumptions in the FTP. The SAI procedure converts exhaust emission factors for specific vehicle states at 26 mph into start emissions in grams per trip. Using the start emission factors and the number of vehicle trips reduced by type, the SAI procedure estimates the reduction in vehicle-start emissions.

Hot soak emission changes are estimated based on the reduction in vehicle trips. Hot-soak emissions will decrease with the reduction in vehicle trips from the TCM implementation.

Diurnal emission changes are also estimated from the number of vehicle trips reduced. These unused vehicles increase the diurnal emissions in the region.

The total emission change is the sum of each of the above components: starts, hot soak, and diurnals.

STEP 2: EMISSION ANALYSIS OF VMT CHANGES

Several emission types are also reduced when VMT is reduced. These emission types are hot-stabilized exhaust emissions and VMT-related evaporative emission changes. The VMT-related evaporative emission changes account for running loss, crankcase, and refueling emissions. The total emission changes from VMT reduction is the sum of the hot-stabilized exhaust and VMT-related evaporative emission changes.

STEP 3: EMISSION ANALYSIS OF IDLE AND LOCAL SPEED CHANGES

This step is used to determine the idle and running emission reductions due to traffic flow improvements for the peak and off-peak periods.

STEP 4: EMISSION ANALYSIS OF FLEET SPEED CHANGES

As regional congestion decreases, regional speeds increase. This step is used to determine the emissions changes due to increases in regional fleet speeds. Hot-stabilized exhaust and running loss emission factors are used for this analysis.

STEP 5: TOTAL EMISSION CHANGES DUE TO TCM IMPLEMENTATION

This step totals the emission changes estimated in the previous four steps. The total emission reduction is reported in grams per day. The output units can be easily modified into kilograms per day, metric tons per day, or English tons per day changes in emissions for CO, HC, and NOx.

CHAPTER VII. COST-EFFECTIVENESS MODULE

This module is based on work for the San Diego Association of Governments (SANDAG) by Sierra Research, Inc. and JHK & Associates (5). Costs of each TCM are reduced into a daily cost of implementation for the TCM. Capital costs are annualized over their useful life and then converted into daily costs. The module uses only the direct costs of the TCM implementation. Indirect costs such as health effects, travel time savings, etc., are not included. After the daily cost is calculated, it is divided by the emission reduction calculated in the Emissions Module to yield the cost per kilogram of emission reduction. The steps used in this module are described below.

STEP 1: CALCULATE PUBLIC SECTOR COST

This step determines the direct costs of implementing the selected TCM. These costs include design, construction, and maintenance of facilities, as well as other costs.

STEP 2: CALCULATE PRIVATE SECTOR COST

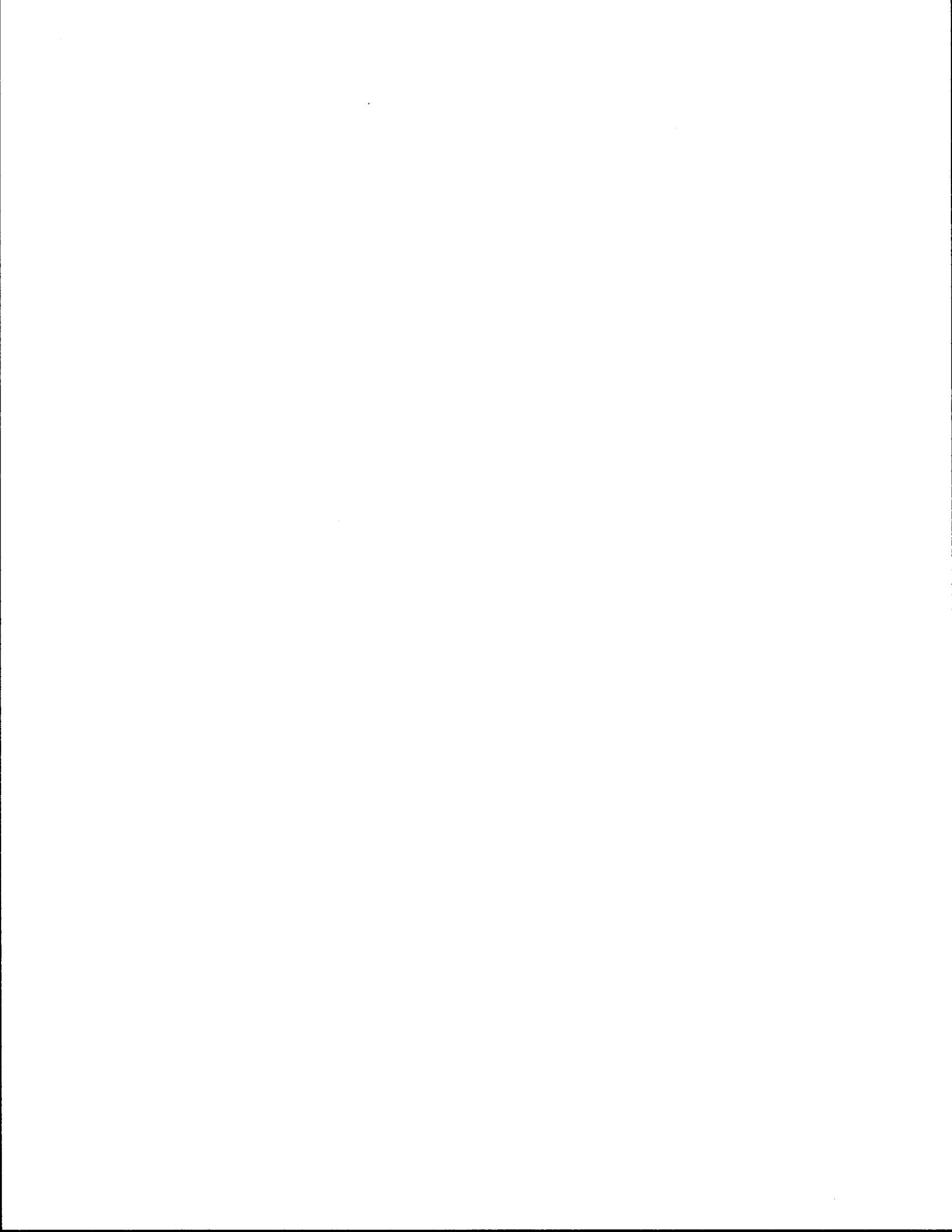
The direct costs to the private sector are determined in this step. These costs include the purchase of equipment and management of programs.

STEP 3: CALCULATE INDIVIDUAL COST

This step estimates the direct cost to the individual to participate in the selected TCM.

STEP 4: CALCULATE GROSS TOTAL COST

The direct costs for the public and private sector and the individual are summed and shown in this step.



