TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-92/1279-5		

4. Title and Subtitle	5. Report Date
A CRITICAL ANALYSIS OF SKETCH-PLANNING TOOLS FOR EVALUATING THE EMISSION BENEFITS OF TRANSPORTATION CONTROL MEASURES	December 1993
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Jason A. Crawford and Raymond A. Krammes	Research Report 1279-5
9. Performing Organization Name and Address	10. Work Unit No.
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. Study no. 0-1279
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas Department of Transportation Office of Research and Technology Transfer P.O. Box 5080 Austin, Texas 78763-5080	Interim: September 1991 - August 1993
	14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration. Research Study Title: Air Pollution Implications of Urban Transportation Investment Decisions.

16. Abstract

The role of transportation control measures (TCMs) in the transportation planning process has increased since the passage of the 1990 Clean Air Act Amendments. TCM analysis began in the early 1980s and several sketch-planning tools are now available.

The two premier sketch-planning tools used for evaluating transportation control measures are the Systems Applications International (SAI) method and the San Diego Association of Governments (SANDAG) method. Both methods were adapted to an available spreadsheet for easy use and modification. The SAI method required full programming in the spreadsheet, whereas the SANDAG method, originally developed for spreadsheet use, required only minor revisions.

A critical analysis, base scenario comparison, and sensitivity analysis were performed on the SAI and SANDAG methods. Results of the sensitivity analysis showed that the tools are most sensitive to the scope descriptors and work-related variables.

The report concludes that (1) recent work in the field has greatly advanced the state-of-the-practice; (2) the SAI method proved to be a better analysis tool than the SANDAG method; and (3) although sketch-planning tools are gross estimating techniques, they are currently the best TCM analysis tools.

17. Key Words	18. Distribution Statement
Systems Applications International, San Diego Association of Governments, Transportation Control Measure Estimation, Emission Estimation, Sketch-Planning Tools, Air Quality, Mobile Source Emissions	No Restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	113	

Form DOT F 1700.7 (8-69)

A CRITICAL ANALYSIS OF SKETCH-PLANNING TOOLS FOR EVALUATING THE EMISSION BENEFITS OF TRANSPORTATION CONTROL MEASURES

by

Jason A. Crawford
Assistant Research Scientist

and

Raymond A. Krammes
Associate Research Engineer

Air Pollution Implications
of Urban Transportation Investment Decisions
Research Study Number 0-1279
Research Report 1279-5

Sponsored by

Texas Department of Transportation

in cooperation with the

U.S. Department of Transportation
Federal Highway Administration

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

December 1993

IMPLEMENTATION STATEMENT

This research will assist metropolitan planning organizations and state departments of transportation in choosing a sketch-planning tool for evaluating transportation control measures (TCMs). The research includes a critical analysis of the Systems Application International (SAI) method and the San Diego Association of Governments (SANDAG) method and presents results of the comparison and recommendations. The SAI method was recommended for use.

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.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

SUMMARY

This report examines the two premier sketch-planning tools used for evaluating transportation control measures (TCMs). The two sketch-planning tools are the Systems Applications International (SAI) method and the San Diego Association of Governments (SANDAG) method.

Both methods were adapted to an available spreadsheet for easy use and modification. The SAI method required full programming in the spreadsheet, whereas the SANDAG method, originally developed for spreadsheet use, required only minor revisions.

A critical analysis, base scenario comparison, and sensitivity analysis were performed on the SAI and SANDAG methods. Results of the sensitivity analysis showed that the tools are most sensitive to the scope descriptors and work-related variables.

The report concludes that (1) recent work in the field has greatly advanced the state-of-the-practice; (2) the SAI method proved to be a better analysis tool than the SANDAG method; and (3) although sketch-planning tools are gross estimating techniques, they are currently the best TCM analysis tools.

CHAPTER I
INTRODUCTION

BACKGROUND

Motor vehicles are an important part of modern society. Significant trends in automobile use have become apparent during the last 20 to 30 years. These trends are growth in vehicle miles of travel (VMT), number of licensed drivers, number of registered motor vehicles, and amount of fuel consumption.

VMT has increased dramatically since the early 1970s. In 1986, VMT had increased 19.7 percent from 1972 levels, to 1,849 trillion miles. This mileage equated to 10,500 miles per vehicle annually in 1986 (*1*). A large portion of this annual VMT is produced on metropolitan freeway systems. Lindley (*2*) reports that freeways accounted for 2.6 percent of the 1987 roadway milage in urban areas and were responsible for more than 31 percent of the total VMT. The U.S. Department of Transportation (DOT) has underestimated the growth rate since 1983. The forecast was a 2.4 percent average annual VMT growth rate; however, the actual VMT growth rate has been 3.6 percent, 50 percent higher than projected (*3*). The VMT increase is due to an increase in drivers and automobiles.

The number of licensed drivers has also been increasing. In 1950, 57 percent of the driving age population was licensed to drive. In 1986 this number had increased by 86 percent. Even more surprising is the increase in the number of registered vehicles. The ratio of licensed drivers to registered motor vehicles has steadily declined since 1950's ratio of 1.26. The ratio in 1972 had dropped to about 1.00, and in 1986 the ratio had declined to 0.90 (*1*).

Fuel consumption has risen in accordance with the increased number of drivers and automobiles on our nation's transportation network. In fact, after a short decrease in highway fuel consumption in the late 1970s, fuel consumption for highway use has increased every year since 1982 (*1*).

The combination of these trends has produced congestion in urban areas. The increase in congestion has brought mobile source emissions to the forefront of environmental concerns.

Motor vehicles produce several categories of emissions. The principal pollutants are particulate matter (PM), sulfur dioxide (SO_2), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), ozone, and lead. Particulate matter from automobiles originates from several locations. Horowitz (*5*) describes particulate matter as all solid particles or liquid droplets in the air, except pure water. SO_2 originates from the combustion of sulphur-containing fuels, including coal and oil (*5*). CO is produced by the incomplete combustion of organic fuels. HC includes a variety of volatile organic substances in air quality studies (*5*). Their sources are automobile exhaust and evaporation of organic solvents. NOx includes primary and secondary pollutants. The primary pollutant is nitric oxide formed during the high-temperature combustion process of the automobile. This pollutant, when oxidized, produces nitrogen dioxide. Ozone is a secondary pollutant caused by the chemical process between hydrocarbons and nitrogen oxides. Lead pollution is caused by the combustion of leaded gasolines.

The main transportation-related pollutants are CO, HC, and NOx. The U.S. Environmental Protection Agency (EPA) has reported that 78 million Americans live in the 41 metropolitan areas that exceed CO standards (*4*). Horowitz (*5*) notes that the distribution of the pollutants (mobile versus stationary) emitted within a metropolitan area varies across the nation. The distribution of mobile source emissions within metropolitan areas is shown below for each of the transportation-related pollutants:

Pollutant	Distribution of Mobile Sources
CO	89% to 100%
HC	43% to 82%
NOx	31% to 74%

The Clean Air Act Amendments of 1990 (CAAA) were enacted to reduce the extent of mobile source emissions in urban areas. These amendments specifically call for transportation control measures (TCMs) to reduce air pollution. TCMs are best defined by the California Clean Air Act Amendments of 1988 (*6*) which describe them as strategies that "reduce vehicle trips, vehicle use, vehicle miles traveled, vehicle idling, or traffic congestion for the purposes of reducing motor vehicle emissions."

Specific TCMs in the CAAA are described in Section 108(f):

- 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 areas of emission concentration, particularly during periods of peak use;
- Programs for the provision of all forms of high-occupancy, shared ride services;
- 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 caused by extreme cold start conditions;
- 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 for pedestrian use 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.

Before TCMs can be used to reduce emissions in metropolitan areas, the type and extent of their implementation must be decided. These steps are part of the transportation air quality planning process. This process has been used since the late 1970s in metropolitan areas throughout the U.S. Surprisingly, the selection process for TCMs has not been refined much since then. It still relies on sketch-planning tools to evaluate potential TCMs for a region.

Several sketch-planning tools for TCM evaluation have been devised over the years. Most have built upon past work, whereas others have strived to break new ground through their own methodologies. The two most current methodologies are (1) the Systems Applications International (SAI) methodology prepared for EPA, and (2) the San Diego Association of Governments (SANDAG) methodology developed by Sierra Research, Inc., with support from JHK & Associates.

PROBLEM STATEMENT

Sketch-planning tools are used to predict the effects of engineering actions before they are implemented. The SAI and SANDAG methodologies best represent the state-of-the-practice for sketch-planning tools to evaluate the potential benefits of TCM implementation.

Two needs exist concerning the use of these sketch-planning tools. First, an independent critical evaluation of the logic, data requirements, and assumptions of these tools should be performed. One critique of these sketch-planning methods exists, but it does not provide an in-depth analysis of previous methods. This critique includes the SANDAG method; however, it does not include the SAI method. Second, the SAI method should be analyzed and compared to the SANDAG method. Both critiques are valuable in determining which methods are better predictors of TCM implementation results.

OBJECTIVES/SCOPE

This study has one primary objective and several secondary objectives. The primary objective is to critically analyze sketch-planning methods that evaluate the emission benefits of TCMs. This analysis will examine each method's logic, data requirements, and results. The secondary objectives are to determine which methodologies are better suited for estimating the emission benefits of TCMs, to assess each methodology's sensitivity to specific data inputs, and to identify areas for improvement and suggest possible solutions to enhance the current models.

The scope of this report will be limited to only two sketch-planning methodologies: the SAI method and the SANDAG method. In addition, only one non-attainment region, El Paso, Texas, will be used to analyze the two methodologies. El Paso is categorized as a serious ozone non-attainment area and a moderate CO non-attainment area. Therefore, available TCMs need to be assessed to aid in El Paso's attainment of air quality standards. This region is also part of a case study undertaken by the Texas Transportation Institute (TTI) for the Texas Department of Transportation (TxDOT) entitled "Air Pollution Implications of Urban Transportation Investment Decisions."

This report is organized into five chapters. The first chapter provides a general overview of the problem and the events that have prompted this study. Chapter II provides a discussion of sketch-planning tools used to evaluate TCMs. The third chapter describes the study design. Chapter IV presents the results of the critical analysis. Finally, Chapter V offers conclusions and recommendations based on the results of the study.

CHAPTER II
LITERATURE REVIEW

Several emission reduction estimation methods have been developed during the past 20 years. The first document on TCM analysis was NCHRP Report 263, published in the early 1980s. Little subsequent development occurred until the late 1980s. Since then, several new methods have been developed through California's leadership in air quality analysis. The Sacramento 1991 Air Quality Attainment Plan summarized the state-of-the-practice: "There is currently no universally acceptable methodology for evaluating TCMs" (7). Table 1 provides an overview of the dates of development for the methods critically reviewed in this chapter.

Table 1
TCM Sketch-Planning Methods

Method	Year
NCHRP Report 263	1983
AQAT-3	1990
Turnbull	1990
San Luis Obispo Air Pollution Control District	1991
Sacramento Air Quality Management District	1991
San Diego Association of Governments	1991
Systems Applications International	1992
North Central Texas Council of Governments	1992
Houston-Galveston Area Council	1992
Texas Department of Transportation	1993

NCHRP REPORT 263: SIMPLIFIED PROCEDURES FOR EVALUATING LOW-COST TCM PROJECTS

General Description

NCHRP 263 was the first attempt to provide transportation professionals with a methodology to assess the impacts of TCMs. The method uses a flowchart-type process beginning with problematic transportation conditions and ending with suggested solutions.

Thirty-seven TCMs are profiled for use with this methodology. Table 2 shows the TCMs that can be evaluated. The report places a heavy emphasis on the implementation factors and problems associated with the TCMs. NCHRP 263 also provides instructions on the estimation procedures and techniques for evaluating TCM impacts.

The supporting software for this method is limited. The software assists the user only for the flowchart process described above. The software does not evaluate any of the TCMs selected for analysis.

Estimation of Travel Effects

NCHRP 263 uses selection aides to evaluate the effectiveness of TCMs. Selection aids provide information on estimation procedures as well as methods and conditions for estimating travel effects. The selection aids also list additional references.

Effectiveness is determined from performance characteristics: supply/capacity, travel time and user cost, safety, travel volumes, financial, air quality impacts, and energy use. The effectiveness of a TCM project is then determined from the results obtained from some or all of the components above.

Estimation of Emission Changes

The air quality analysis method in NCHRP 263 is limited. No specific guidelines are available for the user to consult when evaluating the emission reductions from TCMs. Estimation techniques range from applying graphs and tables from other references to network analysis or simulation models.

The direct estimation aid is a table provided in the report that leads the user to five air quality references for consultation and use in further analysis. These references date

Table 2
TCMs Examined in NCHRP 263

- Staggered work hours
- Increased peak period roadway, bridge, or tunnel tolls
- Residential parking permits
- Park-and-ride lots along transit route
- Parking reserved for short-term use
- Parking rates, fines, and time limit adjustments
- Freeway ramp closure
- Travel on freeway shoulders during peak periods
- Reversible lanes
- Two-way left-turn lanes
- New street segments
- Reroute turning traffic
- Employer-based carpool matching programs
- Freeway lanes reserved for buses or carpools
- Arterial street lanes reserved for express buses or carpools
- Circulation buses or vans
- Expanded regular-route bus service
- Pedestrian-only streets
- Employer vanpool programs
- Bus transfer stations
- Limited and skip-stop bus routes
- Elderly/handicapped paratransit service brokerage
- One-way streets to improve flow
- Flexible work hours
- Toll discounts for carpools during peak periods
- Neighborhood traffic barriers
- On-street parking bans during peak periods
- Increased parking rates
- Expanded off-street parking
- Freeway ramp control
- Priority freeway access/egress for buses or carpools
- Shuttle buses or vans
- Community transit services
- One-way streets to impede flow
- Signal phases for left turns
- Use of fleet vehicles for carpooling
- Shared ride taxi

from the late 1970s and early 1980s. Mobile source emission technology has progressed greatly since the references were published. For instance, NCHRP 263 considers only running emissions. Starting fractions (cold or hot) are not accounted for in the TCM analysis. These starting fractions contribute more to overall emissions in the travel cycle than emissions produced while the vehicle is traveling at a constant speed. By not accounting for the starting fractions, the method fails to examine the full scope of emissions.

NCHRP 263 allows users to choose the emission factor models of their choice. Therefore, the method can be used with MOBILE for most of the nation and with EMFAC or BURDEN for California.

Care should be taken when using this method for air quality estimation. Several advancements in estimating emissions have been developed since this report was published and the references provided may not be technologically consistent with evaluation techniques used today.

AIR QUALITY ANALYSIS TOOLS

General Description

The California Department of Transportation and the California Air Research Board developed the Air Quality Analysis Tools (AQAT) to evaluate emissions associated with the transportation system. The current release of this tool is the third version, AQAT-3.

AQAT uses several previously developed evaluation models to estimate emission benefits: URBEMIS #3, EMFAC7PC, CALINE4, and PIVOT POINT. URBEMIS #3 is a land-use-based traffic evaluation model. EMFAC7PC is a California-specific emission factor model. CALINE4 is an emission concentration model which predicts pollutant concentrations near a roadway. Finally, PIVOT POINT is a mode choice model.

Austin et al., (*8*) suggested AQAT-3's strength lies in the use of commonly used computer software programs. This integration may allow users to work more easily with the method, because they may be familiar with the software. However, these integrated software programs lack the ability to specifically describe the extent of TCM programs and, therefore, lack the ability to assess those programs' effectiveness.