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APPENDIX A
DEFAULT DATA

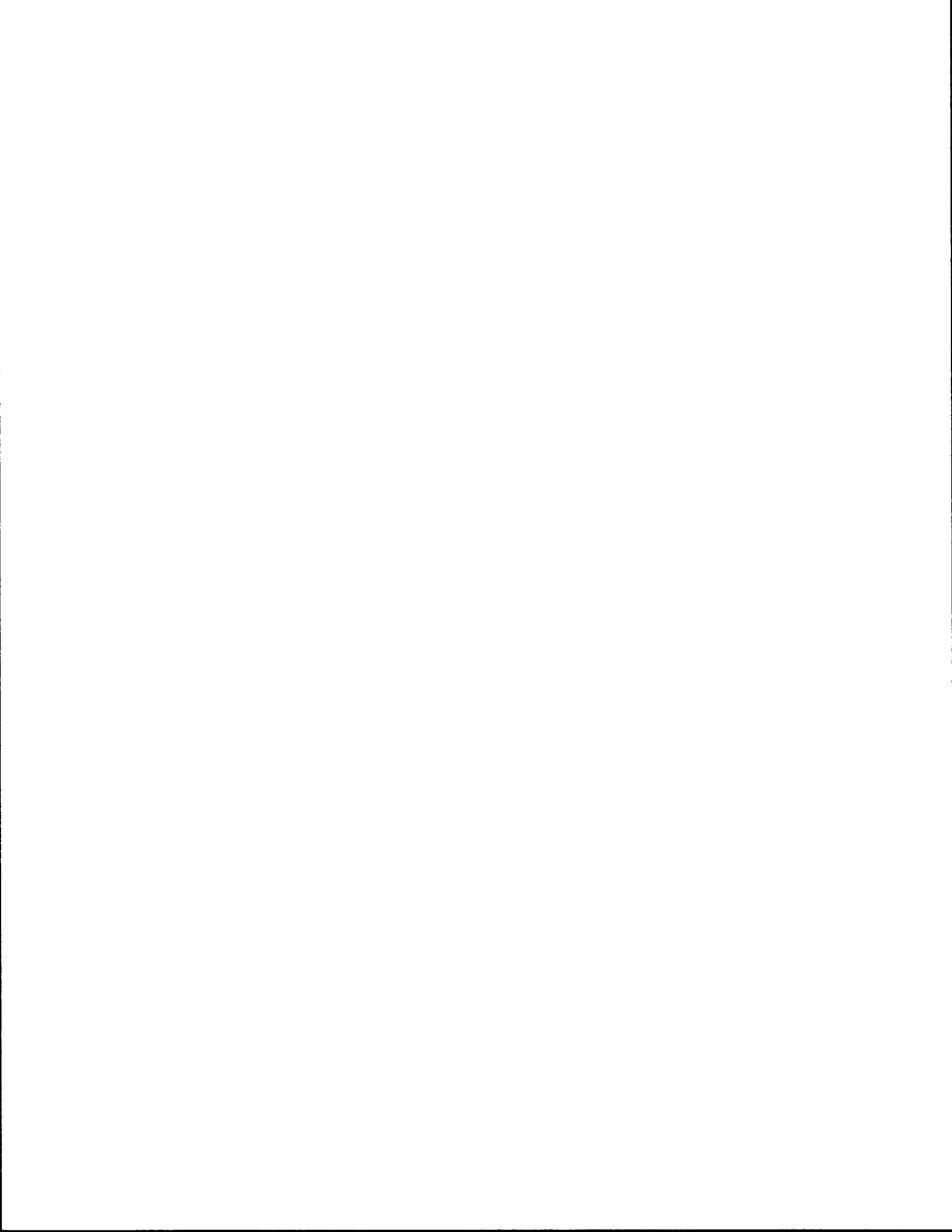


Table A-1
Default Values for TCM Analyst Variables

Variable	Value	Source
Average vehicle occupancy	1.15	5
	1.35	8
	1.09	9
	1.36	11
	1.09	12
Average number of people per carpool	2.2	10
Average work trip length (miles)	13.9	4
	7.7	8
	10.4	11
Average non-work trip length (miles)	7.5	4
	5.4	8
	5.64	11
Elasticity of HOV demand with respect to speed on adjacent lanes	- 1.500	1
Elasticity of mode choice with respect to cost	-0.400	2
Elasticity of off-peak speed with respect to volume	- 0.375	6
	-0.017	4
Elasticity of parking demand with respect to cost for commute trips	- 0.200	3
Elasticity of peak speed with respect to volume	- 0.750	6
	-1.295	4
Elasticity of transit use with respect to cost	- 0.510	7
	-0.400	7
Fraction of new carpoolers who join existing carpools and don't meet at park-and-ride lots	62%	2
Fraction of new carpoolers who join new carpools and don't meet at park-and-ride lots	33%	2
Fraction of potential trips that will rideshare	62.6%	2
Fraction of potential trips that will use fringe parking	0.0%	2
Fraction of potential trips that will use transit	37.4%	2
Fraction of trips made via shared mode	28.6%	2
	16.0%	12
Non-work trip generation rate for SOV users (trips per day)	3.25	2

Table A-1 Continued

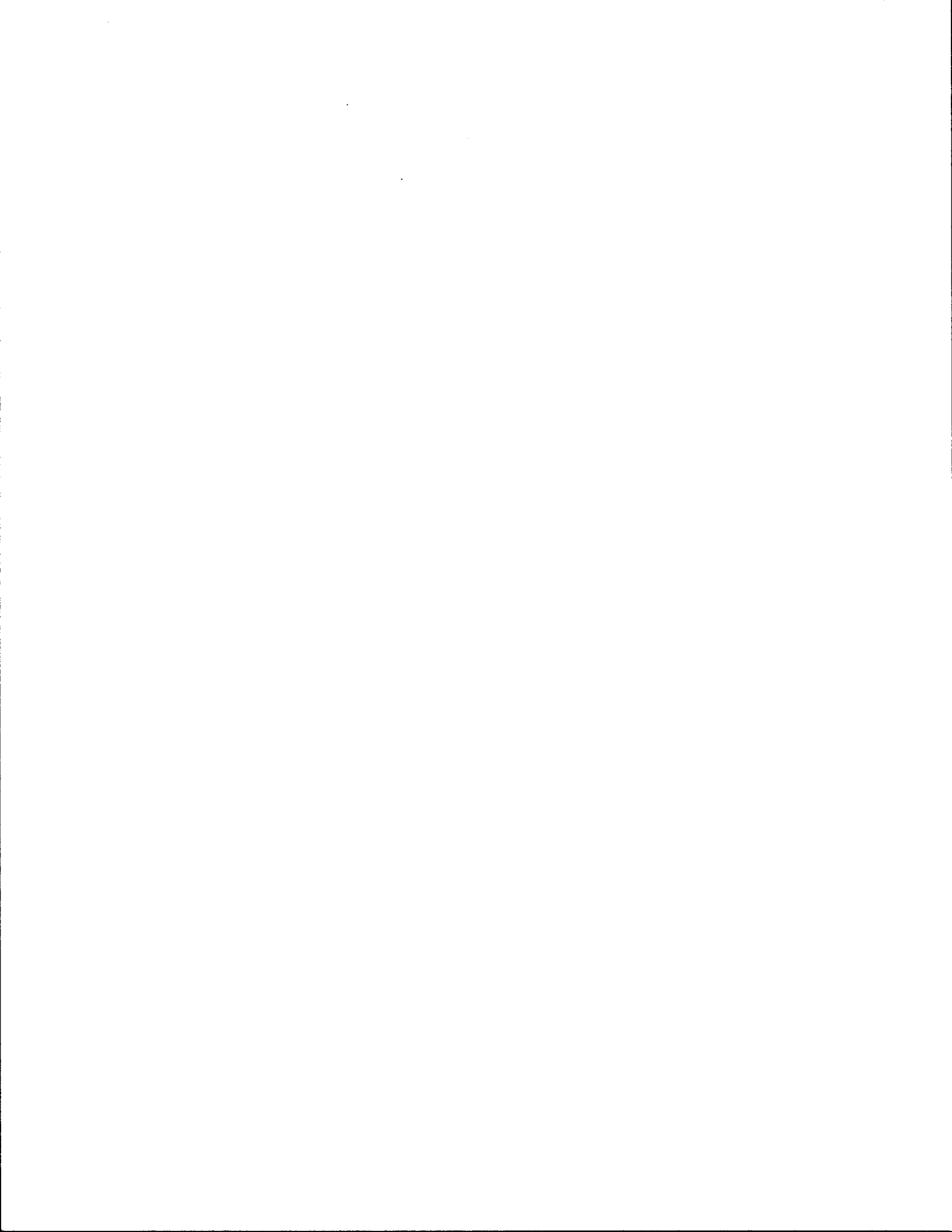
Variable	Value	Source
Percent of non-work travel that occurs in the peak period	28.8%	2
	35.2%	4
	30.8%	11
Percent of work travel that occurs in the peak period	60.8%	2
	64.3%	4
	56.8%	11
Work trip generation rate for SOV users (trips per day)	1.71	2

**Table A-2
Supplemental Values for Value Derivations**

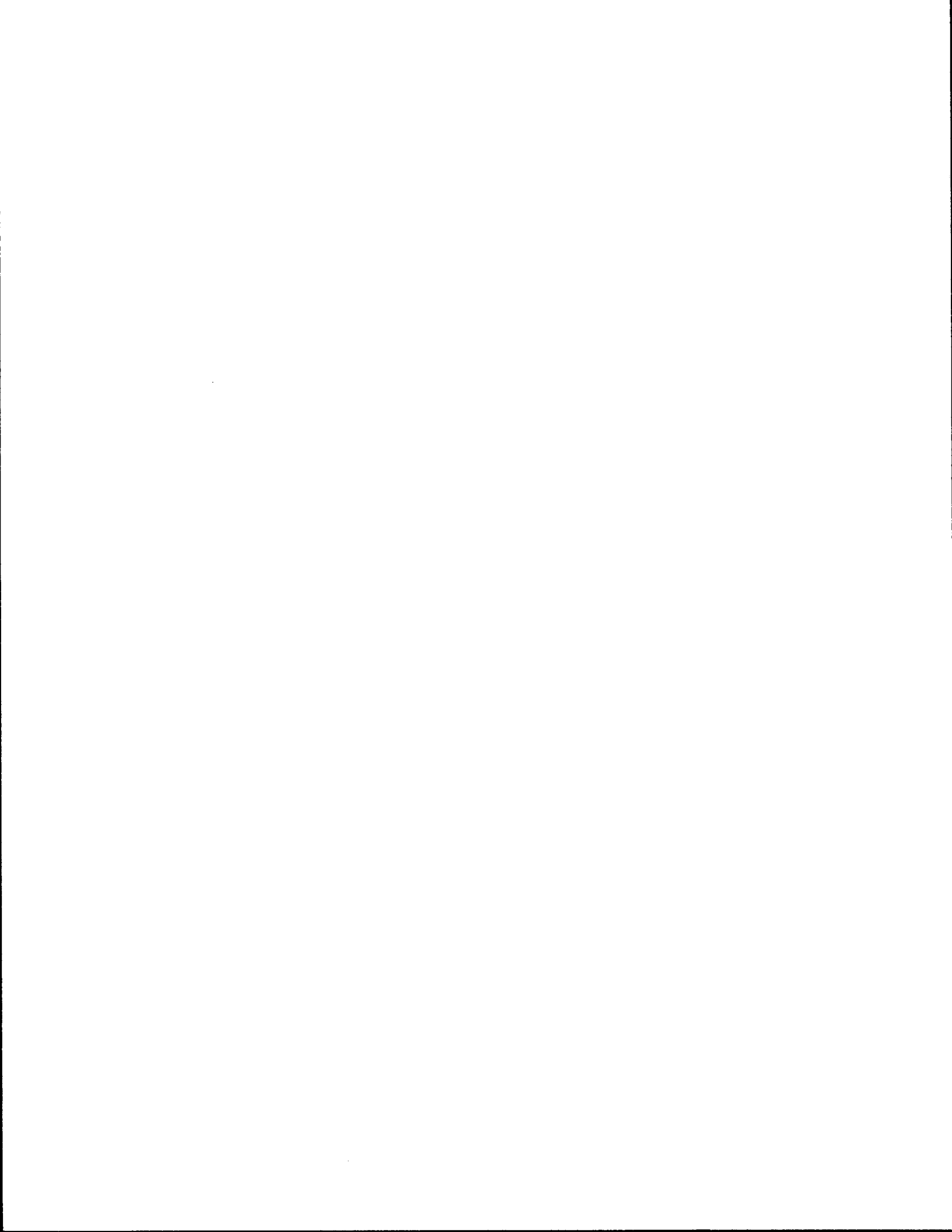
Variable	Value	Source
Percent of all trips in peak period	39.6%	3
	40.7%	4
Percent of peak trips that are work trips	51.9%	3
	29.7%	4
Total work-related vehicle trips	60% of all AM vehicle trips	5
Total peak-period work trips	45% of all AM person trips	5
Transit work trips	42% of all transit trips	5