Estimation of Travel Effects

PIVOT POINT is the only model in this method used to evaluate travel impacts of the transportation system. PIVOT POINT estimates the shift of trips between drive alone and shared ride modes. It estimates trip shift or mode use by using a multinomial logit model:

$$Pr\ (mode_i) = f\ \left(\frac{util_{mode_i}}{\sum_{i=1}^{\infty} util_{mode_i}} \right)$$

Where:

Pr(mode $_i$)	=	probability of using mode$_i$
mode $_i$	=	mode of transportation used (single-occupancy vehicle (SOV), transit, carpool, buspool, vanpool, etc.)
util$_{mode\ i}$	=	utility of using mode$_i$

More specifically, PIVOT POINT uses an incremental form of multinomial logit such that results are "... revised probabilities for choosing a given mode based upon an existing base modal share and changes in utility for each mode" (*9*).

The output from PIVOT POINT consists of five variables: the revised modal share, percentage change in work trips, percentage change in non-work trips, percentage change in work VMT, and percentage change in total VMT. These outputs are the foundations for current sketch-planning model outputs.

PIVOT POINT has several limitations. First, it considers only work trips in its evaluation; non-work trip changes are deduced. Non-work trips are equally important to study. Second, PIVOT POINT uses data collected in Washington, D.C., during the late 1960s. The data may not accurately represent modern modal trends or other regions. Finally, Austin et al., noted that it ". . . does not precisely calculate how the changes in modal shares would translate to trip, VMT, and speed changes." These three important variables are used in calculating emission changes from TCM implementation.

This method does not account for latent demand or indirect trip effects from automobiles left at home. It also does not differentiate between work and non-work trips. Travel changes calculated in PIVOT POINT can be used for analysis in URBEMIS #3.

Estimation of Emission Changes

AQAT uses three modules for evaluating emissions: URBEMIS #3, EMFAC7PC, and CALINE4. The URBEMIS #3 module allows the computation of mobile source emissions as a function of the number of vehicle trips associated with a given land use and the VMT for each trip type (*9*). The emissions calculated in this program are HC, NOx, PM10, and sulfur oxide (SOx).

EMFAC7PC is a California emission factor model. This module can be used only in California because EMFAC uses California-specific values for estimating emission factors. EMFAC's emission estimates are based on California fleet mix, year, temperature, and operating speeds. Because EMFAC is incorporated into AQAT, it is difficult to use this tool outside of California.

Finally, CALINE4 evaluates several pollutants: CO, NO_2, PM, and other inert gaseous pollutants. CALINE4 estimates the concentration levels of these pollutants on and near roadways using a Gaussian diffusion algorithm.

TURNBULL METHOD

General Description

The Turnbull method was used to quantify the potential effects of TCMs in the Minneapolis, Minnesota, area in the late 1980s. It estimates the travel effects of four TCMs: ridesharing, employer-based strategies, transit and HOV actions, and variable work hours programs (*10*).

Estimation of Travel Effects

The Turnbull method calculates the effects of TCMs in terms of the potential trips affected and the number of vehicles removed from the roadway. Only peak-period work trips are considered.

The PIVOT POINT model for calculating mode shift from single-occupant vehicles to shared ride modes is used to estimate TCM benefits. Latent demand and indirect trip effects resulting from the implementation of TCMs are not considered in this method. Figure 1 is a schematic of the travel estimation algorithm.

The Turnbull method lacks two key variables for estimating emissions: VMT and speeds. However, the user could estimate these key travel variables. The change in VMT could be estimated by multiplying the peak-period work trip reduction by the average work trip length. Likewise, estimates of speed changes could be made by multiplying the percentage change in VMT by an elasticity of peak-period speed with respect to volume.

Estimation of Emission Changes

Emissions are not considered in the Turnbull method. The original intent of the developers did not include estimating emission changes; therefore, the user must develop an emission module. Because of the gross travel estimation and the limited scope of trip types considered in the analysis, caution should be used in developing an emission module.

SAN LUIS OBISPO AIR POLLUTION CONTROL DISTRICT

General Description

The San Luis Obispo Air Pollution Control District (SLO) method was developed with simplicity in mind. This method calculates the changes in emissions and the cost-effectiveness of the TCM. The method was developed for use with a spreadsheet.

Estimation of Travel Effects

The SLO method does not specifically estimate the travel effects of TCMs. Instead, estimations of variables affected by the TCM are used to calculate changes in emissions. The developer noted that the cost analysis should attempt to account for effects caused by latent demand on the facilities (*11*). This method does not differentiate between work and non-work trips or between peak and off-peak periods.

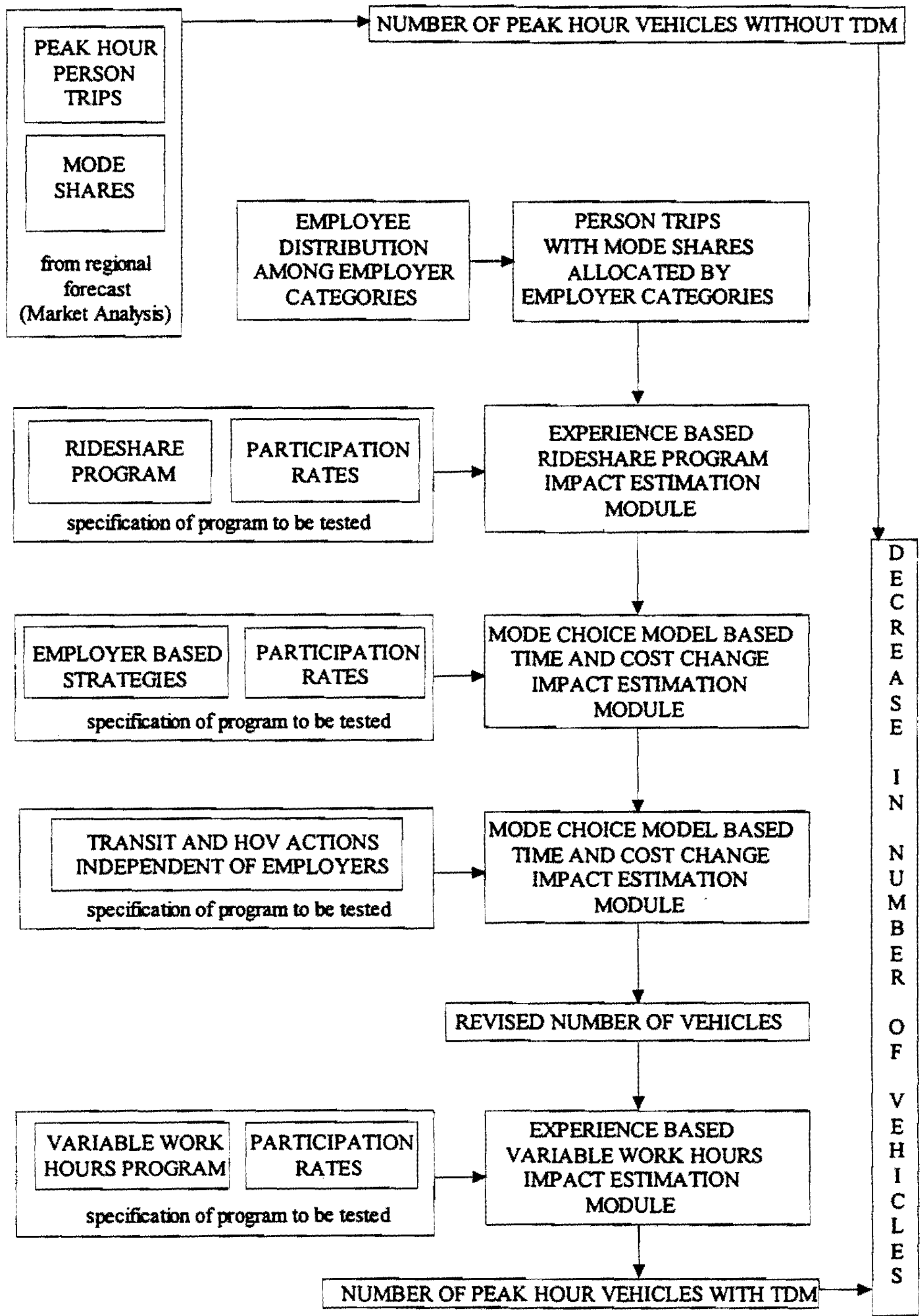

Figure 1. Turnbull method travel estimation algorithm (adapted from *10*).

Estimation of Emission Changes

This methodology estimates the changes in three pollutants: reactive organic gases (ROG), NOx, and PM10. Changes in emissions from TCM implementation are estimated from the following general efficiency equations:

$$\textit{Emissions Reduced (or Avoided)} = (\textit{Uncontrolled Emissions}\, Y_i) - (\textit{Controlled Emissions}\, Y_i)$$

$$\textit{Control Efficiency} = 1 - \frac{\textit{Controlled Emissions } Y_i}{\textit{Uncontrolled Emissions } Y_i}$$

Where:

Y_i = pollutant from mode $_i$

These equations are applicable when evaluating any desired pollutant.

The method does not specify the emission factor model to be used. Therefore, either California-specific emission factor models or MOBILE5A, the EPA emission factor model used elsewhere in the U.S., may be used to estimate emission factors.

The SLO method calculates a variety of emission categories. These include running exhaust, hot- and cold-start exhaust, idle, and hot-soak evaporation emission factors for ROG and NOx. The transit improvement evaluation does not include the effects of start emissions, hot-soak emissions, or idle emissions from a reduction in vehicle trips. PM10 calculations include re-entrained dust, PM10 exhaust, and tire wear.

SACRAMENTO METROPOLITAN AIR QUALITY MANAGEMENT DISTRICT

General Description

The Sacramento Metropolitan Air Quality Management District (SMAQMD) method uses five modules to assess the impacts of TCMs: (1) TCMMARK, (2) TCMPACT, (3) RAVDEM, (4) emission impacts, and (5) cost-effectiveness. The method considered several TCMs based on their implementation window: near-term, mid-term, and long-term. The number of TCMs examined in each time window was 20, 11, and 7, respectively. The near-term TCMs are listed in Table 3.

Austin et al., noted that this methodology was the "first step in determining which combinations of TCMs would be most effective in achieving desired mobile source emission reductions." Overall, Austin noted that this method is highly qualitative.

Some important assumptions are used in this methodology. First, the methodology assumes a no-build scenario, such that ". . . no construction of transportation facilities, rail or roads/highways approved after 1990 are considered" (*7*). Second, no assumptions in the model account for ". . . changes to aggregate levels of population growth or major land use changes" (*7*).

The SMAQMD has abandoned this method. In place of their method, the SMAQMD has recommended using the SANDAG method, discussed later in this chapter, because it is more thorough and easier to use (*12*).

Table 3
Near-Term TCMs Examined in SMAQMD Method

- Employer commute alternatives rule
- Worksite commute alternatives rule
- Institutional commute alternatives rule
- Commute data rule
- Enhanced rideshare matching and placement
- Expand TMAs
- Expand guaranteed ride home effort
- Preferential on-street parking
- Preferential off-street parking
- Improve bus routes, service, and schedules
- Improve fare collection system
- Ramp meter bypass lanes
- Bicycle safety and enforcement
- Shuttle service
- Enhanced tax incentives
- Telecommunications
- Alternative work schedules
- Truck idling regulations

Estimation of Travel Effects

TCMMARK determines the scope of TCMs as they affect GRACIE (goods movement, recreation, activity center, commercial, institutional, and employment) travel markets. These travel markets consider all trips affected, instead of focusing on work trips. The transportation impacts of TCMs on each GRACIE travel market is rated by a yes/no response. These impacts are further assessed in the TRAVDEM (travel demand forecasting model) module.

The TCMPACT module qualitatively ranks each TCM by its impact on several emission sources: cold-start, hot-start, VMT, idle time, speed, and time of day. Each TCM is ranked on a scale ranging from -6 to +6, based on the emission sources listed above through a table identifying a score with percentage reduction in overall emissions. A negative ranking indicates an increase in emissions for several emission categories. It should be noted that TCMs may have overall positive effects (a positive rank) although they may cause an increase in some emission categories.

TRAVDEM is the travel demand forecasting model. It is used to evaluate the travel impacts of each TCM. Predictions for travel effects are determined as potential trips and VMT reduction. The SMAQMD method does not account for latent demand or indirect effects of TCMs.

Estimation of Emission Changes

Emission reduction estimates are calculated for on-road mobile source emissions in the SMAQMD method. The method considers changes in three pollutants: ROG, NOx, and CO. The SMAQMD method determines changes in four emission categories: VMT emissions, cold-start emissions, hot-start emissions, and hot-soak emissions. The VMT emissions are evaluated from running exhaust (ROG, CO, and NOx) and running losses (ROG). The cold-start emissions examine the cold-start exhaust emissions associated with ROG, CO, and NOx. The hot-start emissions associated with ROG, CO, and NOx are examined. Finally, the hot-soak emissions examine only the hot-soak evaporation for ROG.

The emission impacts are calculated based on data obtained from the EMFAC and BURDEN emission factor models and results of the travel effects of the TCMs. The SMAQMD methodology cannot be easily used outside of California because of the use of California-specific emission factor models.

SAN DIEGO ASSOCIATION OF GOVERNMENTS

General Description

The SANDAG methodology is structured into three modules: (1) travel impacts, (2) emission impacts, and (3) cost-effectiveness. The method is designed to predict the effect of single TCMs *(13)*. Twenty-five TCMs are included in the method, and user-defined TCMs can be used. These TCMs are listed in Table 4. The method was developed using LOTUS 1-2-3 and FORTRAN. The cost-effectiveness module uses output from the travel and emission modules. It then converts annualized costs to daily costs.

This method enables the user to evaluate TCM alternatives. In addition, the method was developed for several air basins and counties in California for greater use of the method within the state.

Table 4
TCMs Examined in SANDAG Method

• Growth controls	• Telecommuting
• Jobs/housing balance	• Flextime
• Densification	• Staggered work hours
• Mixed use	• Compressed work week
• Transit service increases	• Delivery timing
• Park-and-ride lots	• Capacity increases
• Bicycle improvements	• HOV lanes
• Ridesharing	• Trip reduction ordinances
• VMT tax	• Parking management
• Pedestrian improvements	• Gas tax/cost increase
• Traffic signal improvements	• Motorist information
• Employee transit pass subsidy	• Incident management and response

Estimation of Travel Effects

The travel impacts module estimates the changes in trips, VMT, and speeds from TCM implementation. Inputs for this method include baseline travel characteristics, TCM-specific parameters, and underlying assumptions throughout the model. The

SANDAG method uses several elasticities that are based on empirical data from the western U.S. (*13*).

The changes in travel impacts are differentiated by travel period: peak or off-peak. In addition, the method determines the effects on work and non-work trips; however, trip type and time period are not correlated (e.g., peak work trip, off-peak work trip, peak non-work trip, and off-peak non-work trip).

The SANDAG method relies heavily on default data. Defaults are provided for several variables where the data are not readily available for calculation. Caution should be exercised when using the defaults because they may not accurately represent the study region; therefore, local data should be collected and used to accurately assess the impacts of TCMs.

The SANDAG method begins to examine the effects of latent demand and indirect trips. Unfortunately, these effects are not calculated from changes in travel characteristics; the effects of latent demand and indirect trips must be input by the user.

Estimation of Emission Changes

The emission module uses emission factor data obtained from EMFAC7E and BURDEN7C (another California emission factor model). Therefore, this method can be used only in California; however, FHWA is funding a conversion of the SANDAG method to MOBILE emission factors so that the method can be used nationally. The method examines four pollutants when estimating the impacts of TCMs: ROG, CO, NOx, and PM10.

SYSTEMS APPLICATIONS INTERNATIONAL

General Description

The SAI methodology is the most recent attempt by the EPA to estimate the potential emission benefits from the implementation of TCMs. Its basic structure consists of two modules: travel effects and emission effects. Documentation is provided for seven TCMs:

- Telecommuting

- Flextime
- Compressed work week
- Ridesharing
- Transit improvements
- HOV lanes
- Parking management

The documentation of the methodology provides step-by-step instructions on how to estimate the effects of trips, VMT, and speeds from selected TCMs. This process allows the user to develop similar estimating techniques for TCMs not included in the documentation.