Sources for Tables A-1 and A-2

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APPENDIX B
EXAMPLE ANALYSIS TOOL OUTPUT



Sensitivity Analysis

Transportation Control Measure Analysis

Run Title..... Ridesharing: Participation Level

Change in Emissions

kilograms/day

Value	CO Season		
	HC	CO	NOx
1000	-19	-195	-14
2000	-38	-391	-28
3000	-57	-586	-42

Value	Ozone Season		
	HC	CO	NOx
1000	-12	-113	-12
2000	-24	-227	-24
3000	-35	-340	-37

tons/day

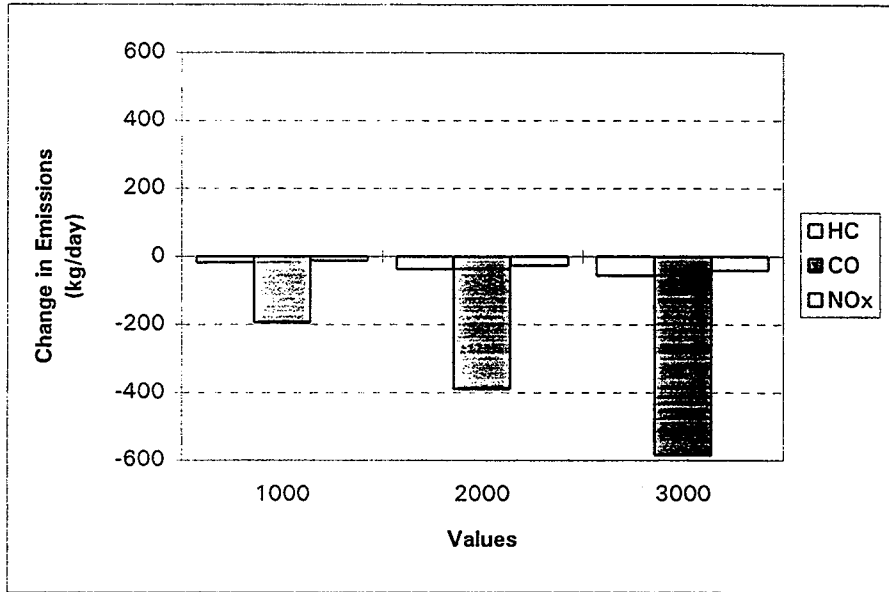
Value	CO Season		
	HC	CO	NOx
1000	-0.02	-0.21	-0.02
2000	-0.04	-0.43	-0.03
3000	-0.06	-0.64	-0.05

Value	Ozone Season		
	HC	CO	NOx
1000	-0.01	-0.12	-0.01
2000	-0.03	-0.25	-0.03
3000	-0.04	-0.37	-0.04

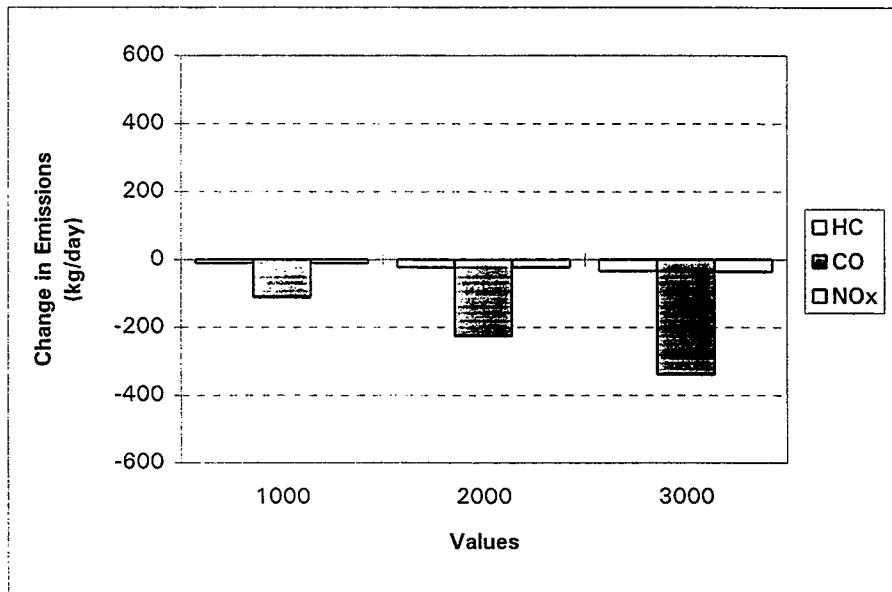
Change in Travel

Value	Vehicle Trips		VMT		Speed	
	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak
1000	-331	-208	-2,672	-1,730	0.1%	0.0%
2000	-661	-416	-5,345	-3,460	0.1%	0.0%
3000	-992	-623	-8,017	-5,190	0.2%	0.0%

Ridesharing: Participation Level

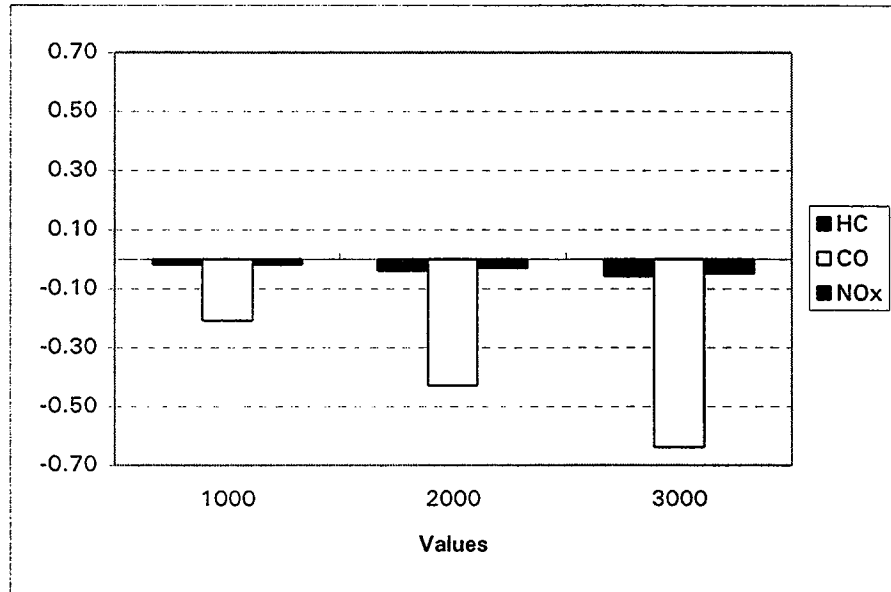


a) CO Season

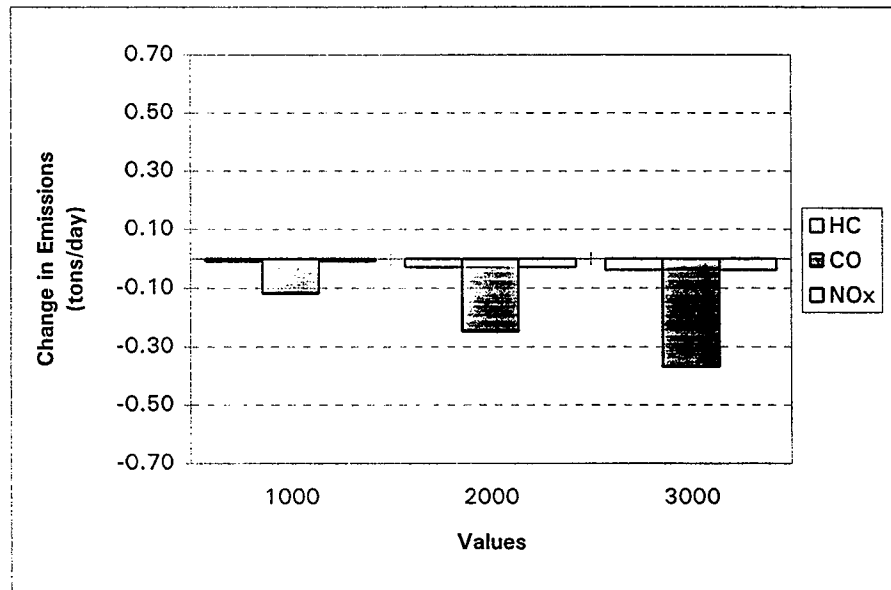


b) Ozone Season

Ridesharing: Participation Level

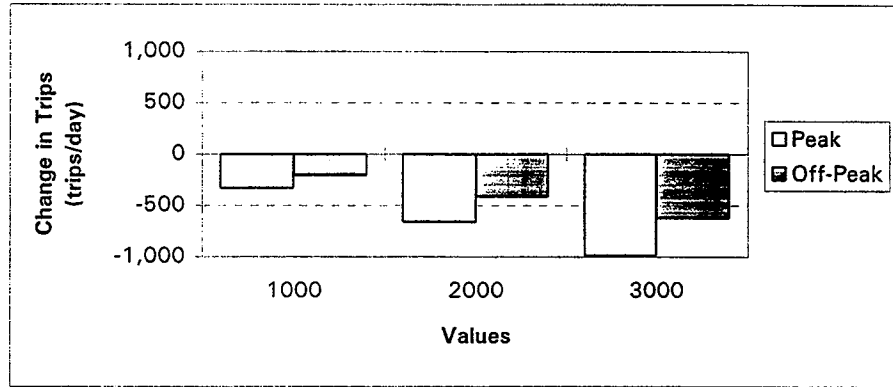


a) CO Season

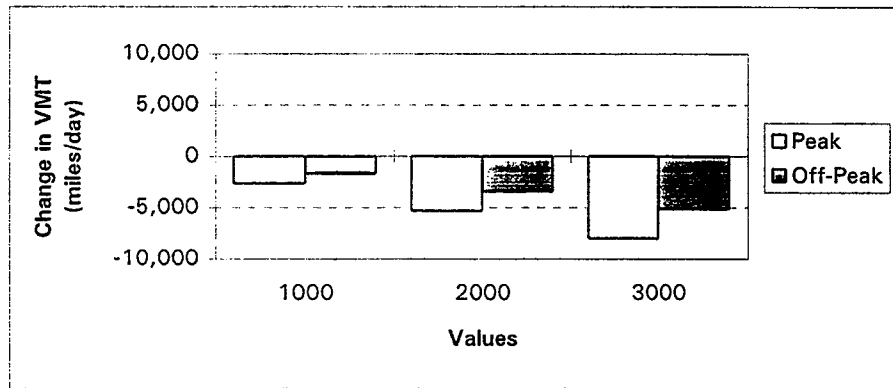


b) Ozone Season

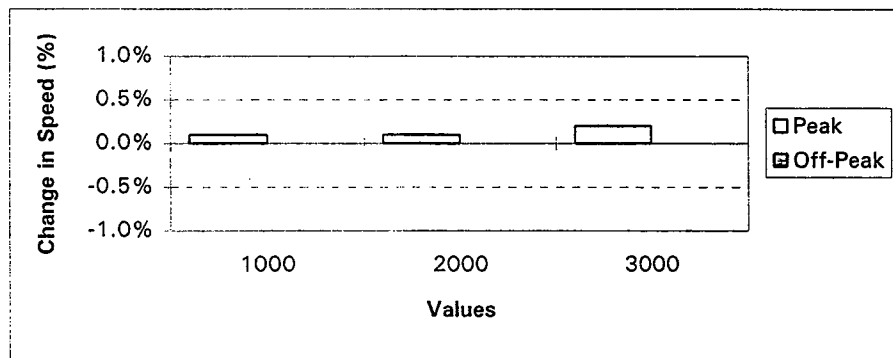
Ridesharing: Participation Level



a) Trips



b) VMT



c) Speeds

Trend Analysis

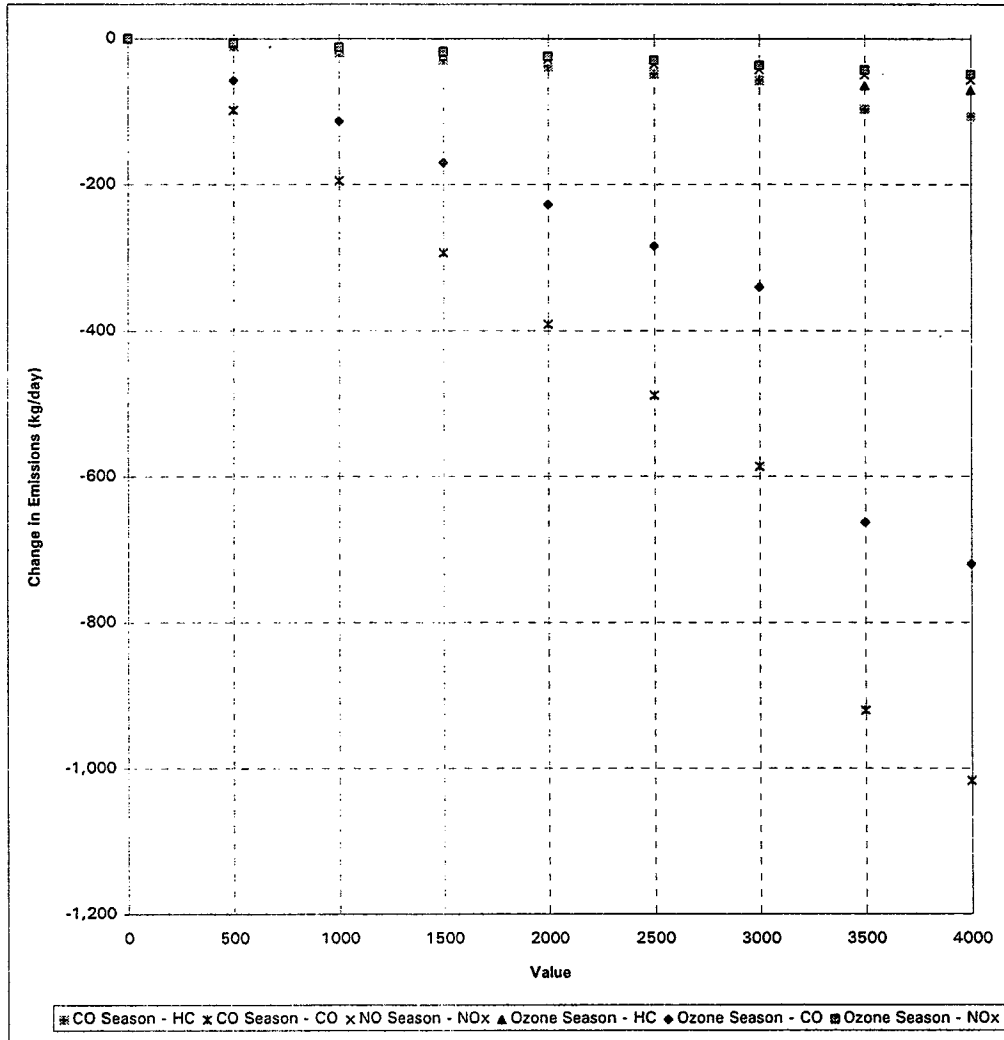
TCM Range Analysis

Run Title: Ridesharing: Participation Level

Value	CO Season			Ozone Season			Trips		VMT		Speed	
	HC	CO	NOx	HC	CO	NOx	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak
500	-10	-98	-7	-6	-57	-6	-165	-104	-1,336	-865	0.0%	0.0%
1000	-19	-195	-14	-12	-113	-12	-331	-208	-2,672	-1,730	0.1%	0.0%
1500	-29	-293	-21	-18	-170	-18	-496	-312	-4009	-2595	0.1%	0.0%
2000	-38	-391	-28	-24	-227	-24	-661	-416	-5345	-3460	0.1%	0.0%
2500	-48	-488	-35	-29	-284	-30	-826	-519	-6,681	-4,325	0.1%	0.0%
3000	-57	-586	-42	-35	-340	-37	-992	-623	-8,017	-5,190	0.2%	0.0%
3500	-97	-920	-49	-64	-663	-43	-1157	-727	-9354	-6055	0.2%	0.0%
4000	-107	-1017	-56	-70	-720	-49	-1322	-831	-10690	-6920	0.2%	0.0%