Two limitations have been identified with this method. First, no computer software is available to implement the method. Second, the method requires a large amount of data which are difficult to collect.

Estimation of Travel Effects

The SAI method predicts trip, VMT, and speed changes from selected TCMs. These variables represent crucial data required during the emission evaluation. Direct trip reductions and indirect trip increases, as well as trip shifts into and out of the peak period, are calculated.

Trip types (work and non-work) are associated with their time of occurrence (peak and off-peak). This organization of trips provides an accounting system which includes all trips that occur in a region. Through this accounting process, a better estimation of TCM effects can be made, since TCMs can be used in the peak period, off-peak period, or both.

SAI provides guidance on estimating indirect trip effects and latent demand. Indirect trip effects are those caused by a commuter leaving the vehicle at home and another family member using the vehicle for other purposes. Latent demand is the demand attracted to a roadway because of improved conditions. The indirect trip effect is an important consideration for real world modeling, since not all vehicles will be left in the driveway when the commuter changes modes. Unlike the SANDAG method, the SAI method attempts to quantify latent demand. SAI, however, does not add the latent demand effects into the overall travel effects estimates.

VMT changes are calculated based on trip changes and changes in trip length. Speed changes are determined from the VMT changes.

Estimation of Emission Changes

Three pollutants are estimated in the emission evaluation: CO, NOx, and HC. These are the same pollutants for which MOBILE calculates emission factors. Changes in these emissions are calculated from trip, VMT, and fleet speed changes due to TCM implementation.

The SAI method uses a wide array of emission factors in its analysis. Cold-start, hot-start, and hot-stabilized emission factors are calculated for all three pollutants. Hot soak and diurnal emission factors are calculated for HC. In addition, the method includes crankcase, running losses, resting losses, and refueling emission factors in the analysis.

This method does not specify an emission factor model. Instead, emission variables are identified, and the choice of emission factor model is left to the user; therefore, this method can be used in California as well as the rest of the U.S.

NORTH CENTRAL TEXAS COUNCIL OF GOVERNMENTS

General Description

The North Central Council of Governments (NCTCOG) method was developed to aid in selecting TCMs to be included in the Transportation Improvement Program. It is a qualitative process that evaluates individual TCMs based on several variables.

Transportation professionals in the Dallas-Fort Worth area selected the evaluation criteria from an initial list of 21 variables. This selection process resulted in the adoption of five criteria. Table 5 shows the five criteria and their weight.

Estimation of Travel Effects

Travel effects were modeled with the Dallas-Fort Worth Regional Travel Model. This method does not differentiate between either trip types or the time period affected.

Table 5
NCTCOG Project Criteria

Criteria	Weight
Current cost-effectiveness	25
Future cost-effectiveness	20
Air quality/energy conservation benefits	20
Project commitment/local cost participation	20
Intermodal/multimodal projects/social mobility	15
TOTAL	100

Estimation of Emission Changes

The NCTCOG method predicts the effectiveness of TCMs based on HC emission reduction. The air quality score is based on the change in vehicular emissions caused by a change in vehicle speeds and VMT.

MOBILE4.1 was used to calculate the emission factors used in the air quality analysis. NCTCOG analysts gave special attention to spatial and temporal parameters so that emission calculations were accurately estimated.

HOUSTON-GALVESTON AREA COUNCIL

General Description

The Houston-Galveston Area Council (H-GAC) method was used to calculate emission reductions from selected TCMs in the 1993 Transportation Improvement Program for the Houston-Galveston area.

Estimation of Travel Effects

Travel changes from TCMs were modeled with runs of the travel demand forecasting models for the Houston-Galveston area.

Estimation of Emission Changes

The H-GAC method calculates VOC emissions exclusively. These emissions were calculated using basic emission estimation procedures. The emissions changes were determined by multiplying speed-sensitive emission factors obtained with MOBILE4.1 by the VMT on each link of the highway network.

TEXAS DEPARTMENT OF TRANSPORTATION

General Description

The TxDOT emission estimation tool was developed in TxDOT's Division 8. The tool consists of basic equations used to estimate the emission impact of five TCMs: roadway widening, transit improvements, intersection improvements, HOV lanes, motorist assistance patrols/incident detection and response, and bikeways.

The TxDOT method was developed to assist Texas MPOs in estimating emission reductions resulting from transportation projects being considered in transportation improvement programs and for determining Congestion Mitigation/Air Quality funding eligibility under the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA). The method determines the effects on travel and emissions from TCMs and then calculates their cost-effectiveness.

Estimation of Travel Effects

The TxDOT method examines the emission benefits of TCMs on an individual project basis as opposed to a regional basis. Generally, speeds after TCM implementation are determined from speed-flow relationships (i.e., increased capacity leads to improved level-of-service which leads to higher speed).

This method does not account for any indirect effects of latent demand. In addition, the method does not differentiate between trip types or travel periods.

Estimation of Emission Changes

The TxDOT method can be used to calculate VOC, CO, and NOx by inputing speed-based emission rates. The method does not specifically use an emission factor model.

Therefore, the method may be used in Texas and elsewhere in the nation. The method does not estimate the effects of start fractions.

SUMMARY

Sketch-planning methodologies for estimating the potential emission benefits from TCMs have been used since the early 1980s. Recent work has been done to improve sketch-planning methods.

Older methods generally were concerned with determining the reduction in either trips or vehicles. Current methods investigate these changes as well as changes in VMT and speeds. These latter variables are important when estimating the emission benefits from TCMs.

Many of the California-based methods were not developed with out-of-state use in mind. Specifically, these methods incorporate California emission factor models, impeding their use outside of California.

Table 6 summarizes the pollutants estimated by each method. Most of the methods calculate NOx and TOG/ROG/HC. TOG, ROG, and HC are grouped together because they belong in the same family of pollutants. PM10 is used in both the SANDAG and SLO methods for evaluating particulates generated from tire wear.

Latent demand and indirect trip effects are evaluated in the more recent methodologies (SAI and SANDAG). Previous methods do not estimate these factors or document that they are a concern. The three methods used in Texas also do not estimate these factors.

The SAI and SANDAG methodologies are at the forefront of sketch-planning methods to evaluate emission reductions from TCMs. These methods begin to evaluate the travel effects generated from latent demand and indirect trips caused by TCM implementation. They also begin to account for start fractions and emissions generated for the whole trip.

Table 6
Summary of Pollutants Calculated by Method

Method	Pollutant				
	HC	CO	NOx	PM10	SO_x
NCHRP Report 263		X			
AQAT-3	X (TOG)	X	X	X	X
Turnbull[1]					
Sacramento Metropolitan Air Quality Management District	X (ROG)	X	X		
SLO	X (ROG)		X	X	
SANDAG	X (ROG)	X	X	X	
SAI	X	X	X		
North Central Texas Council of Governments	X (VOC)				
H-GAC	X (VOC)				
TxDOT	X	X	X		

[1] The Turnbull method estimates travel effects only, not specific pollutants.

CHAPTER III
STUDY DESIGN

CONVERSION OF SAI AND SANDAG METHODOLOGIES TO SPREADSHEET

Currently, the SAI and SANDAG methods are available in different media. The SAI method is only described in a report and does not have any supporting software. The SANDAG method, however, has been programmed through LOTUS 1-2-3 spreadsheets and compiled in FORTRAN code.

Both methods were programmed and/or imported into an available spreadsheet. The SAI method was programmed in its entirety. The Texas Transportation Institute (TTI) is in the process of making the SAI spreadsheet model available in 1994. A user's manual for the spreadsheet version of the SAI method will be documented as a separate report under this project. The SANDAG method was imported and modified to the available spreadsheet's standards; however, these actions were not sufficient for a complete evaluation of results obtained by the two methods. Additional modifications were then made to the SANDAG method so that emission estimates could be compared between the two methods.

The SANDAG method estimates emission reductions using the California-specific emission factor model, EMFAC7. Modifications to the SANDAG emission module could not be made so that MOBILE emission factors could be used. Thus, the SANDAG emission module could not be used to directly compare those results obtained from the SAI method. Therefore, the SAI emission module was adapted for use with the SANDAG method to calculate emission reduction.

Fourteen travel effect variables used in the SAI emission module were identified. The SANDAG method had equivalent variables for each of the 14 variables identified. This similarity made the use of the SAI emission module compatible with the SANDAG travel variables; and, therefore, the two should produce similar emission estimates.

DESCRIPTION OF STUDY REGION

This report is based on the best available information from El Paso, Texas. El Paso was selected as the study site based on two criteria: it is a non-attainment area, and it represents a smaller metropolitan area.

El Paso is located in west Texas and borders New Mexico and the Republic of Mexico. The city's population has increased steadily during the past decade to a 1990 census population of 561,965, the fourth largest in Texas. The city is at an altitude of 4,000 feet above sea level and has several mountains around the perimeter of the central business district, forming an air basin. Figure 2 is a map of the El Paso area.

The transportation system in El Paso is centered around Interstate Highway 10, east-west, and U.S. Highway 54, north-south. In addition to the geographical and transportation characteristics, other factors including the proximity to Juarez, Mexico, make the El Paso region unique.

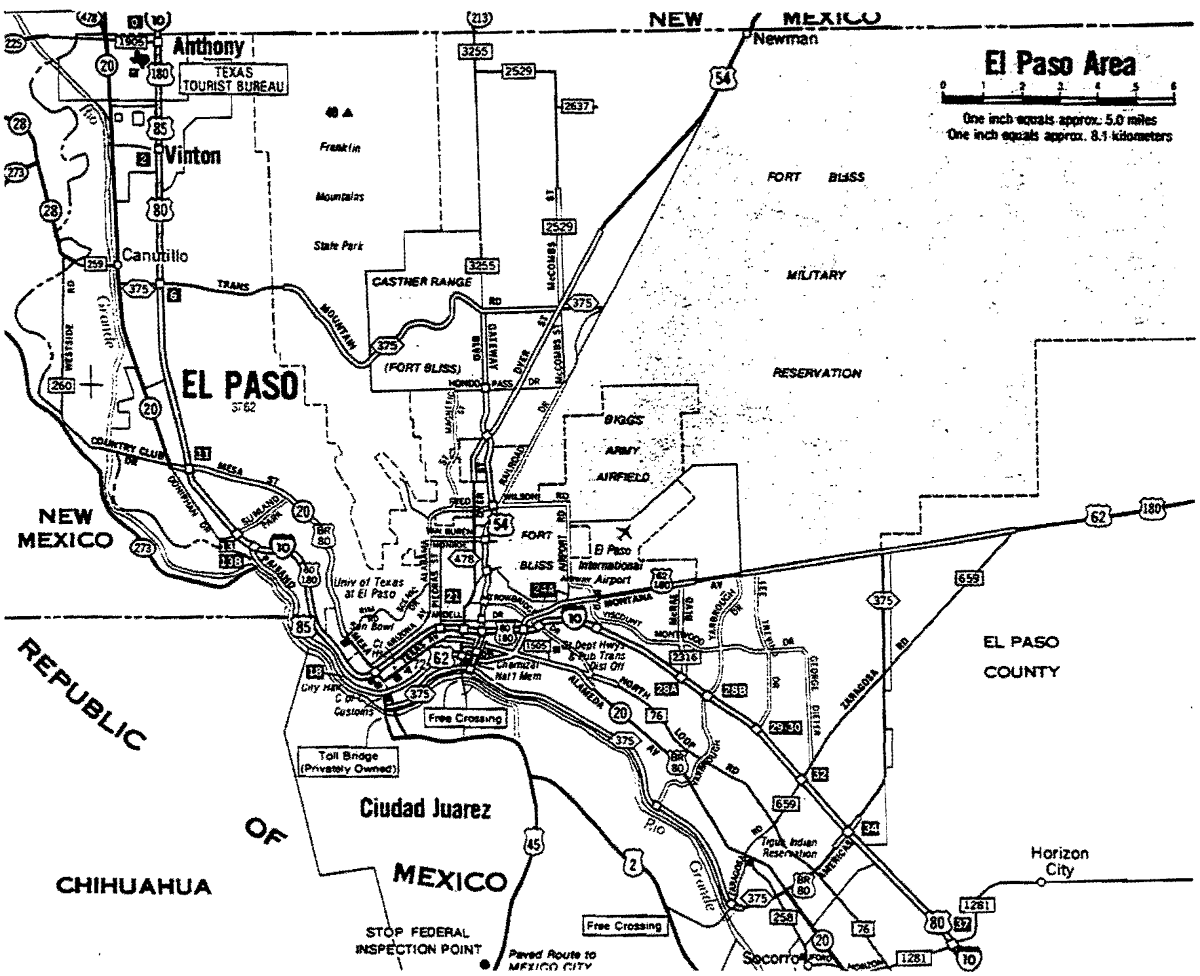

Figure 2. Map of El Paso area.

Juarez, Mexico, is located across the Rio Grande River from the El Paso central business district and has an approximate population of 1,500,000 persons. Because of the location of Juarez, many work trips are made into El Paso by Mexican citizens via several international bridges. These foreign workers use the El Paso transit system (Sun Metro) to reach their workplaces and shop in American stores. Unfortunately, these employment statistics and transit trips are not accounted for in the census data collected. Therefore, estimates of employment and transit ridership may be inaccurate and low.

DATA COLLECTION

Data requirements for the two methods cover several areas: demographics, travel characteristics, and specific TCM data. More than 100 variables were identified for evaluating TCMs for the SAI and SANDAG methods.

Several types of data were collected from various sources in El Paso. These sources include TxDOT, El Paso MPO, Sun Metro, and the City of El Paso. Data collected from these sources accounted for approximately 60 percent of the baseline data required.

The remaining data were collected by other means. For these data, suggested values developed in other regions of the U.S. were used; and other values were calculated from published sources. In particular, several sources were used to determine general and peak-hour travel characteristics. Peak-hour characteristics were estimated using peak-period modeling data based on the San Antonio 1990 Travel Survey. San Antonio was used to estimate El Paso's peak-period travel characteristics because the two cities are closer in size than other cities examined in the study.

MOBILE5A HIGHWAY VEHICLE EMISSION FACTOR MODEL

The MOBILE5A emission factor model was used in this analysis to calculate mobile source emission factors for the El Paso region. This version of MOBILE is the most current release from EPA. El Paso, like most nonattainment areas, is required to use mobile source emission factors developed from this model for evaluating mobile source emissions in the region. MOBILE data requirements include several control flags as well as additional input describing the region and scenario.

Control flags and additional data developed by the Texas Air Control Board (now the Texas Natural Resource Conservation Commission) were used for this report. The appendix provides a summary of the control flag settings.

METHODOLOGY COMPARISON AND CRITICAL ANALYSIS

Comparing and analyzing the SAI and SANDAG methods involved the critical analysis of three elements: (1) data requirements, (2) procedural logic, and (3) assumptions within the methods. These elements represent the foundation for each method's functionality.

The data requirements for SAI and SANDAG are very important. Extensive data requirements are not desirable to the user; conversely, insufficient data requirements will not yield accurate model estimates. The reasonableness of the data requirements were assessed based on how difficult they were to obtain. In particular, emphasis was placed on the ability of MPOs to satisfy the data requirements.

It is important to understand how each method processes its data to estimate travel and emission benefits. A comparison between the two methods allows a first examination of TCM evaluation and different means of estimating travel and emission effects.

Assumptions made in a methodology are critical to that model's performance. Several traffic characteristic and driver behavior assumptions were made. The SANDAG method relies more on these assumptions than the SAI method. First, it is important that these assumptions be valid and reasonable. Second, the assumptions should have documentation supporting their use in the model.