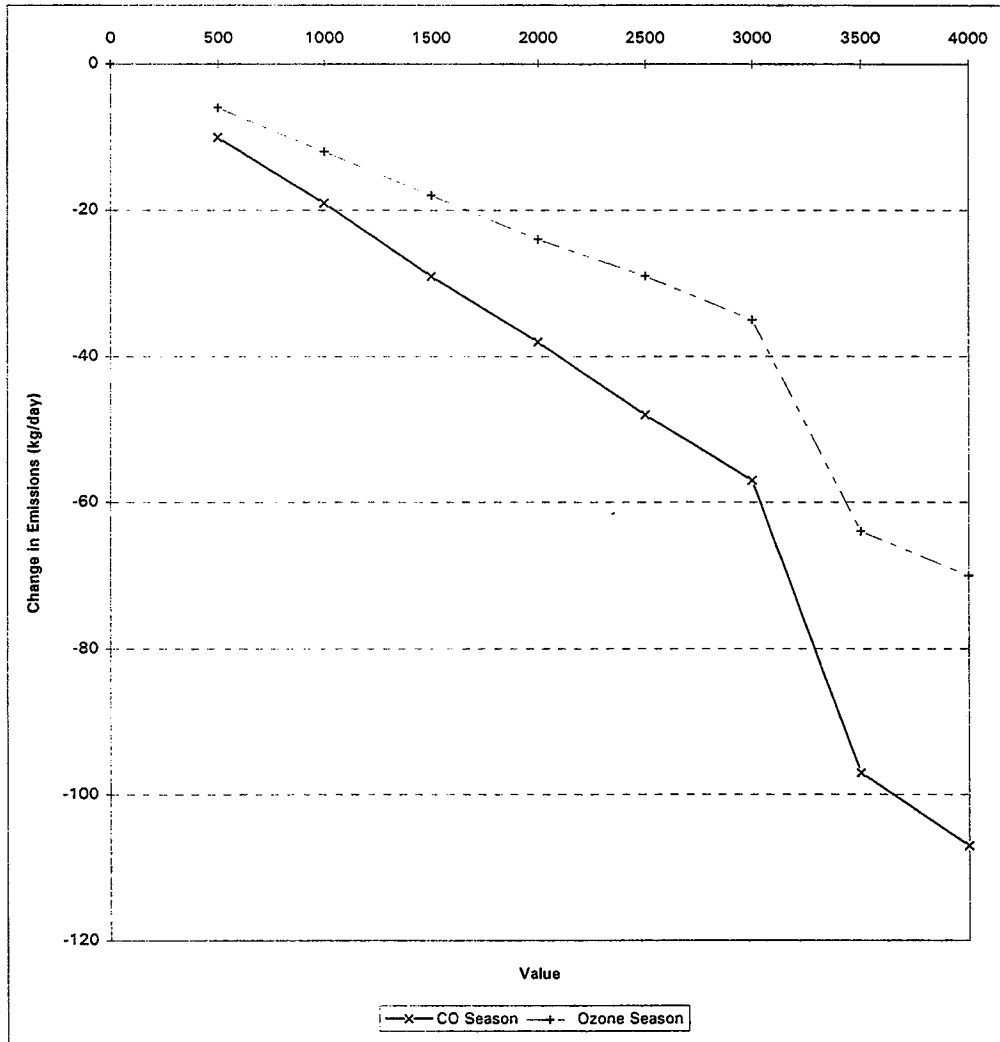
Ridesharing: Participation Level

Emission Reductions



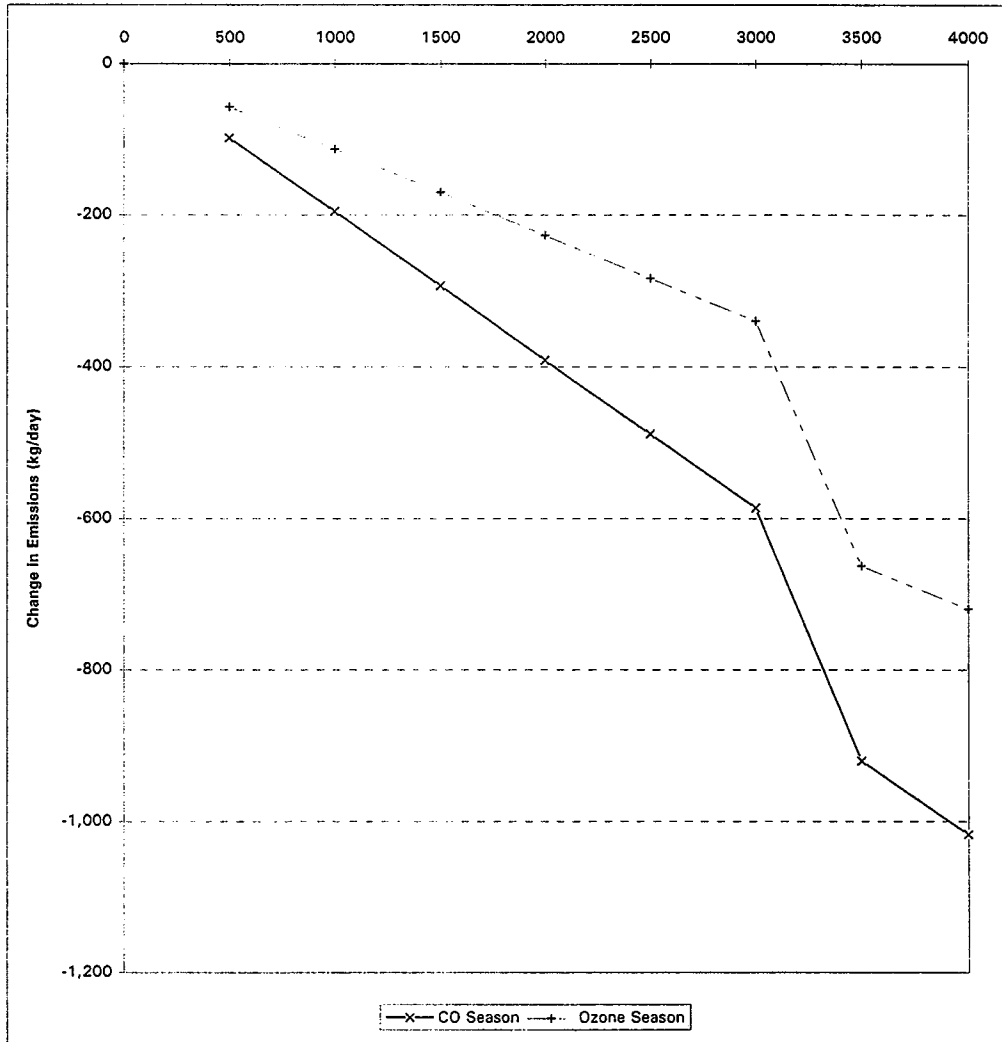
Ridesharing: Participation Level

HC Changes



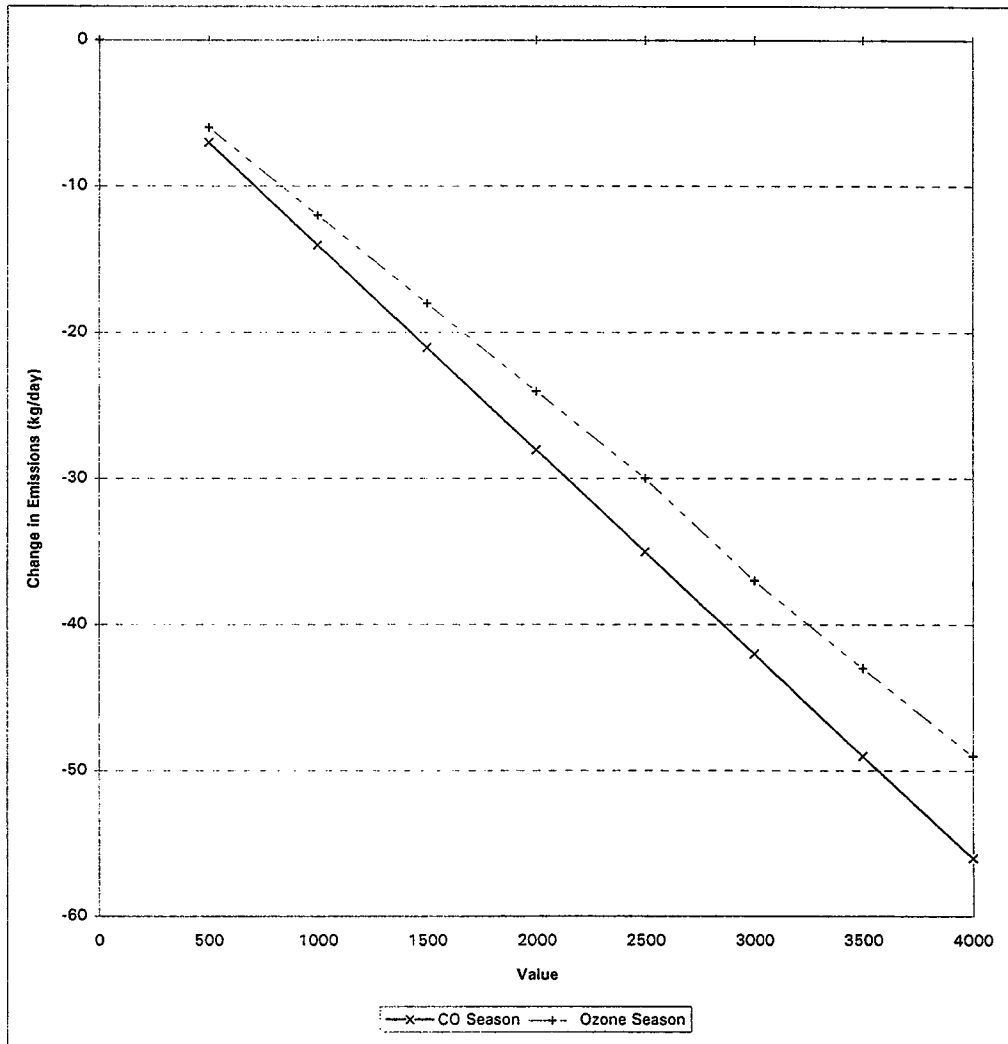
Ridesharing: Participation Level

CO Changes



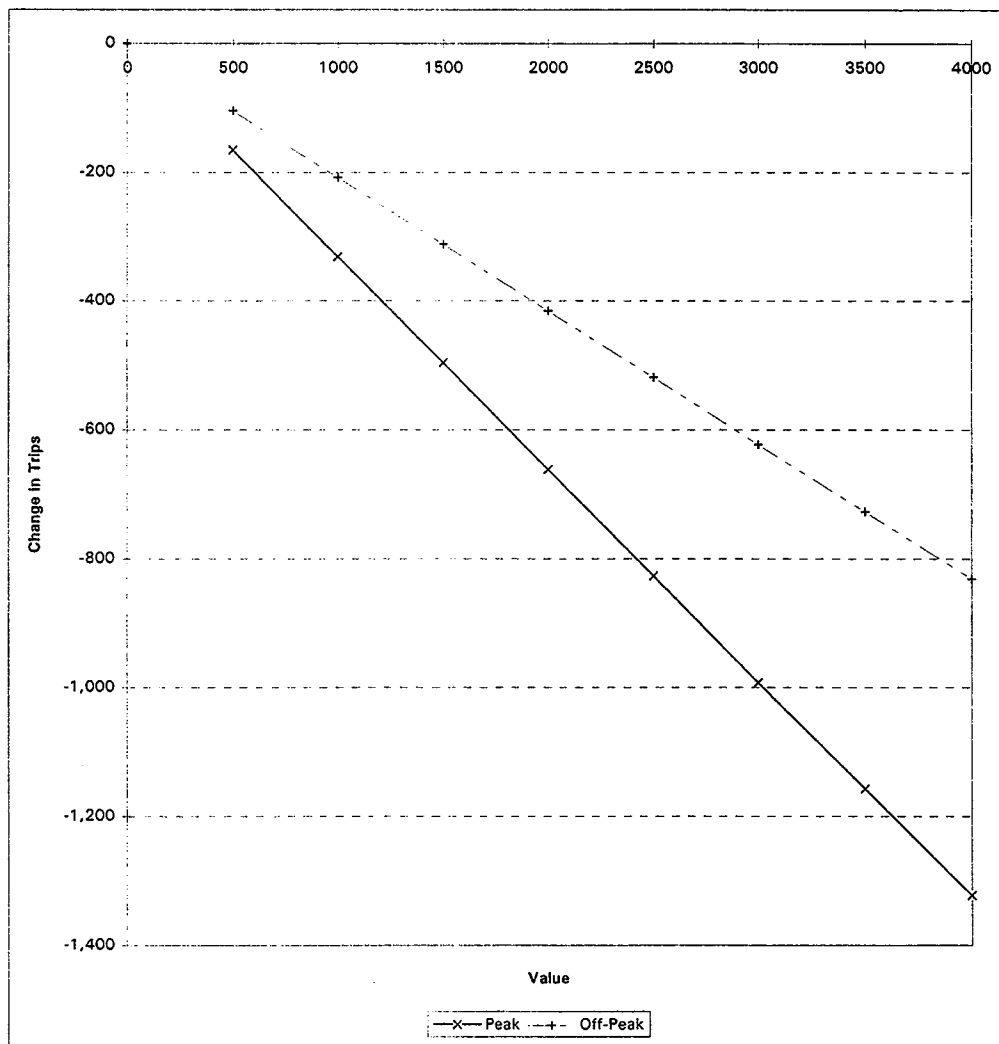
Ridesharing: Participation Level

NOx Changes



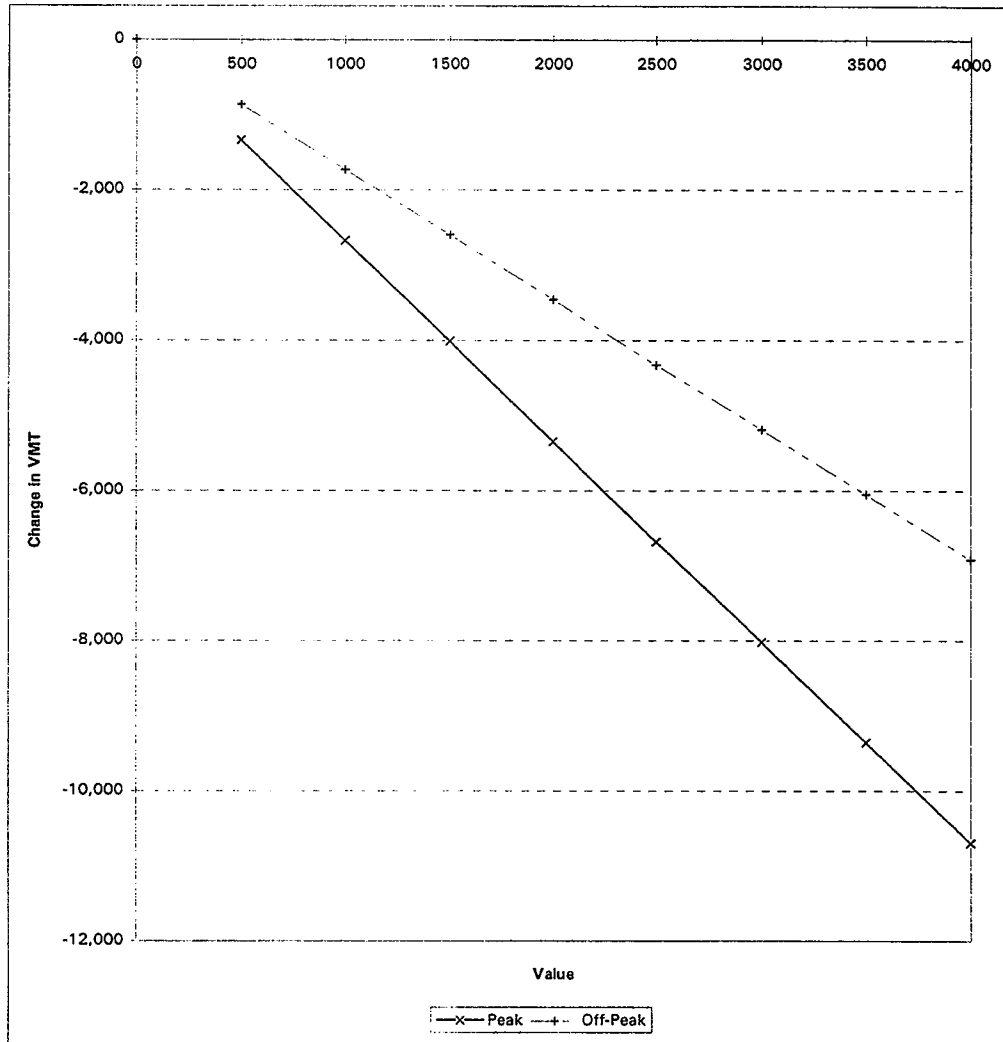
Ridesharing: Participation Level

Trip Changes



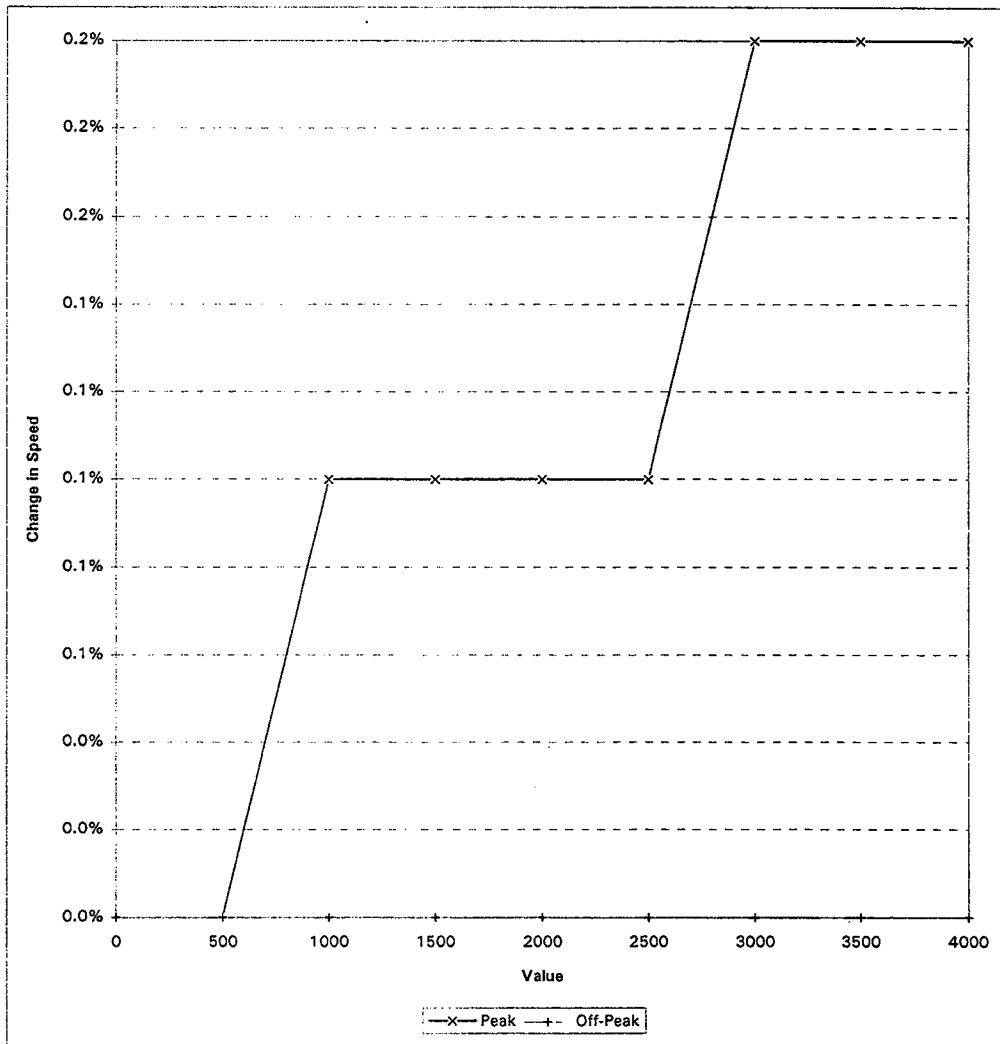
Ridesharing: Participation Level

VMT Changes



Ridesharing: Participation Level

Speed Changes



Detailed TCM Analyst Results

Run Title: Ridesharing: Participation Level

	Values											
	1000		1,500		2,000		2,500		3,000		3,500	
TRAVEL												
Step 1	1,200		1,800		2,400		3,000		3,600		4,200	
Step 2												
Work	-594		-891		-1,188		-1,485		-1,782		-2,079	
Non-Work	0		0		0		0		0		0	
Step 3												
Work	45		68		91		114		136		159	
Non-Work	10		15		20		25		30		36	
Latent Demand	16		25		33		41		49		57	
Step 4												
Into Peak	0		0		0		0		0		0	
Into Off-Peak	0		0		0		0		0		0	
Step 5												
Work, Peak	-333		-500		-667		-834		-1,000		-1,167	
Work Off-Peak	-215		-323		-430		-538		-645		-753	
Non-Work, Peak	3		4		6		7		9		10	
Non-Work, Off Peak	7		11		14		18		22		25	
Step 6												
Peak	-2,555		-3,833		-5,110		-6,388		-7,666		-8,943	
Off-Peak	-1,619		-2,428		-3,237		-4,046		-4,856		-5,665	
Step 7												
Peak	-229		-343		-457		-571		-686		-800	
Step 8												
Peak	-2,672		-4,009		-5,345		-6,681		-8,017		-9,354	