TCM BASE CASE SCENARIO COMPARISONS

Five TCMs were evaluated using the SAI and SANDAG methods: flextime, ridesharing, transit fare decrease, transit service increase, and parking management. These TCMs are common to the two methods and are of interest to El Paso officials.

The TCM scenarios were based on data obtained from the El Paso region. Where data were not available, suggested values from other regions were used. Base cases were first run with the SAI method. This method is easier to use in describing the TCMs. The

SAI results were then used to determine equivalent base cases in the SANDAG method. The number of vehicle trips reduced by the TCM was used to equate the two methods. The SANDAG results were then compared to the SAI results. Tables 7 and 8 show the variables and values used for each TCM base case scenario.

A comparison of the two methods was performed based on the results of the TCM base case scenarios. Nine variables were examined for this comparison. Six variables represent the travel effects associated with TCMs: change in peak and off-peak period trips, VMT, and speeds. The last three variables are the emission effects of the TCMs: change in CO, HC, and NOx.

SENSITIVITY ANALYSES

Sensitivity analyses were performed on many variables for two reasons: (1) to determine their impact on the methods, and (2) to identify which variables are most critical to the estimation of travel and emission effects. These variables include several elasticities, user-specified values, and assumed data values for TCM evaluation. Table 9 shows these variables and the range of values studied for each TCM used in the SAI method. Table 10 shows similar information for the SANDAG method.

The following equations were used to identify the sensitivity of each variable to vehicle trip changes and VMT changes in the peak and off-peak periods:

$$\textit{Sensitivity of Change in Vehicle Trips} = \frac{\Delta\ \textit{Variable}}{\Delta\ \textit{Vehicle Trips}}$$

$$\textit{Sensitivity of Change in VMT} = \frac{\Delta\ \textit{Variable}}{\Delta\ \textit{VMT}}$$

These equations allow comparison between variables, because each slope has a common denominator. Because there is not an absolute base from which to judge the sensitivity of each variable, they could only be compared to one another or within a particular TCM.

Table 7
TCM Base Case Scenario Descriptors for SAI

TCM	Variable	Value
Flextime	Number of participants	6,500
	Number of days per week flextime in operation	3
Ridesharing	Number of participants	6,500
	Number of days per week carpooled	3
Transit fare decrease	Number of individuals experiencing change in cost	19,950
	Percentage change in fare	-.25
Transit service increase	Number of new patrons	6,500
Parking management	Number of spaces subject to price increase	500
	Percentage change in parking price	50

Table 8
TCM Base Case Scenario Descriptors for SANDAG

TCM	Variable	Value
Flextime	Percentage of all employees that shift out of the peak period	0.3
Ridesharing	Percentage increase in non-drive alone modes	25.9
	Percentage of maximum VMT reduction realized due to circuity of ridesharing or access to transit	80.0
	Percentage of new carpool riders that still make a trip, does not include carpool driver	33.9
	Percentage of employees affected	63.0
Transit fare decrease	Average percentage fare decrease	-.25
	Percentage of transit ridership that equals the trip reduction	74.1
Transit service increase	Increase in transit vehicle miles	7,415
	Percentage of transit ridership that equals the trip reduction	74.1
Parking management	Average daily increase in parking charge	$0.40
	Percentage of employees affected	0.3
	Percentage of maximum VMT reduction realized due to circuity of ridesharing or access to transit	80.0

Table 9
Sensitivity Analysis Values for SAI Method

TCM	Variable	Range
Flextime	Number of participants	0 - 20,000
	Number of days per week flextime in operation	1 - 5
	Elasticity of peak speed with respect to volume	0 - (-1.000)
	Elasticity of off-peak speed with respect to volume	0 - (-1.000)
	New work trip length	0 - 6
	Non-work trip generation rate for SOV users	0 - 6
	Work trip generation rate for SOV users	0 - 6
	Number of non-work trips per day per vehicle	0 - 6
	Number of work trips per vehicle commute day	0 - 6
	Fraction of trips made via shared mode	0 - 0.50
	Peak-period speed prior to TCM implementation	20 - 40
	Off-peak period speed prior to TCM implementation	30 - 50
	Fraction of work trips of the total TCM-related work trips during the peak period	0 - 1.000
	Fraction of non-work trips of the total TCM-related non-work trips during the peak period	0 - 1.000
Ridesharing	Number of participants	0 - 20,000
	Number of days per week carpooled	1 - 5
	Fraction of ridesharers who join existing carpools and do not meet at park-and-ride	0 - 1.000
	Fraction of ridesharers who join new carpools and do not meet at park-and-ride	
	Elasticity of peak speed with respect to volume	0 - (-1.000)
	Elasticity of off-peak speed with respect to volume	0 - (-1.000)
	New work trip length	0 - 6
	Non-work trip generation rate for SOV users	0 - 6
	Work trip generation rate for SOV users	0 - 6
	Number of non-work trips per day per vehicle	0 - 10

Table 9 (Continued)
Sensitivity Analysis Values for SAI Method

TCM	Variable	Range
Ridesharing (continued)	Number of work trips per vehicle commute day	0 -4
	Fraction of trips made via shared mode	0 - 0.50
	Peak-period speed prior to TCM implementation	20 - 40
	Off-peak period speed prior to TCM implementation	30 - 50
	Fraction of work trips of the total TCM-related work trips during the peak period	0 - 1.000
	Fraction of non-work trips of the total TCM-related non-work trips during the peak period	0 - 1.000
Transit fare decrease	Percentage change in fare	0 - (-100)
	Number of individuals experiencing change in cost	0 - 20,000
	Percentage change in ridership given percentage change in fare	0 - (-1.000)
	Elasticity of peak speed with respect to volume	0 - (-1.000)
	Elasticity of off-peak speed with respect to volume	0 - (-1.000)
	New work trip length	0 - 6
	Non-work trip generation rate for SOV users	0 - 6
	Work trip generation rate for SOV users	0 - 6
	Number of non-work trips per day per vehicle	0 -10
	Number of work trips per vehicle commute day	0 - 4
	Fraction of trips made via shared mode	0 - 0.50
	Peak-period speed prior to TCM implementation	20 - 40
	Off-peak period speed prior to TCM implementation	30 - 50
	Fraction of work trips of the total TCM-related work trips during the peak period	0 - 1.000
	Fraction of non-work trips of the total TCM-related work trips during the peak period	0 - 1.000
Transit service increase	Number of new patrons	0 - 20,000
	Elasticity of peak speed with respect to volume	0 - (-1.000)
	Elasticity of off-peak speed with respect to volume	0 - (-1.000)
	New work trip length	0 - 6

Table 9 (Continued)
Sensitivity Analysis Values for SAI Method

TCM	Variable	Range
Transit service increase (continued)	Work trips generation rate for SOV users	0 - 6
	Number of non-work trips per day per vehicle	0 - 10
	Number of work trips per vehicle commute day	0 - 4
	Fraction of trips made via shared mode	0 - 0.50
	Peak-period speed prior to TCM implementation	20 - 40
	Off-peak period speed prior to TCM implementation	30 - 50
	Fraction of work trips of the total TCM-related work trips during the peak period	0 - 1.000
	Fraction of non-work trips of the total TCM-related work trips during the peak period	0 - 1.000
Parking management	Number of spaces subject to price increase	0 - 7,000
	Percentage change in parking price	0 - 100
	Parking elasticity	0 - (-1.000)
	Fraction of participants who will use transit	0 - 1.000
	Fraction of participants who will rideshare	
	Fraction of new carpoolers who join existing carpools and do not meet at park-and-ride	0 - 1.000
	Fraction of new carpoolers who join new carpools and do not meet at park-and-ride	
	Elasticity of peak speed with respect to volume	0 - (-1.000)
	Elasticity of off-peak speed with respect to volume	0 - (-1.000)
	New work trip length	0 - 6
	Non-work trip generation rate for SOV users	0 - 6

Table 9 (Continued)
Sensitivity Analysis Values for SAI Method

TCM	Variable	Range
Transit service increase (continued)	Work trip generation rate for SOV users	0 - 6
	Number of non-work trips per day per vehicle	0 - 10
	Number of work trips per vehicle commute day	0 - 4
	Fraction of trips made via shared mode	0 - 0.50
	Peak speed prior to TCM implementation	20 - 40
	Off-peak speed prior to TCM implementation	30 - 50
	Fraction of work trips of the total TCM-related work trips during the peak period	0 - 1.000
	Fraction of non-work trips of the total TCM-related non-work trips during the peak period	0 - 1.000

Table 10
Sensitivity Analysis Values for SANDAG Method

TCM	Variable	Range
Flextime	Percentage of all employees that shift out of the peak period	0 - 100
	Elasticity of peak speed with respect to volume	0 - (-1.000)
	Elasticity of off-peak speed with respect to volume	0 - (-1.000)
Ridesharing	Percentage increase in non-drive-alone modes	0 - 100
	Percentage of maximum VMT reduction realized due to circuity of ridesharing or access to transit	1 - 100
	Percentage of new carpool riders that still make a trip, does not include carpool driver	0 - 100
	Percentage of employees affected	0 - 100
	Drive alone share of commute person trips	1 - 100
	Elasticity of peak speed with respect to volume	0 - (-1.000)
	Elasticity of off-peak speed with respect to volume	0 - (-1.000)
Transit fare decrease	Average percentage fare decrease	0 - (-100)
	Percentage of transit ridership that equals the trip reduction	0.5 - 100
	Elasticity of transit use with respect to service	0.005 - 1.000
	Elasticity of transit use with respect to cost	-0.005 - (-1.000)
	Elasticity of peak speed with respect to volume	0 - (-1.000)
	Elasticity of off-peak speed with respect to volume	0 - (-1.000)
Transit service increase	Increase in transit vehicle miles	0 - 7,500
	Percentage of transit ridership that equals the trip reduction	0.5 - 100
	Elasticity of peak speed with respect to volume	0 - (-1.000)
	Elasticity of off-peak speed with respect to volume	0 - (-1.000)

Table 10 (Continued)
Sensitivity Analysis Values for SANDAG Method

TCM	Variable	Range
Parking management	Average daily increase in parking charge	\$0.00 - \$0.80
	Percentage of employees affected	0 - 100
	Percentage of maximum VMT reduction realized due to circuity of ridesharing or access to transit	5 - 100
	Elasticity of parking demand with respect to cost for commute trips	(-0.005) - (-1.000)
	Elasticity of peak speed with respect to volume	(-0.005) - (-1.000)
	Elasticity of off-peak speed with respect to volume	(-0.005) - (-1.009)

These travel variables represent each method uniquely. Emissions were not compared for two reasons: (1) the use of the SAI emission model in both of the spreadsheet models would not allow for a unique comparison between the two methods, and (2) emission estimates are calculated based on the travel effects.

The sensitivity analysis will help MPOs determine which variables might cause problems in estimating the travel and emission results due to the lack of regional data used in the analysis. The sensitivities forewarn the TCM analyst which variables are estimated most accurately.

CHAPTER IV
RESULTS

COMPARISON AND CRITICAL ANALYSIS

The comparison and critical analysis of the SAI and SANDAG methods include an examination of the methods' logic (data requirements, outputs, structure), travel module, and emission module. The analysis of the travel and emission modules focuses on specific elements of the module and how they operate within the framework of the methodology as a whole.

Methodology Logic

Data Requirements

Both the SAI and SANDAG methods have positive and negative aspects with respect to data requirements. Negatively, both have several data requirements that are difficult to satisfy. Tables 11 and 12 list the difficult data requirements for the SAI and SANDAG methods, respectively.

Both methods require information about trips made during the peak period. This information is difficult to obtain. Traditional planning models cannot discern trips that occur during specific time intervals within the 24-hour period modeled. Because the models do not disaggregate trips by time of day, peak-period modeling is needed to satisfy these data requirements.

Scope descriptors are variables used to define the TCM's scope when implemented. Examples of scope descriptors are *number of participants* and *frequency of participation.* TCM project descriptors include scope descriptors and supplemental inputs used to determine the TCM's effectiveness. An example of this descriptor is the *new work trip length*. The SAI method provides better TCM scope descriptors than the SANDAG method, and it allows the TCM analyst to specify a target participation rate for the TCM in a clear and direct manner. Participation rates are defined by *number of participants* and *frequency of participation* for most of the TCMs in the SAI method.

Table 11
SAI Inputs That Are Difficult to Quantify

Variable
Work trip generation rate for SOV users
Non-work trip generation rate for SOV users
Fraction of work trips of the total TCM-related work trips during the peak period
Fraction of non-work trips of the total TCM-related work trips during the peak period
Fraction of work VMT that occurs in the peak period
Fraction of ridesharers who join existing carpools and do not meet at park-and-ride
Fraction of ridesharers who join new carpools and do not meet at park-and-ride
Fraction of participants who will use transit
Fraction of participants who will rideshare
Fraction of participants who will use fringe parking
Total VMT in peak period
Total VMT in off-peak period
Number of work trips per vehicle commute day
Number of non-work trips per day per vehicle

The SANDAG method is burdened with variables that are difficult to understand. These difficult-to-understand variables cause a tendency to use the defaults provided in the SANDAG method, even though the use of defaults may provide inaccurate results for the study region.

Both the SANDAG and SAI methods require that the user input a target participation rate for the TCM under analysis; however, estimating these rates is a problem for MPOs. MPOs design TCMs in terms of the amount of new subsidies, creation of new programs, and increase in service. Both methods fail to cover the total TCM planning process in their analysis. This process includes governmental actions, traveler reactions, and transportation system changes. The process involves three steps: (1) estimating the number of travelers who will participate in the TCM, (2) estimating the change in travel demand resulting from this level of participation, and (3) estimating the change in traffic conditions resulting from this change in demand. Both the SAI and SANDAG sketch-planning tools require the TCM analyst to perform the first step and provide its results as input for the second step in the form of the level of participation for the TCM. The sketch-planning tools perform the second and third steps; however, possibly the most important component, travel reactions to governmental actions, is not considered in the analysis. MPOs need tools to evaluate how the actions they take affect participation in their area. Governmental actions are not designed to force travelers into a particular mode or departure time; they encourage alternative transportation modes and departure times to relieve congestion in the transportation system.

Table 12
SANDAG Inputs That Are Difficult to Quantify

Variable
Percentage of maximum VMT reduction realized due to circuity of ridesharing or access to transit
Percentage of transit ridership that equals the trip reduction
Percentage increase in non-drive alone modes
Total peak VMT
Total off-peak VMT
Percentage of all trips in peak period
Percentage of commute trips in peak period
Percentage of non-commute trips in peak period
Percentage of peak trips that are commute trips
Percentage of off-peak trips that are commute trips
Average mode shift from drive alone per mile of HOV lane per hour
Percentage of all employees that shift out of the peak period

Outputs

Reports of estimated emission changes are important since the objective of TCMs is to influence mobile emissions. Reports of travel changes are equally important. Travel changes are easier to estimate because the techniques are better developed than those for estimating emissions. Techniques to estimate emission changes still have not been tested for accuracy. More work is needed to accurately estimate changes in emissions associated with travel changes.

Both the SAI and SANDAG methods provide output in relative terms. The SAI and SANDAG travel outputs are changes in vehicle trips, VMT, and regional speed. The SAI method's emission changes cover HC, CO, and NOx and are reported in grams per day. SANDAG emission output was not examined.

SANDAG reports its travel changes in a confusing manner. The wording of the outputs implies reductions when the output is positive and increases when the output is negative. Generally, positively reported values are associated with increases, whereas negatively reported values are associated with decreases. Thus, the wording of the variables and reported output should be modified to reflect changes in an easy to understand manner, such as changes in trips accompanied by increases with positive values and decreases with negative values.