Off-Peak	-1,730		-2,595		-3,460		-4,325		-5,190		-6,055	
Step 9												
Peak	0.05254%		0.07880%		0.10507%		0.13134%		0.15761%		0.18387%	
Off-Peak	0.00985%		0.01447%		0.01930%		0.02412%		0.02894%		0.03377%	
EMISSIONS	CO	Ozone	CO	Ozone	CO	Ozone	CO	Ozone	CO	Ozone	CO	Ozone
Step 1												
Trip Changes												
Total	-538	-538	-807	-807	-1,077	-1,077	-1,346	-1,346	-1,615	-1,615	-1,884	-1,884
Cold-Start	-544	-544	-816	-816	-1,088	-1,088	-1,360	-1,360	-1,632	-1,632	-1,904	-1,904
Hot-Start	6	6	9	9	12	12	14	14	17	17	20	20
Start Changes												
Cold-Start												
HC	-10,060	-2,981	-15,089	-4,471	-20,119	-5,962	-25,149	-7,452	-30,179	-8,943	-35,208	-10,433
CO	-109,180	-23,835	-163,770	-35,753	-218,360	-47,670	-272,950	-59,588	-327,539	-71,505	-382,129	-83,423
NOx	-1,675	-1,660	-2,512	-2,489	-3,350	-3,319	-4,187	-4,149	-5,024	-4,979	-5,862	-5,809
Hot-Start												
HC	11	15	16	22	21	30	26	37	32	45	37	52
CO	72	61	109	91	145	122	181	152	217	182	253	213
NOx	17	11	25	17	33	23	41	28	50	34	58	40
Hot-Soak												
Diurnal												
Work	1,545	2,101	2,317	3,152	3,089	4,202	3,862	5,253	4,634	6,304	5,406	7,354
Non-Work	-11	-16	-17	-23	-23	-31	-29	-39	-34	-47	-40	-55
Total	1,533	2,086	2,300	3,128	3,066	4,171	3,833	5,214	4,600	6,257	5,366	7,300
Total												
HC	-9,235	-2,838	-13,852	-4,257	-18,469	-5,676	-23,086	-7,095	-27,704	-8,514	-32,321	-9,933
CO	-109,107	-23,774	-163,661	-35,662	-218,215	-47,549	-272,769	-59,436	-327,322	-71,323	-381,876	-83,210
NOx	-1,658	-1,648	-2,487	-2,472	-3,316	-3,297	-4,146	-4,121	-4,975	-4,945	-5,804	-5,769