Structure

The SAI method is straightforward. Its travel module consists of nine steps. The method first calculates the number of person trips affected. It then transforms these trips into a reduction of vehicle trips based on the person trips affected. The change in vehicle trips is calculated for work and non-work trips. The method then determines the indirect trip effects for each TCM for work- and non-work-related vehicle trips. Trip shifts out of the peak period and into the off-peak period are determined for TCMs associated with flextime and compressed work week programs. After these trip changes are determined, the method calculates the total vehicle trip changes associated with four trip categories: (1) work, peak; (2) work, off-peak; (3) non-work, peak; and (4) non-work, off-peak. Then the reduction in VMT is calculated by the sum of VMT associated with vehicle trip reduction and changes in trip lengths. Finally, the change in regional speed is determined from changes in VMT, initial VMT level, and elasticities. Changes in emissions are estimated from the travel changes.

The emission module consists of four steps. Emission changes are first calculated from vehicle trip changes. The second step determines emission changes associated with VMT changes. Changes in emissions are then calculated from fleet speed changes. Finally, all the previous steps are summed to yield a total emission change associated with TCMs.

The SAI method is currently in a workbook format and can be confusing at times. This research has converted the method from a workbook to a spreadsheet model. The spreadsheet makes analysis much easier to perform because the TCM scope descriptors are easier to change, and the results can be obtained more quickly.

The SANDAG method generally processes each TCM the same way, but there are exceptions. The travel module consists of four basic steps. The first step determines the changes in person trips. For some TCMs, this step is omitted or included in the step that estimates vehicle trip changes. The second step estimates changes in vehicle trips for the peak and off-peak periods. After the change in vehicle trips is determined, changes in VMT in the peak and off-peak periods are calculated from the trip changes. Finally, speed changes are determined for the peak and off-peak periods.

The emission module that accompanied the travel module was not evaluated because the module is California-specific and does not allow analysis for areas outside California. The SAI emission module was used to estimate emissions associated with travel changes determined from the SANDAG method. The use of the SAI emission module was possible because all of the travel variables used in the SAI emission module were available in the SANDAG travel module.

The SANDAG method was originally developed for spreadsheet applications. The spreadsheet is cumbersome, however, because it covers a large space and requires the user to traverse its area frequently. Relocating sections of the spreadsheet would reduce the amount of required user movement. Another problem is that the method first uses a spreadsheet, then a FORTRAN program, and then returns to the spreadsheet. It would be more convenient to keep the methodology in one media instead of switching back and forth.

Neither method is able to evaluate TCM packages. The methods can evaluate the additive effects of TCM packages but lack the ability to estimate the synergistic and negative effects of TCM combinations. It is important to consider these effects when designing a

TCM program. Individual TCM analysis within a package of TCMs may lead to a false conclusion about their combined effectiveness if these effects are not considered. Many TCMs work in concert with other TCMs to further increase the emission benefits from a TCM program. Conversely, many TCMs compete for the same traveler market. Analyzed separately, the TCM may indeed exhibit sizable benefits; but once implemented within a program, it may not be cost-effective because of this competition.

Travel Module

Discussion of the travel module covers several areas: trip reduction estimation, indirect trip effects, latent demand, and use of defaults.

Trip Reduction Estimation

Both the SAI and SANDAG methods calculate the change in person and vehicle trips; however, different procedures are used to estimate these trip changes. The SAI method first estimates the potential number of person trips affected. Inconsistencies were found in this step. For the flextime and ridesharing TCMs, the person trip analysis first determines the number of participants and then multiplies this number by two to represent the number of trips that each person would make to work. For instance, a person leaves home to commute to an office in the central business district and then returns home at the end of the work day. The first trip is made to work and the second trip occurs when the person returns home. For the transit improvement (fare decrease and service increase) and parking management TCMs, the number of participants was not multiplied by two. The transit improvements analysis considers only one trip per participant. Parking management analysis considers only the number of parking spaces affected, thus discounting the total number of trips for travelers to and from work. These TCMs were modified to reflect a consistent, logical approach for estimating affected person trips.

Vehicle trip reduction is estimated after the affected person trips are calculated. SAI uses several conversion factors to change person trips reduced to vehicle trips reduced. These conversion factors are dependent upon the TCM under analysis. The simplest case divides the affected person trips by the average vehicle occupancy to determine the change in vehicle trips. These conversion factors could be difficult to derive for TCMs that are not covered in the workbook. The method first determines the vehicle trip reduction associated with work and non-work trips and then associates these trip types with their occurrence, peak or off-peak, based on peak period information.

The SANDAG method also determines changes in person and vehicle trips. In most instances, calculating the change in person trips is not a separate step in the analysis. It is, however, combined in the step that determines the reduction in vehicle trips associated with a particular TCM. The vehicle trip changes are determined in a different manner from the SAI method. The SANDAG method first determines vehicle trip reduction for the peak and off-peak periods and then divides those trip reductions into work and non-work trips.

Two problems were identified in the analysis of SANDAG's trip reduction estimation. First, there is a conflict in the work trip definition between sketch-planning tools and traditional planning models. In sketch-planning tools, a work trip is defined as a trip from A to C, as shown in Figure 3. In traditional planning models, this trip is broken into components if there is an intermediate stop B between points A and C. The original trip would then become two distinct trips: first from A to B and then from B to C. These two trips cannot be reassembled. The problem with traditional planning models then arises; the user cannot obtain complete information for work trips in the study region.

Second, both methods lack a mode choice model for determining mode shift due to TCM implementation. The only sketch-planning tools that use a mode choice model are the AQAT-3 program and the Turnbull method. A complete analysis of TCMs must include the effects of mode shift to accurately determine the full impact a measure has on the transportation system.

Indirect Trip Effects

Indirect trip effects refer to additional trips that occur when a commuter leaves a vehicle at home and another household member uses the vehicle for other purposes. These effects must be estimated to model the complete travel effects of a TCM.

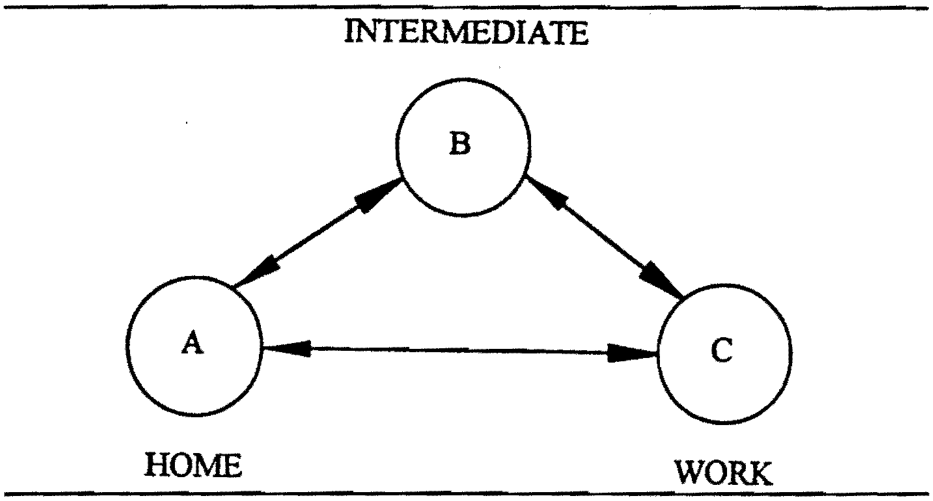

Figure 3. Typical work trips.

Only the SAI method estimates indirect trip effects. SAI estimates increases related to work and non-work travel based on several variables including the fraction of the population that does not own a vehicle and the work and non-work trip generation rates for SOV users. When a dimensional analysis was performed for this step, however, the units were not reasonable. The final units should be vehicles; however, the dimensional analysis revealed that the units were person-trips per household-days. It would be difficult to transform this unit to vehicles without the addition of a variable to convert the result to the desired units. The SAI method is the first method to attempt to quantify the effects of indirect trips. It is obvious that more work is needed in this area.

Latent Demand

Latent demand is the demand attracted to a roadway because of improved conditions. This recently defined phenomenon is still not understood completely, and research is ongoing to determine its processes. As a result, both methods lack the completeness needed in this area.

SAI is the first model to attempt to calculate latent demand; however, it does not use its results in subsequent calculations to assess its impact. For completeness, SAI should have included the results in the overall estimation of trip changes instead of including the process in the report for additional material. The authors do not provide discussion on how the results could be used in the analysis.

SANDAG estimates the latent demand associated with TCMs different than SAI. First, the method does not evaluate latent demand effects for all TCMs. Where it is used, the method requires the user to input either the increase in volume or the change in speeds. This information is difficult for the user to estimate and should not be required.

Defaults

Defaults are used in many analysis tools as a means of managing the burdens of data collection. The same principle applies to these sketch-planning tools.

Both methods use elasticities. Elasticities are used to predict human behavior as well as travel characteristics. Elasticities for predicting human behavior estimate the travel responses to cost increases. Elasticities used in predicting travel characteristics estimate the changes in travel speed with respect to volume. Much work has been completed and validated on travel characteristics and can be found in the *Highway Capacity Manual* (*14*); however, work on modeling human behavior is more difficult and not easily validated. For that reason, defaults are primarily used. The TCM analyst should be aware that the speed-volume elasticity is not constant over a wide range of volumes as implied when using a single elasticity. The elasticity should be a reflection of the expected volumes on the transportation network.

Both methods note that TCM analysts should develop elasticities for their particular region to accurately model the effects of TCMs on the regional transportation system; however, the SANDAG method relies heavily on these elasticities as well as several abstract variables which are onerous to quantify. In these cases, the user's only option is to use the default values provided. The TCM analyst must understand that results might be substantially different if regional data were used.

In addition to these elasticities, the SAI method uses a Gaussian distribution to estimate the fraction of trips that shift out of the peak period for flextime and compressed work week measures. The distribution is labor intensive to develop for a specific region; therefore, the analyst must use the values defined by the authors of the method. The allowable input values are limited by the authors and may not fit the scope of the TCM under evaluation.

Emission Module

The SANDAG method's emission module could not be evaluated against the SAI method, because it relies on a different emission factor model than the SAI method. Therefore, only the SAI emission module is discussed here. The module has four steps.

Step 1: Emission Changes Associated with Trip Changes

The first step in the SAI emission module is to determine the change in emissions associated with vehicle trip changes. The user may obtain emission factors for the different vehicle classes from the MOBILE program. The SAI method requires a vehicle distribution which should be the same distribution used in MOBILE. The vehicle distribution is used to estimate emission reductions for each vehicle class.

The method then determines the cold-start and hot-start trip changes. This step requires two important inputs: the percentages of cold-start trips for both work and non-work trips. These fractions directly affect subsequent emission reduction estimation. SAI provides default values for the TCMs included in the workbook. It is safe to assume that the percentage of cold-starts associated with work trips will be 100 percent, because the vehicle has a sufficient amount of time to cool down between trips to and from work. The percentage of cold-starts for non-work trips is more difficult to estimate. The percentage assumed in the SAI method is 43 percent, the MOBILE4.1 default fraction of cold-starts for non-work trips. One possible source for this information is the local air control district. After these trip changes are determined, the method calculates the respective cold- and hot-start emission factors.

Cold- and hot-start emission factors are determined by subtracting the stabilized emission factor from emission factors obtained under the respective conditions: 100 percent of vehicles in cold-start operating mode operating at a speed of 26 miles per hour, and 100 percent of vehicles in hot-start operating modes operating at a speed of 26 miles per hour. The calculated factors are then used with the trip changes to determine emission changes. The step has an important assumption: "the trip-start driving conditions are uniform and comparable to the trip-start driving conditions of the Federal Test Procedure (FTP) driving cycle" (*8*). As the authors state (*8*), this assumption is reasonable because the FTP driving cycle was designed to simulate urban driving conditions, and the emission factors derived from MOBILE are based on this driving cycle.

Step 1 further evaluates the hot-soak and diurnal emissions associated with trip changes. It should be noted that diurnal emissions increase when vehicle trips decrease. Neither of these categories are expected to produce significant emission reductions. The emission components are then summed to yield the total emission changes due to trip changes.

Step 2: Emission Changes Associated with VMT Changes

The emission reduction estimated from VMT changes is the second step in the methodology. The vehicle distribution is used again for this step. Hot stabilized exhaust emission changes are first calculated. The emission factors used in this step are derived from MOBILE output from the peak and off-peak period speeds prior to TCM implementation. Evaporative emissions related to VMT are then determined. These two emission categories are summed to determine the total emission changes from VMT changes.

Step 3: Emission Changes Associated with Fleet Speed Changes

The third step is determining the emission change from fleet speed changes. These emission changes are a result of decreased congestion and improved levels-of-service. CO is reduced more substantially in this step than the other two pollutants (HC and NOx) because a decrease in recurrent congestion decreases the amount of vehicle idling, which is a direct and major contributor to CO hot spots. The unique attribute for this step compared to the two previous steps is that the emission changes are due to the assumption that all vehicles are affected by the TCM, regardless of participation in the TCM. This assumption is made because the TCM will benefit the region by increasing the speed, affecting all drivers in the region.

Step 4: Total Emission Changes

The final step sums the results of the three previous steps. The results are reported in grams per day. At present, many organizations report emission changes in tons per day. A change in units may be needed in the future when metrication is completed. But even then, the units might be changed to kilograms per day or metric tons per day, due to the large numbers occasionally obtained when using grams per day.

The emission module seems complete. SAI has invested tremendous effort including many emission components that are small contributors to total tailpipe emissions. Perhaps most importantly, SAI developed a step for determining fleet emission changes from TCM implementation. In many cases, a TCM project may experience greater benefits if the fleet speed is increased by only one or two miles per hour.

One problem in this emission analysis is the failure to account for modal emissions. Modal emissions are now being researched by the EPA as a part of understanding the interrelationships within the acceleration, cruise, deceleration, and idle cycle. Some researchers and practitioners suggest that the emissions associated with accelerations and decelerations when aggregated are more difficult to reduce than those emissions associated with cruising or idling. Numerous acceleration and deceleration cycles have been known to increase fuel consumption, which in turn leads to increased automotive emissions.

TCM BASE CASE SCENARIO COMPARISON

The base scenarios used in this analysis were determined by estimating TCM participation rates in the El Paso region. TCM participation was set at 5 percent of the peak commute trips. TCM scope descriptors are variables which define the scope of the TCM to be implemented and include such information as participation, frequency of use, and changes in price.

The defined TCM participation did not apply to two of the TCMs, transit fare decreases and parking management. In the case of transit fare decreases, the decrease was applied to all transit riders. Parking management required a much different solution. The scope of this TCM was limited to the central business district. Therefore, the 5 percent participation rate was applied to the total central business district employment and then converted into the number of automobiles based on an average vehicle occupancy.

The SANDAG descriptors were equated to SAI using a goal-seeking function in a spreadsheet. The equity point was defined as the estimated number of vehicle trips in the SAI method. This point was chosen because it represented a point in both methods where few calculations had been performed. After the equivalent values had been identified in SANDAG, they were rounded to match the precision used in the input.

Emission outputs were examined for both the carbon monoxide and ozone emission seasons. The carbon monoxide season occurs in the winter, whereas the ozone season is during the summer.

Flextime

The SAI scope descriptors allow the analyst to describe the flextime TCM better than the SANDAG method. SAI provides three inputs to describe a flextime project: number of participants, number of days per week flextime is in operation, and the average number of commute days per week. The SANDAG method provides only one input: percentage of all employees that shift out of the peak period. Both methods present results for an average day of the week.

Tables 13 and 14 list the results for this TCM. There is a slight difference in the calculation of trip shifts into and out of the peak period. This difference arises from the input precision of the SANDAG method and directly affects the net change in peak and off-peak-period VMT.

Ridesharing

SAI scope descriptors for the ridesharing TCM are similar to those used in the flextime analysis: number of participants, number of days per week carpooled, and average number of commute days per week. These variables are used to estimate benefits for an average weekday. The SANDAG descriptors, *percentage increase in non-drive-alone modes* and *percentage of maximum VMT reduction realized due to circuity of ridesharing or access to transit*, are abstract and difficult to use.