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Detailed Analysis

Detailed TCM Analyst Results

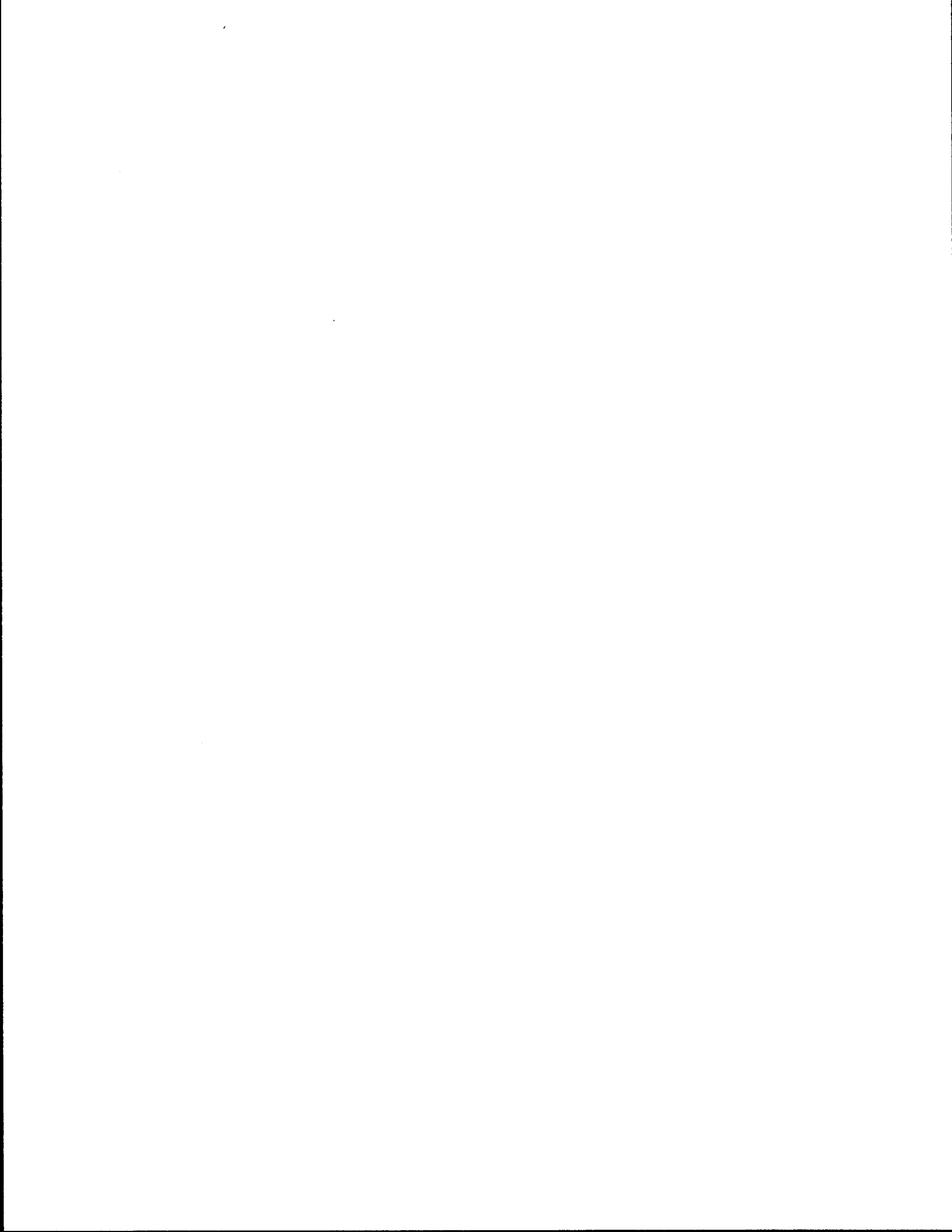
Run Title: Ridesharing: Participation Level

	Values											
	1,000		1,500		2,000		2,500		3,000		3,500	
Step 2												
Hot-Stabilized Exhaust Peak												
HC	-4,699	-4,419	-7,048	-6,628	-9,397	-8,837	-11,747	-11,046	-14,096	-13,256	-16,445	-15,465
CO	-56,942	-59,591	-85,413	-89,386	-113,884	-119,181	-142,355	-148,977	-170,826	-178,772	-199,297	-208,568
NOx	-7,455	-6,308	-11,183	-9,463	-14,910	-12,617	-18,638	-15,771	-22,365	-18,925	-26,093	-22,079
Off-Peak												
HC	-2,352	-2,205	-3,528	-3,307	-4,704	-4,409	-5,880	-5,512	-7,056	-6,614	-8,232	-7,716
CO	-29,247	-30,047	-43,871	-45,071	-58,494	-60,094	-73,118	-75,118	-87,742	-90,141	-102,365	-105,165
NOx	-5,005	-4,225	-7,508	-6,337	-10,010	-8,450	-12,513	-10,562	-15,015	-12,675	-17,518	-14,787
Evaporative Peak												
HC	-1,819	-1,534	-2,729	-2,302	-3,639	-3,069	-4,549	-3,836	-5,458	-4,603	-6,368	-5,370
CO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NOx	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Off-Peak												
HC	-929	-796	-1,394	-1,194	-1,858	-1,592	-2,323	-1,990	-2,787	-2,388	-3,252	-2,786
CO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NOx	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total												
HC	-9,799	-8,954	-14,699	-13,430	-19,599	-17,907	-24,498	-22,384	-29,398	-26,861	-34,298	-31,337
CO	-86,189	-89,638	-129,284	-134,457	-172,378	-179,276	-215,473	-224,094	-258,567	-268,913	-301,662	-313,732
NOx	-12,460	-10,533	-18,690	-15,800	-24,920	-21,067	-31,151	-26,333	-37,381	-31,600	-43,611	-36,867
Step 3												
Peak												
HC	0	0	0	0	0	0	0	0	0	0	0	0
CO	0	0	0	0	0	0	0	0	0	0	0	0
NOx	0	0	0	0	0	0	0	0	0	0	0	0
Off-Peak												
HC	0	0	0	0	0	0	0	0	0	0	0	0
CO	0	0	0	0	0	0	0	0	0	0	0	0
NOx	0	0	0	0	0	0	0	0	0	0	0	0
Step 4												
Peak												
HC	0	0	0	0	0	0	0	0	0	0	-30,447	-22,836
CO	0	0	0	0	0	0	0	0	0	0	-235,967	-266,415
NOx	0	0	0	0	0	0	0	0	0	0	0	0
Off-Peak												
HC	0	0	0	0	0	0	0	0	0	0	0	0
CO	0	0	0	0	0	0	0	0	0	0	0	0
NOx	0	0	0	0	0	0	0	0	0	0	0	0
Step 5												
HC	-19,034	-11,792	-28,551	-17,687	-38,068	-23,583	-47,585	-29,479	-57,101	-35,375	-97,066	-64,106
CO	-195,297	-113,412	-292,945	-170,118	-390,593	-226,824	-488,242	-283,530	-585,890	-340,237	-919,506	-663,358
NOx	-14,118	-12,182	-21,178	-18,272	-28,237	-24,363	-35,296	-30,454	-42,355	-36,545	-49,415	-42,636
Cost-Effectiveness												
Step 1												
Gross	\$301.37	\$301.37	\$301.37	\$301.37	\$301.37	\$301.37	\$301.37	\$301.37	\$301.37	\$301.37	\$301.37	\$301.37
Step 2												
Gross	\$2,612.33	\$3,812.33	\$5,012.33	\$6,212.33	\$7,412.33	\$8,612.33	\$9,812.33	\$11,012.33	\$12,212.33	\$13,412.33	\$14,612.33	\$15,812.33
Step 3												
Gross	\$869.65	\$1,304.48	\$1,739.30	\$2,174.13	\$2,608.95	\$3,043.78	\$3,478.60	\$3,913.43	\$4,348.25	\$4,783.08	\$5,217.90	\$5,652.73
Step 4												
Gross	\$3,783.35	\$5,418.18	\$7,053.00	\$8,687.83	\$10,322.65	\$11,957.48	\$13,592.30	\$15,227.13	\$16,861.95	\$18,496.78	\$20,131.60	\$21,766.43

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APPENDIX C

**ADDITIONS TO SYSTEMS APPLICATIONS INTERNATIONAL
TCM ANALYSIS METHODOLOGY**



HOV LANES

Description

The original HOV lane methodology was omitted from the final SAI report. It is included in the TCM Analyst after revisions were made to the original methodology; the revisions better represent the behavior of HOV lanes. The revisions to the original methodology are included below for reference.