Table 13
Flextime Base Case Travel Results

Travel Variable	Travel Period	Method	
		SAI (per day)	SANDAG (per day)
Trips	Peak	-1,084	-1,047
	Off-Peak	1,084	1,047
VMT	Peak	-8,359	-8,074
	Off-Peak	8,359	8,074
Speed	Peak	0.2%	0.2%
	Off-Peak	0.0%	0.0%

Table 14
Flextime Base Case Emission Results

Emission Season	Pollutant	Method	
		SAI (kg per day)	SANDAG (kg per day)
Carbon Monoxide	HC	-5	-4
	CO	-37	-36
	NOx	1	1
Ozone	HC	-4	-4
	CO	-41	-40
	NOx	1	1

The results of the base case analysis are shown in Tables 15 and 16. There is a slight difference in peak and off-peak trip changes. Hot-start emissions are omitted from the SANDAG method for this TCM. This omission is not reasonable because a majority of work trips begin in the cold-start state, although there is a percentage that start in the hot-start state.

Table 15
Ridesharing Base Case Travel Results

Travel Variable	Travel Period	Method	
		SAI (per day)	SANDAG (per day)
Trips	Peak	-2,149	-2,343
	Off-Peak	-1,350	-1,510
VMT	Peak	-17,371	-14,450
	Off-Peak	-11,244	-9,316
Speed	Peak	0.3%	0.3%
	Off-Peak	0.1%	0.1%

Table 16
Ridesharing Base Case Emission Results

Emission Season	Pollutant	Method	
		SAI (kg per day)	SANDAG (kg per day)
Carbon Monoxide	HC	-154	-149
	CO	-1,505	-1,474
	NOx	-92	-79
Ozone	HC	-100	-92
	CO	-1,003	-919
	NOx	-79	-69

Transit Fare Decrease

SAI provides greater flexibility for the transit fare decrease TCM than SANDAG. Both methods require the percentage reduction in fare but request the remaining project descriptors differently. SAI allows the user to input the number of transit patrons affected by the fare decrease. The SAI procedure then estimates how many people will actually shift to transit by using an elasticity. SANDAG applies the fare decrease differently. The SANDAG user inputs the percent of transit ridership increase that equals the trip reduction.

This percentage is applied to the total transit person trips in combination with a cost elasticity to estimate the number of person trips that shift away from other modes to the transit mode. This process acts in a double reduction manner, decreasing the reported estimates of trip and emission changes. The user is able to model the effects of targeting a specific transit market (e.g., peak commute trips) with both methods.

Tables 17 and 18 show the results of the transit fare decrease TCM. SAI estimates a greater non-work trip reduction, and the SANDAG diurnal emissions are much greater than those calculated in the SAI method. Although the peak fleet speed change is similar for both methods, the SANDAG method predicted a greater reduction in CO and HC emissions. The manner in which the fleet speed change was handled internally was the major contributor to the differences in estimated emission benefits between the SANDAG and SAI methods.

Table 17
Transit Fare Decrease Travel Results

Travel Variable	Travel Period	Method	
		SAI (per day)	SANDAG (per day)
Trips	Peak	-1,312	-1,312
	Off-Peak	-2,377	-2,458
VMT	Peak	-8,233	-8,659
	Off-Peak	-13,589	-14,516
Speed	Peak	0.2%	0.2%
	Off-Peak	0.1%	0.1%

Table 18
Transit Fare Decrease Emission Results

Emission Season	Pollutant	Method	
		SAI (kg per day)	SANDAG (kg per day)
Carbon Monoxide	HC	-86	-119
	CO	-833	-1,149
	NOx	-73	-77
Ozone	HC	-64	-84
	CO	-526	-828
	NOx	-62	-66

Transit Service Increase

The SAI and SANDAG methods require different input variables for assessing the transit service increase TCM. SAI requires the user to input the expected number of new transit patrons. The SANDAG method requires the user to input the increase in transit VMT and the percentage of transit ridership that equals the trip reduction. This last input would be difficult to quantify for most small MPOs. SANDAG supplies a default value and a definition of the variable, but it remains difficult to quantify.

The travel and emission results are shown in Tables 19 and 20. The differences between the two methods are due to the calculation of trip effects and VMT effects. The two methods calculate the work and non-work trips occurring in the peak and off-peak period differently. SAI's estimations are less than SANDAG because of the indirect trip effects. The VMT estimates differ due to the differences in estimated vehicle trip reduction.

Several differences in estimations by the two methods occur. SANDAG estimates a greater work trip reduction, but SAI estimates greater non-work trip reduction. SANDAG diurnal estimates are also greater than those estimated from SAI. Finally, SAI estimates greater off-peak fleet speed changes than SANDAG.

Table 19
Transit Service Increase Travel Results

Travel Variable	Travel Period	Method	
		SAI (per day)	SANDAG (per day)
Trips	Peak	-3,354	-3,352
	Off-Peak	-6,074	-6,278
VMT	Peak	-21,039	-22,118
	Off-Peak	-34,725	-37,077
Speed	Peak	0.4%	0.4%
	Off-Peak	0.2%	0.2%

Table 20
Transit Service Increase Emission Results

Emission Season	Pollutant	Method	
		SAI (kg per day)	SANDAG (kg per day)
Carbon Monoxide	HC	-270	-277
	CO	-2,559	-2,677
	NOx	-174	-190
Ozone	HC	-213	-205
	CO	-1,824	-1,822
	NOx	-152	-164

Parking Management

The scope of the parking management TCM was defined in the SAI method by the number of spaces that 5 percent of the central business district employment would be expected to use. The price increase was defined based on a reasonable estimation for the El Paso region. The SANDAG inputs were found using a goal-seeking function to match the results obtained from the SAI vehicle trip reduction because the SANDAG descriptors are so different from the SAI counterparts.

Tables 21 and 22 show the results of the base case analysis. The travel effects are minimal due to the small scope of the TCM. Since the TCM scope is narrow, it is logical to expect the emission benefits to be equally small. Greater benefits would result if the TCM scope were broadened to cover a greater area; however, a broader scope is not reasonable for El Paso.

SANDAG estimated the hot-start emissions for the parking management TCM to be zero. The estimation is not reasonable because, although a majority of work trips begin in the cold-start state, there is still a percentage that start in the hot-start state. SANDAG estimates a greater reduction in vehicle trip changes than SAI. This difference is not evident in the final estimation of emission benefits from both methods.

Table 21
Parking Management Travel Results

Travel Variable	Travel Period	Method	
		SAI (per day)	SANDAG (per day)
Trips	Peak	-60	-64
	Off-Peak	-37	-41
VMT	Peak	-469	-393
	Off-Peak	-300	-253
Speed	Peak	0.0%	0.0%
	Off-Peak	0.0%	0.0%

Table 22
Parking Management Emission Results

Emission Season	Pollutant	Method	
		SAI (kg per day)	SANDAG (kg per day)
Carbon Monoxide	HC	-3	-3
	CO	-35	-34
	NOx	-2	-2
Ozone	HC	-2	-2
	CO	-20	-18
	NOx	-2	-2

SENSITIVITY ANALYSIS

A sensitivity analysis was performed on many variables for each of the TCMs studied to determine their effect on the TCM's benefits. The sensitivity analysis is based on changes from the base scenarios. In each sensitivity test, base case values were used except for the variable being tested.

Variables were rated on their sensitivity and data reliability. Sensitivity ratings were based on percentage changes between the set of variables examined within each TCM. If a variable exhibited a significantly higher percentage change than other variables within the TCM, it was ranked as possessing a high sensitivity. Data reliability was based on the data used in this analysis. Low reliability ratings were given to those variables for which default values were used. Conversely, high ratings were given to those variables whose values were based on data obtained from El Paso. Moderate ratings were given to TCM scope descriptors because target TCM participation rates are estimated values and, therefore, are not highly reliable.

The reliability of target TCM participation rates is a concern for the TCM analyst. Currently, there is no basis for selecting participation rates of TCMs. Thus, the sketch-planning tools act as a test bed for "what if" scenarios. Past reactions of travelers to governmental actions have been neither identified nor quantified. These reactions must be understood before accurate and meaningful estimates of TCM participation can be made. Therefore, MPO programs are designed to attain the target participation rate without the assistance of analysis tools to evaluate and predict their results.

The relationship between sensitivity and data reliability is important to understand. Table 23 shows possible combinations of sensitivity and data reliability. If the outputs are found to be highly sensitive to a variable, the TCM analyst must be certain that the reliability of the data for that variable is high. If the reliability is low for that variable, the estimated benefits of the TCM may not be represented accurately, and this case represents a maximum for potential error. Therefore, the TCM analyst should exert a greater effort in quantifying those variables with a high sensitivity. The minimum potential error in TCM estimation lies in variables where the sensitivity is low and the data reliability is high. Potential error in TCM estimation increases toward the variables categorized as having a high sensitivity and low reliability.

Table 23
Potential Error in TCM Estimation

		Sensitivity		
		High	Moderate	Low
Reliability	High			MINIMUM
	Moderate			
	Low	MAXIMUM		

Flextime

The flextime sensitivity analysis results are shown in Tables 24 and 25. The estimated travel impacts were sensitive to three variables: *number of participants, number of days per week flextime in operation*, and *percentage employees that shift out of the peak period*. The first two variables are used in the SAI method, whereas the final variable is used in the SANDAG method. None of the remaining variables in Table 10 had an effect on the travel results for the flextime TCM; the flextime TCM targets only trip shifts, not vehicle removal from the roadway.

Table 24
Sensitivity Analysis Results for Flextime Measure

Method	Variable	Percentage Change				
		Variable	Peak Trips	Off-Peak Trips	Peak VMT	Off-Peak VMT
SAI	Number of participants	10	-0.0205	0.0134	-0.0219	0.0124
	Number of days per flextime in operation	33	-0.0674	0.0442	0.0000	0.0000
SANDAG	Percentage of trips that shift out of peak period	10	0.0000	0.0000	0.0000	0.0000

Table 25
Sensitivity and Reliability Summary for Flextime Variables

Method	Variable	Sensitivity			Reliability		
		High	Moderate	Low/None	High	Moderate	Low
SAI	Number of participants	X				X	
	Number of days per week flextime in operation						
SANDAG	Percentage of trips that shift out of peak period	X					X

SAI

The *number of participants* and *number of days per week flextime in operation* result in a high sensitivity of the outputs in the evaluation of a flextime measure. Combined, the two define participation in terms of person-days. The user should be confident about the values used for these variables since they greatly influence the outcome of the TCM evaluation. SAI reduces the participation level through the use of a Gaussian distribution. The reasoning behind this technique is that not all drivers will shift from their original travel departure times out of the peak period; some drivers will shift their trip enough to the outer tails of the peak period or to the off-peak period to relieve congestion within the peak period.

SANDAG

Like its SAI counterpart, the SANDAG variable *percentage of employees that shift out of the peak period* also results in a high output sensitivity. In fact, it is more sensitive than the SAI variables. Although Table 24 shows no sensitivity for this variable, experience using the method proves how sensitive the outputs are to this variable. The low sensitivity reported in Table 24 is due to the low base value used and the percentage change of this value. High sensitivity is caused by the direct application of this variable to the total number of vehicle work trips. The SANDAG method assumes that the user knows or expects a certain percentage of employees to shift out of the peak period, thus relieving some congestion that might be present. It is difficult for the user to determine this percentage since the tools for evaluating driver behavior are not sufficiently developed at this time. Therefore, the user may tend to overestimate the effect of a flextime measure and, thus, estimate emission reductions much greater than could be reasonably expected.

Ridesharing

Tables 26 and 27 present the ridesharing sensitivity analysis results. Scope descriptors were found to produce a high sensitivity in this TCM. Also, work trip-related variables showed a greater sensitivity than non-work-related variables.

SAI

The variables *number of participants* and *number of days per week carpooled* produce a high sensitivity in SAI outputs for evaluating flextime measure. The two variables in conjunction define the TCM participation in person-days. The user should have reliable values for these variables since they have a great affect on the outcome of the TCM evaluation. The reliability for the data was moderate because the data represent the user-defined scope of the TCM which is under evaluation.

The *fraction of work trips of the total TCM-related work trips during the peak period* variable is used when determining the total trip changes that will occur in the peak or off-peak periods. The SAI method specifically notes that this variable is region-specific and should be obtained by the TCM modeler. SAI also notes that the variable may be estimated from the following expression:

$$\frac{\textit{Peak Work Vehicle Trips}}{\textit{Total Peak Vehicle Trips}}$$

The SAI method's outputs have a high sensitivity to this variable. It is used directly with the sum of direct vehicle trip reductions and indirect vehicle trip increases. Sensitivity is greater for the peak period than the off-peak period, as seen in Table 26. Default data provided in the SAI methodology were used because data obtained for El Paso were not available; therefore, the reliability was low.

The variables, *fraction of ridesharers who join existing carpools and do not meet at park-and-ride* and *fraction of ridesharers who join new carpools and do not meet at park-and-ride*, affect the estimation of vehicle trip reduction based on a defined participation level. The first variable attempts to account for vehicle trips saved from ridesharing, whereas the second variable accounts for vehicle trips that still take place by drivers of carpools. The effect of participants driving to park-and-ride lots or other locations to meet their carpools are accounted for in the SAI methodology during the estimation of effects from trip length changes. In effect, the *fraction of ridesharers who join existing carpools and do not meet at park-and-ride* and *fraction of ridesharers who join new carpools and do not meet at park-and-ride* variables are subtracted from 100 percent, thus resulting in the percentage of ridesharing

Table 26
Sensitivity Analysis Results for Ridesharing Measure

Method	Variable	Percentage Change				
		Variable	Peak Trips	Off-Peak Trips	Peak VMT	Off-Peak VMT
SAI	Number of participants	10	-0.0405	-0.0167	-0.0455	-0.0167
	Number of days per week carpooled	33	-0.1338	-0.0552	-0.1503	-0.0600
	Fraction of work trips of the total TCM-related work trips during the peak period	10	-0.0409	0.0268	-0.0438	0.0249
	Fraction of ridesharers who join existing carpools and do not meet at park-and-ride; and fraction of ridesharers who join new carpools and do not meet at park-and-ride	10	-0.0171	-0.0071	-0.0200	-0.0066
	New work trip length	10	0.0000	0.0000	0.0020	0.0011
	Work trip generation rate for SOV users	10	0.0034	0.0014	0.0036	0.0013
	Fraction of trips made via shared mode	10	0.0038	0.0020	0.0039	0.0017
	Fraction of non-work trips of the total TCM-related non-work trips during the peak period	10	0.0004	-0.0002	0.0003	-0.0002
	Non-work trip generation rate for SOV users	10	0.0004	0.0006	0.0003	0.0004

Table 26 (Continued)
Sensitivity Analysis Results for Ridesharing Measure

Method	Variable	Percentage Change				
		Variable	Peak Trips	Off-Peak Trips	Peak VMT	Off-Peak VMT
SANDAG	Percentage increase in non-drive-alone modes	10	-0.0442	-0.0187	-0.0379	-0.0139
	Drive-alone share of commute person trips	10	-0.0531	-0.0225	-0.0443	-0.0166
	Percentage of new carpool riders that still make trips, does not include carpool driver	10	0.0726	0.0307	0.0622	0.0227
	Percentage of employees affected	10	-0.0442	-0.0187	-0.0379	-0.0139
	Percentage of maximum VMT reduction realized due to circuity of ridesharing or access to transit	10	0.0000	0.0000	-0.0386	-0.0144

Table 27
Sensitivity and Reliability Summary for Ridesharing Variables

Method	Variable	Sensitivity			Reliability		
		High	Moderate	Low/None	High	Moderate	Low
SAI	Number of participants	X				X	
	Number of days per week carpooled						
	Fraction of ridesharers who join existing carpools and do not meet at park-and-ride; and fraction of ridesharers who join new carpools and do not meet at park-and-ride		X				X
	New work trip length		X				X
	Work trip generation rate for SOV users		X				X
	Fraction of trips made via shared mode		X		X		
	Fraction of work trips of the total TCM-related work trips during the peak period		X				X
	Fraction of non-work trips of the total TCM-related non-work trips during the peak period			X			X
	Non-work trip generation rate for SOV users			X			X

Table 27 (Continued)
Sensitivity and Reliability Summary for Ridesharing Variables

Method	Variable	Sensitivity			Reliability		
		High	Moderate	Low/None	High	Moderate	Low
SANDAG	Percentage increase in non-drive-alone modes	X					X
	Drive-alone share of commute person trips	X			X		
	Percentage of new carpool riders that still make trips, does not include carpool driver	X					X
	Percentage of employees affected	X					X
	Percentage of maximum VMT reduction realized due to circuity of ridesharing or access to transit	X					X

participants that still make a vehicle trip and are not drivers of the carpool. These variables are moderately sensitive. The values input for the variables had a low reliability because default data values were used.

The *new work trip length* variable is used in analyzing VMT changes due to trip length changes. The outputs are moderately sensitive to this variable which has a low reliability. The variable affects only VMT estimates, as seen in Table 26. The methodology requires the user to estimate the new work trip length before the carpool driving patterns are known. This variable is difficult to quantify and, therefore, must be estimated, resulting in a low reliability rating. The value used in the analysis represents half of the reported work trip length in the El Paso travel survey.

The *work trip generation rate for SOV users* variable is used in determining the indirect trip effects associated with the TCM. The results are moderately sensitive to this variable. The moderate sensitivity may be due to the high estimated number of vehicles being left at home. If the number of carpoolers who drive to meet their group instead of being picked up increases, the sensitivity of this variable should decrease. Because default values were used, a low reliability was given.

The variable, *fraction of trips made via shared mode*, is used in determining the indirect trip effects associated with the TCM. The SAI results are moderately sensitive to this variable. It is used to calculate the increase in work and non-work trips from vehicles left at home. The value obtained for this variable was region specific; therefore, a high reliability rating was given.

The *fraction of non-work trips of the total TCM-related non-work trips during the peak period* variable is used in determining the total trip changes that will occur during the peak or off-peak periods. Like its work trip counterpart, the variable can be estimated from the following expression:

$$\frac{\textit{Peak Non-Work Vehicle Trips}}{\textit{Total Peak Vehicle Trips}}$$

The results of the ridesharing analysis are not sensitive to this variable due to the focus of the TCM on work trips rather than non-work trips. The reliability for this variable was also low because default data were used in place of regionally obtained data.

The *non-work trip generation rate for SOV users* variable is used to determine the indirect trip effects associated with the TCM. The SAI method's outputs are not sensitive to this variable because the indirect trip effects generally do not have a significant impact on the outcome of the TCM analysis. A small change in this variable leads to an even smaller change in the overall trip changes associated with the TCM because default data were used for this variable; therefore, it was given a low reliability rating.

SANDAG

The reliability for all SANDAG ridesharing variables was low because the input values were obtained through the SAI method. A higher reliability rating might have been given if the data were input directly into the SANDAG method without assistance from the SAI method.

The *percentage increase in non-drive-alone modes* variable is difficult to quantify. It is defined as the "percent increase in number of person trips that are made by a mode other than a single-occupant vehicle" (*15*). The method's sensitivity for this variable is high. This variable is an important scope descriptor and could cause errors if not correctly estimated.

There is a high sensitivity in SANDAG due to the *drive-alone share of commute person trips* variable. The variable is used to determine the percentage of shared-ride work trips currently made in the transportation system. This variable, in combination with the *total commute person trips* variable, defines the maximum number of participants for the TCM; therefore, the high sensitivity for this variable is logical.

The effects of ridesharing are highly sensitive to the variable *percentage of new carpool riders that still make a trip, does not include carpool driver* for estimating both trips and VMT reduction. This variable represents the percentage of new ridesharers who will drive to meet their carpools. Thus, there are still trips and associated emissions which detract from the benefit of the carpool. Specifically, the start emissions will still be present for both the carpool driver and the new carpooler.

The *percentage of employees affected* variable results in a high sensitivity for the method's outputs in this TCM. This variable defines the participation level of the TCM based on the total commute person trips in the region; therefore, this variable has a high sensitivity. The SANDAG (*15*) definition of this variable, the "percent of all employees in the area that are affected by this strategy," is misleading. The authors note that affected employees include those outside the urban area as well as those employees that commute in the off-peak period. This definition suggests that all employees commuting will receive some benefit of this TCM whether in the peak or off-peak periods. On the contrary, the variable represents only the percentage of the commute trips that will switch to the rideshare TCM.

The variable, *percentage of maximum VMT reduction realized due to circuity of ridesharing or access to transit*, affects only VMT estimates and is difficult to quantify. The "reduction in VMT as a result of the reduction in number of trips of an average trip length will partially be offset by additional VMT incurred by the carpool vehicle due to pick-ups and drop-offs" defines the variable (*15*). Because the definition is unclear, the user must rely on the default value provided in the methodology. Hence, its reliability is low. This variable has a high sensitivity because the variable directly determines VMT reduction and, therefore, regional speed changes.

Transit Fare Decrease

The transit fare decrease results are provided in Tables 28 and 29. Both methods produced similar sensitivity results for equivalent variables.

SAI

The variables, *percentage change in fare* and *number of individuals experiencing change in cost*, result in a high sensitivity of the outputs for this TCM. These two variables are TCM scope descriptors and have a moderate reliability because they represent specific TCM scenarios input by the user.

Table 28
Sensitivity Analysis Results for Transit Fare Decrease Measure

Method	Variable	Percentage Change				
		Variable	Peak Trips	Off-Peak Trips	Peak VMT	Off-Peak VMT
SAI	Percentage change in fare	10	0.0248	0.0294	0.0216	0.0202
	Number of individuals experiencing change in cost	10	-0.0248	-0.0294	-0.0216	-0.0202
	Percentage change in ridership given percentage change in fare	10	0.0248	0.0294	0.0216	0.0202
	Fraction of work trips to the total TCM-related work trips during the peak period	10	-0.0078	0.0051	-0.0084	0.0048
	Fraction of non-work trips of the total TCM-related non-work trips during the peak period	10	-0.0157	0.0103	-0.0118	0.0067
	Work trip generation rate for SOV users	10	0.0007	0.0003	0.0008	0.0003
	Fraction of trips made via shared mode	10	0.0008	0.0004	0.0009	0.0004
	Non-work trip generation rate for SOV users	10	0.0001	0.0001	0.0001	0.0001
	New work trip length	10	0.0000	0.0000	0.0001	0.0001
SANDAG	Average percentage fare decrease	10	-0.0248	-0.0304	-0.0227	-0.0216
	Percentage of transit ridership increase that equals the trip reduction	10	-0.0248	-0.0304	0.0227	0.0216
	Elasticity of transit use with respect to cost	10	-0.0248	-0.0304	-0.0227	-0.0216

Table 29
Sensitivity and Reliability Summary for Transit Fare Decrease Variables

Method	Variable	Sensitivity			Reliability		
		High	Moderate	Low/None	High	Moderate	Low
SAI	Percentage change in fare	X				X	
	Number of individuals experiencing change in cost	X				X	
	Percentage change in ridership given percentage change in fare	X					X
	Fraction of work trips to the total TCM-related work trips during the peak period		X				X
	Fraction of non-work trips of the total TCM-related non-work trips during the peak period		X				X
	Work trip generation rate for SOV users			X			X
	Fraction of trips made via shared mode			X	X		
	Non-work trip generation rate for SOV users			X			X
	New work trip length			X			X
SANDAG	Average percentage fare decrease	X				X	
	Percentage of transit ridership increase that equals the trip reduction	X					X
	Elasticity of transit use with respect to cost	X					X

The *percentage change in ridership given percentage change in fare* variable is an elasticity that estimates the travel behavior of a typical traveler. The outputs are also highly sensitive, because this variable manipulates the TCM participation estimate. Low elasticity values would result in low participation levels. Nationally developed defaults may be used, but an effort should be made to estimate this elasticity for the study region. The reliability for this variable was low because a default value was used.

The variables, *fraction of work trips of the total TCM-related work trips during the peak period* and *fraction of non-work trips of the total TCM-related non-work trips during the peak period*, had a moderately sensitive effect in the transit fare decrease analysis and had a low reliability. They affect the estimation of vehicle trip reduction by trip type and time period. Because they influence the four trip categories discussed in the travel module, the estimated reduction in VMT is also affected. Logically, the fraction associated with work trips would be more sensitive than the non-work fraction since TCMs are targeted towards commute trips. However, this logic is not evident, as shown in Table 28. The reason both variables have similar sensitivity results may be due to the fact that the TCM targeted all of the transit riders for the fare decrease and not a certain market share. The low reliability is due to default values being used in place of regional data.

The variables, *non-work trip generation rate for SOV users*, *work trip generation rate for SOV users*, and *fraction of trips made via shared mode*, result in very low sensitivities for the evaluation of this TCM. The indirect trip effects these variables help estimate are not significant enough to alter the overall trip reduction associated with the TCM. The reliability of the trip generation rates was low because regional data were not available. El Paso data for *fraction of trips made via shared mode* were available; thus, this variable has a high reliability.

The sensitivity analysis showed that SAI outputs were not sensitive to the *new work trip length* variable. The variable has only a small effect on VMT estimates, probably because of the small number of participants who drive to a transit station. Although this variable is used to calculate changes in VMT associated with work trip length changes, the overriding variable affecting the estimation is the *fraction of people who drive to the public* *transit station*. El Paso has a low fraction of people who drive to public transit stations because there are no formally established transit stations. As before, the reliability of *new work trip length* was low because it was an estimated value and may not represent regional data.

SANDAG

The *average percentage fare decrease* variable results in a high sensitivity for the SANDAG outputs. The sensitivity of the outputs is the same as its SAI counterpart, as seen in Table 29, for peak trip reduction. The high sensitivity is due to the assumption that all transit riders will receive the fare decrease. When the fare change is coupled with the elasticity used to predict response, the result is sensitive, as expected. The reliability of the data used for this variable was moderate because the data represent a specific TCM scenario that the user wishes to evaluate.

The sensitivity of SANDAG to the *percentage of transit ridership increase that equals the trip reduction* variable was high because it is used to directly estimate the VMT reduction associated with the decrease in vehicle trips due to the transit fare decrease. The reliability for this variable was low. As in previous cases, the variable is difficult to quantify with limited resources and, therefore, a default value was used.

Like the SAI complement, the *elasticity of transit use with respect to cost* variable also resulted in a high sensitivity for the SANDAG method's outputs. The elasticity is important to the analysis of this TCM because it attempts to model the behavior of travelers who shift travel modes in order to get to work. The reliability for this variable was low because the data were not developed from El Paso data.

Transit Service Increase

Tables 30 and 31 display the results for the transit service increase TCM. The SAI and SANDAG scope descriptors have similar sensitivities. These descriptors are more sensitive to trip changes than VMT changes.

SAI

The *number of new patrons* variable is the only scope descriptor of the transit service increase TCM; therefore, the SAI results have a high sensitivity to the variable. The reliability is moderate because the variable is a TCM scope descriptor, and the data represents an El Paso scenario under evaluation.

The *fraction of work trips of the total TCM-related work trips during the peak period* and *fraction of non-work trips of the total TCM-related non-work trips during the peak period* variables result in a high sensitivity for the SAI output. Both variables have a low reliability. The sensitivity for the variables is higher than its transit fare counterparts because the expected number of participants is not influenced by any elasticities that model mode choice. Therefore, a higher number of reduced vehicle trips are estimated, thus allowing for greater impact from these variables. The low reliability is due to the use of default data.

The variables, *work trip generation rate for SOV users* and *fraction of trips made via shared mode*, have a moderate sensitivity when evaluating this TCM. The variables are used to estimate indirect trip increases. The reliability of the *work trip generation rate for SOV users* was low since a default value was used. The *fraction of trips made via shared mode* variable has a high reliability in this analysis.

The analysis shows that the *new work trip length* variable produces a low sensitivity in the SAI results when evaluating this TCM. Similar results were obtained for the transit fare decrease TCM. The reliability of this variable was low because historical regional data are not available.

The *non-work trip generation rate for SOV users* variable resulted in a low sensitivity for the method's outputs. In addition, the reliability of the data used in the analysis was low; regional data were not used. The variable is used to estimate the increase in vehicle trips from those vehicles left at home by the new patrons and which are used by other household members for work or non-work trips.

Table 30
Sensitivity Analysis Results for Transit Service Increase Measure

Method	Variable	Percentage Change				
		Variable	Peak Trips	Off-Peak Trips	Peak VMT	Off-Peak VMT
SAI	Number of new patrons	10	-0.0633	-0.0752	-0.0551	-0.0516
	Fraction of work trips of the total TCM-related work trips during the peak period	10	-0.0229	0.0150	-0.0245	0.0139
	Fraction of non-work trips of the total TCM-related non-work trips during the peak period	10	-0.0404	0.0265	-0.0375	0.0172
	Work trip generation rate for SOV users	10	0.0019	0.0008	0.0020	0.0007
	Fraction of trips made via shared mode	10	0.0021	0.0011	0.0022	0.0010
	New work trip length	10	0.0000	0.0000	0.0003	0.0002
	Non-work trip generation rate for SOV users	10	0.0002	0.0003	0.0002	0.0002
SANDAG	Increase in transit vehicle miles	10	-0.0632	-0.0777	-0.0580	-0.0551
	Percentage of transit ridership increase that equals the trip reduction	10	-0.0632	-0.0777	-0.0580	-0.0551
	Elasticity of transit use with respect to service	10	-0.0632	-0.0777	-0.0580	-0.0551

Table 31
Sensitivity and Reliability Summary for Transit Service Increase Variables

Method	Variable	Sensitivity			Reliability		
		High	Moderate	Low/None	High	Moderate	Low
SAI	Number of new patrons	X				X	
	Fraction of work trips of the total TCM-related work trips during the peak period	X					X
	Fraction of non-work trips of the total TCM-related non-work trips during the peak period	X					X
	Work trip generation rate for SOV users		X				X
	Fraction of trips made via shared mode		X		X		
	New work trip length			X			X
	Non-work trip generation rate for SOV users			X			X
SANDAG	Increase in transit vehicle miles	X					X
	Percentage of transit ridership increase that equals the trip reduction	X					X
	Elasticity of transit use with respect to service	X					X

SANDAG

The SANDAG method's outputs have a high sensitivity to the *increase in transit vehicle miles* variable. This variable is used in conjunction with the elasticity of transit use with respect to service to determine the number of person trips that will be eliminated. Transit agencies are more likely to view an increase in their system in terms of VMT rather than persons. Therefore, this variable is easier to predict than the SAI variable, *number of new patrons*. The reliability in this TCM analysis was low because it could not be directly equated to the increase in patrons defined in the SAI method.

The sensitivity analysis shows that the *percentage of transit ridership increase that equals the trip reduction* variable produces a high sensitivity in the SANDAG outputs when evaluating this TCM because it converts the number of participants into vehicle trips reduced. This calculation has a tremendous effect on the estimation of VMT changes. This variable is difficult to quantify and a low reliability rating was given because regional data were not used for this variable.

The *elasticity of transit use with respect to service* variable results in a high sensitivity of the method's results because it directly affects the estimation of person trips reduced from an increase in transit VMT. A high elasticity would result in greater TCM participation and increase the travel and emission benefits for the TCM. Unfortunately, the reliability is low because a regionally developed elasticity was not used in the analysis.