Travel Methodology

Variable Summary:

PT	=	Participation level (persons)
SPD _M	=	Speed on mixed-flow lanes (mph)
SPD _H	=	Speed on HOV lanes (mph)
USE	=	Number of person-trips on affected freeway(s)
α	=	Fraction of work-related travel
TRAN	=	Fraction of potential trips who will use transit
NOLD	=	Fraction of new carpoolers who join existing carpools and don't meet at park-and-ride lots
RD	=	Fraction of potential trips who will rideshare
NEW	=	Fraction of new carpoolers who join new carpools and don't meet at park-and-ride lots
NCAR	=	Number of people per carpool
AVO	=	Average vehicle occupancy
ω	=	Fraction of direct trip effects assumed to be work related
HOV _L	=	Length of HOV facilities (miles)
TOTVMT _p	=	Total peak-period VMT
ϵ	=	Elasticity of peak (off-peak) speed with respect to volume

STEP 1:

$$PT = \epsilon * \left(\frac{SPD_M}{SPD_H} - 1 \right) * USE$$

STEP 2:

$$\alpha = \frac{-TRAN + (NOLD * RD) + (NEW * RD) * \frac{NCAR - 1}{NCAR}}{AVO}$$

$\omega = \text{User Defined}$

STEP 3:

No change or addition in this step.

STEP 4:

No change or addition in this step.

STEP 5:

No change or addition in this step.

STEP 6:

No change or addition in this step.

STEP 7:

No change or addition in this step.

STEP 8:

No change or addition in this step.

STEP 9:

$$\frac{\frac{USE}{AVO} * HOV_L}{TOTVMT_P} * \frac{\Delta VMT_P}{TOTVMT_P} * \epsilon$$

Emission Methodology

There is no change to the emission methodology.

Cost-Effectiveness

There is no change to the cost-effectiveness methodology.

Additional Information

None

TRANSIT CENTER/PLAZAS

Description

Transit centers/plazas are improvements to the transit system operations. Operations are improved by providing a central location for passengers to embark and disembark.

The effects of the transit center/plaza have the potential to be more far reaching. If parking supply is decreased around the transit center/plaza, there is a greater potential that employees in the area will switch to the transit mode to travel to and from work.

Travel Methodology

Variable Summary:

PT	= Participation level (persons)
N	= Number of participants (people)
$\Delta PRC_{\%}$	= Percent change in parking cost
ϵ_{PRK}	= Elasticity of parking demand with respect to cost
ΔTT	= Change in travel time for trip
ϵ_{TT}	= Elasticity of travel time with respect to cost
α	= Fraction of work-related travel
AVO	= Average vehicle occupancy
ω	= Fraction of direct trip effects assumed to be work related
$TPTRIPS_{P,W}$	= Peak-period work trips attracted through the transit plaza
$TRIPS_{P,W}$	= Total peak-period work trips
β	= Fraction of participants who change their trip length
$DRIV_{TRANS}$	= Fraction of people who drive to the public transit station

STEP 1:

$$PT = N * [(\Delta PRC_{\%} * \epsilon_{PRK}) + (\Delta TT * \epsilon_{TT})] * 2$$

STEP 2:

$$\alpha = \frac{1}{AVO}$$

$$\omega = \frac{TPTRIPS_{P, W}}{TRIPS_{P, W}}$$

STEP 3:

No change or addition in this step.

STEP 4:

No change or addition in this step.

STEP 5:

No change or addition in this step.

STEP 6:

No change or addition in this step.

STEP 7:

$$\beta = DRIV_{TRANS}$$

STEP 8:

No change or addition in this step.

STEP 9:

No change or addition in this step.

Emission Methodology

There is no change to the emission methodology.

Cost-Effectiveness

Variable Summary:

SITE	= Cost of site purchase
DESIGN	= Cost of transit plaza design
AMORT _{i,n}	= Amortization rate for given interest rate (i) and time period (n)
CONST	= Cost of transit plaza construction
O&M _{ANN}	= Annual operation and maintenance cost for transit plaza
365	= Converts annual costs to daily costs

STEP 1

$$\text{Revenue} = 0$$

$$\text{Planning \& Design} = \frac{(\text{SITE} + \text{DESIGN}) * \text{AMORT}_{i,n}}{365}$$

$$\text{Construction} = \frac{\text{CONST} * \text{AMORT}_{i,n}}{365}$$

$$\text{Equipment Purchase} = 0$$

$$\text{Operation \& Maintenance} = \frac{\text{O \& M}_{ANN}}{365}$$

STEP 2

No change or addition in this step.

STEP 3

No change or addition in this step.

STEP 4

No change or addition in this step.

Additional Information

None

TRAFFIC FLOW IMPROVEMENTS - SIGNAL RETIMING AND GEOMETRIC IMPROVEMENTS

Description

The most commonly implemented geometric improvements include adding turn-lanes and increasing the curb return radii. Adding a full lane is considered as roadway widening. Geometric improvements may necessitate a signal retiming to take advantage of the additional capacity added to the intersection, whereas signal retiming can be performed without any geometric improvements in response to changes in traffic conditions.

The results of signal retiming and geometric improvements are reductions in stop delay and improvements in the approach speeds to the intersection. Both of these results reduce emissions, producing a positive impact on the air quality surrounding the intersection.

Travel Methodology

Variable Summary:

PT	= Participation level
$\Delta\text{TFISPD}_{\%, P (\%, OP)}$	= Change in speed from traffic flow improvements in the peak period (or off-peak period)
$\Delta\text{SPD}_{\text{EXPT}}$	= Expected percent change in speed
AM_L	= Length of the AM peak period
PM_L	= Length of the PM peak period
$\text{VMT}_{\text{INT, P (INT, OP)}}$	= VMT passing through the intersections in the peak-period (or off-peak period)
$\text{VMT}_P (\text{OP})$	= Total VMT in peak period (or off-peak period)
20	= Hours per day (excludes midnight to 4 a.m.)

STEP 1

$$\text{PT} = 0$$

This is zero because trips are not reduced with this measure. Only traffic flow is improved.

STEP 2

No change or addition in this step.

STEP 3

No change or addition in this step.

STEP 4

No change or addition in this step.

STEP 5

No change or addition in this step.

STEP 6

No change or addition in this step.

STEP 7

No change or addition in this step.

STEP 8

No change or addition in this step.

STEP 9

$$\Delta TFISPD_{\%, p} = \Delta SPD_{EXPT} * \frac{[(AM_L + PM_L) * VMT_{INT, p}]}{VMT_p}$$

$$\Delta TFISPD_{\%, op} = \Delta SPD_{EXPT} * \frac{[(20 - AM_L - PM_L) * VMT_{INT, op}]}{VMT_{op}}$$

Combined with the original equation yields

$$\Delta SPD_p = \frac{\Delta VMT_p}{VMT_p} * \epsilon_p + \Delta TFISPD_{\%, p}$$

$$\Delta SPD_{op} = \frac{\Delta VMT_{op}}{VMT_{op}} * \epsilon_{op} + \Delta TFISPD_{\%, op}$$

Emission Methodology

Variable Summary:

AM_L	= Length of morning peak period (hours)
PM_L	= Length of afternoon peak period (hours)
Σd	= Sum of stopped delays for each approach (veh-hr)
$\Delta \%_d$	= Expected change in stopped delay
$RUNEM_1$	= Running emissions before improvement (grams)
$RUNEM_2$	= Running emissions after improvement (grams)
$IDEM_1$	= Idle emission before improvement (grams)
$IDEM_2$	= Idle emissions after improvement (grams)
ΣVOL_{apr}	= Sum of the peak hour approach volumes (veh)
L_{apr}	= Length of the approach (miles)
EF_{idle}	= Idle emission factors
EF_{spd}	= Running speed emissions
$EF_{NEW SPD}$	= Running speed emissions for new speed
$\Delta TFIEM$	= Total change in emissions due to improvement (grams)

STEP 1

No change or addition in this step.

STEP 2

No change or addition in this step.

STEP 3

No change or addition in this step.

STEP 4

Before Emissions

Idle:

$$IDEM_1 = (AM_L + PM_L) * \Sigma d * EF_{idle}$$

Running:

$$RUNEM_1 = (AM_L + PM_L) * \Sigma VOL_{apr} * L_{apr} * EF_{spd}$$

After Emissions:

Idle:

$$IDEM_2 = (AM_L + PM_L) * [\Sigma d * (1 + \Delta\%_d)] * EF_{idle}$$

Running:

$$RUNEM_2 = (AM_L + PM_L) * \Sigma VOL_{apr} * L_{apr} * EF_{NEW SPD}$$

Emission Changes

$$\Delta FIE M = (IDEM_2 - IDEM_1) + (RUNEM_2 - RUNEM_1)$$

STEP 5

No change or addition in this step.

Cost-Effectiveness

Variable Summary:

Revenue	= Revenue generated from improvement
Planning & Design	= Cost for planning and design of improvement
Construction	= Cost for construction of improvement
Equipment Purchase	= Cost of equipment purchases for improvement
Oper & Main	= Cost of operating and maintaining the improvement
DEVLP	= Cost to develop signal timing plans

AMORT _{i,n}	= Amortization rate based on interest rate and number of period
365	= Days per year
INST	= Cost to install traffic signals
PURC	= Purchase costs of equipment
ROW	= Cost of right-of-way purchase
Design	= Design costs
CONST	= Construction costs
O&M _{ann}	= Annual cost of operation and maintenance

STEP 1

Signal Improvements

$$Revenue = 0$$

$$Planning \ \& \ Design = \frac{DEVLP * AMORT_{i,n}}{365}$$

$$Construction = \frac{INST * AMORT_{i,n}}{365}$$

$$Equipment \ Purchase = \frac{PURC * AMORT_{i,n}}{365}$$

$$Operation \ \& \ Maintenance = \frac{O \ \& \ M_{ann}}{365}$$

Turn Lane Installation

$$Revenue = 0$$

$$Planning \ \& \ Design = \frac{(ROW + Design) * AMORT_{i, n}}{365}$$

$$Construction = \frac{CONST * AMORT_{i, n}}{365}$$

$$Equipment \ Purchase = 0$$

$$Operation \ \& \ Maintenance = \frac{O \ \& \ M_{ann}}{365}$$

STEP 2

No change or addition in this step.

STEP 3

No change or addition in this step.

STEP 4

No change or addition in this step.

Additional Information

This information required for this methodology can be obtained from the results of the analysis performed to design the signal timing or the results of an intersection capacity analysis.