Parking Management

The sensitivity analysis for the parking management TCM yielded smaller percentage changes in the travel indicators than the other TCMs evaluated due to the small scope of the TCM discussed in the base scenario analysis. The results of the analysis can be seen in Tables 32 and 33. Peak travel indicators were more sensitive to variable changes than off-peak indicators.

Table 32
Sensitivity Analysis Results for Parking Management Measure

Method	Variable	Percentage Change				
		Variable	Peak Trips	Off-Peak Trips	Peak VMT	Off-Peak VMT
SAI	Number of spaces subject to price increase	10	-0.00112	-0.00046	-0.00123	-0.00045
	Percentage change in parking price	10	-0.00112	-0.00046	-0.00123	-0.00045
	Parking elasticity	10	-0.00112	-0.00046	-0.00123	-0.00045
	Fraction of work trips of the total TCM-related work trips during the peak period	10	-0.0011	0.0007	-0.0012	0.0007
	Fraction of potential trips who will use transit	10	-0.0002	-0.0001	-0.0002	-0.0001
	Fraction of potential trips who will rideshare	10				
	Fraction of new carpoolers who join existing carpools and do not meet at park-and-ride	10	-0.0002	-0.0001	-0.0003	-0.0001
	Fraction of new carpoolers who join new carpools and do not meet at park-and-ride	10				
	Work trip generation rate for SOV users	10	0.0001	0.0000	0.0001	0.0000
	Fraction of trips made via shared mode	10	0.0001	0.0001	0.0001	0.0000
	New work trip length	10	0.0000	0.0000	0.0000	0.0000
	Non-work trip generation rate for SOV users	10	0.0000	0.0000	0.0000	0.0000
	Fraction of non-work trips of the total TCM-related non-work trips during the peak period	10	0.0000	0.0000	0.0000	0.0000

Table 32 (Continued)
Sensitivity Analysis Results for Parking Management Measure

Method	Variable	Percentage Change				
		Variable	Peak Trips	Off-Peak Trips	Peak VMT	Off-Peak VMT
SANDAG	Percentage of maximum VMT reduction realized due to circuity of ridesharing or access to transit	10	0.0000	0.0000	-0.0978	-0.0358
	Elasticity of parking demand with respect to cost for commute trips	10	-0.1213	-0.0513	-0.1040	-0.0380
	Percentage of employees affected	10	-0.0012	-0.0005	-0.0010	-0.0004
	Average daily increase in parking charge	10	0.0000	0.0000	0.0000	0.0000

Table 33
Sensitivity and Reliability Summary for Parking Management Variables

Method	Variable	Sensitivity			Reliability		
		High	Moderate	Low/None	High	Moderate	Low
SAI	Number of spaces subject to price increase	X				X	
	Percentage change in parking price	X				X	
	Parking elasticity	X					X
	Fraction of work trips of the total TCM-related work trips during the peak period	X					X
	Fraction of potential trips who will use transit		X				X
	Fraction of potential trips who will rideshare						X
	Fraction of new carpoolers who join existing carpools and do not meet at park-and-ride		X				X
	Fraction of new carpoolers who join new carpools and do not meet at park-and-ride						X
	Work trip generation rate for SOV users		X				X
	Fraction of trips made via shared mode		X				X
	New work trip length			X			X
	Non-work trip generation rate for SOV users			X			X
	Fraction of non-work trips of the total TCM-related non-work trips during the peak period			X			X

Table 33 (Continued)
Sensitivity and Reliability Summary for Parking Management Variables

Method	Variable	Sensitivity			Reliability		
		High	Moderate	Low/None	High	Moderate	Low
SANDAG	Percentage of maximum VMT reduction realized due to circuity of ridesharing or access to transit	X					X
	Elasticity of parking demand with respect to cost for commute trips	X					X
	Percentage of employees affected		X			X	
	Average daily increase in parking charge			X		X	

SAI

The *number of spaces subject to price increase* variable results in a high sensitivity for the outputs of the parking management TCM. This variable is the difference between the total number of spaces located in the area where the TCM will be implemented and those spaces within the area that will not be affected by the price increase. It is logical for the sensitivity to be high since this variable defines the participation in the TCM program. The reliability for this variable is moderate because it represents a specific TCM scenario for the El Paso central business district.

The *percentage change in parking price* variable also results in a high sensitivity of the outputs for the TCM. This sensitivity does not appear logical because historical records of travel costs have shown that American auto owners do not alter their driving habits substantially when faced with increasing costs. Therefore, this variable should exhibit moderate or low sensitivity to changes within the analysis of this TCM. The sensitivity may be linked to the elasticity used in the analysis. The values used for this variable had a moderate sensitivity because the variable is a scope descriptor.

The *parking elasticity* variable used the default value provided in the SANDAG method; therefore, its reliability was considered low. Data were not available to determine the parking elasticity for El Paso. The sensitivity analysis showed that this variable produced a high sensitivity in the outputs. Therefore, TCM analysts should attempt to determine this value for their regions in order to obtain reasonable estimates of benefits.

The *fraction of work trips of the total TCM-related work trips during the peak period* variable resulted in a high sensitivity of the SAI outputs because parking management attempts to modify the mode choice of commuters. The reliability for this variable was low because a default value was used.

The variables, *fraction of participants who will use transit* and *fraction of participants who will rideshare*, have an inversely proportional relationship for the analysis of this study region. These variables have moderately sensitive effects on the SAI outputs. The variables are used to determine the percentage of potential trips affected that will shift modes due to an increase in parking price. The variables are supplemental scope descriptors and can have a moderate effect on estimated benefits. The reliability for the data was low because default data were used in place of regional data.

A third variable not used in the analysis for the study region is the *fraction of participants who will use fringe parking*. Because El Paso does not have fringe parking facilities or service to known fringe parking lots, it was assumed that this fraction would be zero. It is important to note that the *fraction of participants who will use fringe parking*, *fraction of potential trips who will use transit*, and *fraction of participants who will rideshare* variables sum to one. This summation defines their relationship within the TCM analysis.

The *fraction of new carpoolers who join existing carpools and do not meet at park-and-ride* and *fraction of new carpoolers who join new carpools and do not meet at park-and-ride* variables are supplemental scope descriptors that have moderately sensitive effects on the SAI results. The reliability for these variables was low since it is difficult to estimate them without knowledge of the study region's carpooling habits. Therefore, defaults provided in the SAI method were used.

The *new work trip length* variable resulted in a low sensitivity for the SAI method's outputs. For this variable to be moderately to highly sensitive, more commute trips would have to end at a park-and-ride lot or fringe parking area. The variables that define mode shifts resulting from the implementation of this TCM have an important role in affecting the sensitivity of this variable. The reliability of these variables was low because regional data were not available.

The TCM analysis is not sensitive to *non-work trip generation rate for SOV Users*, *work trip generation rate for SOV users*, and *fraction of trips made via shared mode* variables. The low sensitivity may be due to the small TCM scope resulting in a smaller estimate of increases in indirect trip effects. Thus, the small number of indirect trip increases has no effect on the regional trip making process.

The SAI method's sensitivity to the *fraction of non-work trips of the total TCM-related non-work trips during the peak period* variable is zero because this TCM targets work trips rather than non-work trips. The reliability for this variable was low because default data were used.

SANDAG

The SANDAG method's results have a high sensitivity to the *percentage of maximum VMT reduction realized due to circuity of ridesharing or access to transit* variable. The variable directly affects the estimation of VMT reduced in the peak and off-peak period from the estimated net vehicle trip reduction. The TCM analyst could over- or underestimate the VMT if a regional value for this variable is not developed. The reliability for this variable was low due to the use of a default value.

The *elasticity of parking demand with respect to cost for commute trips* variable is used to model the effect of cost on travelers' mode choice. The SANDAG method's sensitivity to this variable is high compared to the other variables in Table 32 and is by far the most sensitive for evaluating the net vehicle trip reduction of the TCM. The reliability for the value used in this analysis was low because the default value provided in the SANDAG model was used instead of an elasticity derived from El Paso data.

The *percentage of employees affected* variable is used with the total number of commute vehicle trips to estimate the total number of potential vehicle trips affected. The SANDAG method has a moderate sensitivity to changes in this variable. The reliability of the data was moderate because it is a TCM scope descriptor and is defined by the user.

The *average daily increase in parking charge* variable is used to define the percentage increase in parking price for the area where the parking management measure is used. The sensitivity analysis showed that the SANDAG output was not sensitive to this variable. This finding is not completely logical, however, because the change in price directly affects the net vehicle trip reduction estimate. The possibility still exists that the scope of the measure is too small to effectively evaluate the sensitivity for this variable, as with the other variables tested for this TCM. A moderate reliability rating was given based on the variable being a TCM scope descriptor.

SUMMARY

The comparison and critical analysis yielded many insights about the SAI and SANDAG methods. Examination of the methods' logic showed that several variables in each method are extremely difficult to quantify. As a whole, the SAI method has a better set of inputs for TCM analysis. There is a greater tendency to use defaults in the SANDAG method because many of the variables are difficult to understand and estimate. Because of this difficulty, many default values were used in the analysis for this report. Both methods require the TCM analyst to input target participation rates; however, MPOs cannot predict TCM participation based on the actions they take. Therefore, the tools act as a test bed for "what-if" scenarios and require the TCM analyst to design a program so that the target participation rate may be achieved.

Both methods report similar outputs. There is, however, less confusion with the SAI outputs because categories report increases as positive values and decreases as negative values.

The SAI structure is consistent and straightforward. A good base has been established for future development of equations to analyze additional TCMs. The spreadsheet version developed in this study for the SAI method was easier to use and preferred over the SANDAG method. The SANDAG structure was difficult to follow and provided the user little information on its assumptions for estimating travel effects. Although the SANDAG method was developed for use on a spreadsheet, it is not user-friendly.

Neither method has the complete ability to assess TCM packages. Currently, the methods can assess the additive effects of TCMs but cannot assess the synergistic and negative effects of TCM combinations.

The travel modules of the methods are not as well developed as they should be. The SAI and SANDAG methods have inconsistencies in their module structure. In both methods, an attempt is made to estimate the change in person trips and then convert this change to a reduction in vehicle trips. The major problem with both methods is their definition of work trips. The sketch-planning tools define a work trip differently than the traditional planning models from which many inputs are obtained. Both the indirect trip effects and latent demand portions of the travel modules need more work. SAI makes a good first attempt at indirect trips, whereas the SANDAG method omitted this effect.

The SAI emission module is thorough. The SANDAG emission module was not examined because it was not suitable for use outside California. Neither method estimates modal emissions because little work has been done on this topic; however, including these modal emissions would complete the framework of emission analysis which ranges from diurnals and tailpipe emissions to starting fractions.

The base scenario analysis showed that the methods produce similar results. Minor differences were found in the estimation of trip and VMT changes. These differences may have been due to the precision used in the methods. The differences between the emission estimates from SAI and SANDAG were due to estimates of fleet speed changes.

The sensitivity analysis showed that TCM scope descriptors are the most sensitive when analyzing a TCM. Supplemental scope descriptors were found to have a moderate sensitivity on the results. The majority of the base travel variables have a moderate sensitivity. The work-related variables are more sensitive than non-work-related variables; therefore, the work-related variables consistently had a high to moderate sensitivity. The SANDAG variables generally had a higher sensitivity than the SAI variables. The higher sensitivity may be attributed to SANDAG's emphasis on peak and off-peak trip changes throughout the analysis. These peak and off-peak trips are broken into work and non-work trip categories after the travel effects have been estimated. This procedure may present a problem to the TCM analyst who chooses to use the SANDAG method. The variables which were difficult to quantify in the SANDAG method have a consistently high sensitivity.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Three conclusions were made based on the results of this report:

1. Recent work on sketch-planning tools has greatly advanced the state-of-the-practice. The two methods examined in this report are evidence of this progress. Currently, more work is being conducted on the analysis procedures for TCMs throughout the country. Many methods provide unique techniques in estimating both travel and emission effects. As work in this area progresses, standard analysis procedures may be developed and implemented.
2. The SAI method provides a better means of estimating the benefits of TCMs than the SANDAG method. The structure and data inputs of the method allow the user to easily adapt new analysis procedures for TCMs not covered by the method. In addition, the SAI method offers less confusion in the method and less reliance on peak-period information. The low reliance on peak-period information is an important factor because information about trips in the peak period is not readily available. One drawback to this method is that few TCMs can be evaluated at this time. Currently, the SAI method can evaluate only eight TCMs, whereas the SANDAG method can evaluate more than 20.
3. The TCM analyst must realize that sketch-planning tools are techniques for gross estimation of TCM benefits. These tools provide the TCM analyst with a "first look" at the potential benefits of TCMs; however, they are the best tools for analysis at this time. Network models and simulation programs do not have the capability at this time to estimate benefits of a wide range of TCMs.

RECOMMENDATIONS

One principal recommendation is made for the SAI method. The remaining recommendations supplement the principal recommendation by identifying specific areas for improvement in the SAI method.

The principal recommendation is for further development of the SAI method. The method is currently the best tool available for TCM analysis; however, it is limited to a few TCMs, compared to the wide range of TCM alternatives. New procedures should be developed for TCMs not included in the SAI workbook. The process for evaluating the TCMs has been prepared and can be followed as a guide. In addition, seven areas are identified for improving and strengthening SAI's analysis capabilities:

1. **Integrate emission factor modeling.** Several emission factor models exist (MOBILE, EMFAC, and BURDEN) and developing a system for each of the models to transfer data between it and the sketch-planning tool may be difficult; therefore, the two most commonly used emission factor models should be considered. These are MOBILE, used throughout the U.S., except in California, and EMFAC, the model used in California. BURDEN was not recommended because EMFAC is the dominant emission factor model used in California.
2. **Incorporate modal emission analysis.** Modal emission analysis may provide insight on which TCMs can most effectively reduce these types emissions. Fewer accelerations and decelerations made by a vehicle decrease fuel consumption and tailpipe emissions. Although the work in this area is just beginning, an effort should be undertaken to determine if this type of analysis can be included in the sketch-planning tools.
3. **Develop tools to assist in determining peak-period travel information.** Peak-period modeling capabilities should be integrated or appended to the sketch-planning tool package. Many MPOs are ill-equipped to collect the required data or are under-staffed to dedicate extensive amounts of time to search for specific peak-period information. The alternative to this recommendation is to remove the reliance of peak-period trip information from the analysis process.
4. **Develop latent demand and indirect trip effects estimation procedures.** The SAI method provides a good first attempt to quantify latent demand and indirect trip effects; however, the procedure should be refined and, in the case of latent demand, should be used in the analysis. Latent demand has a potential of diminishing the improvements a TCM can make. Therefore, continuing research results should be

incorporated into TCM analysis.

5. **Develop procedure for estimating TCM participation rates.** The sketch-planning tools currently require the TCM analyst to input these target participation rates. However, defining and evaluating programs designed to reach these target rates are not available. Therefore, the development of procedures designed to predict traveler reactions to governmental actions is needed.

6. **Evaluate synergistic, additive, and negative effects of TCM programs.** TCM experts agree that single TCMs will not provide as great a benefit as a well designed program of TCMs can deliver. Many TCMs do not have additive effects when implemented simultaneously. For instance, an increase in carpools coupled with a transit fare decrease would detract riders from one of the two TCMs and would not effectively reduce overall emissions. Currently, the only way to assess the potential benefits of a TCM program is to analyze each TCM separately, which is not sufficient.

7. **Validate results.** Currently, MPOs throughout the nation are using sketch-planning tools to estimate the benefits of TCM implementation. Although the benefits are not expected to be greater than a 6 percent regional reduction in emissions, an effort should be undertaken to assess the results of these tools. Transportation professionals must assure the public that these tools reasonably predict the effects of implementing specific TCM programs.

REFERENCES

1. Our Nation's Highways: Selected Facts and Figures. U.S. Department of Transportation, Federal Highway Administration. 1986.

2. J. A. Lindley. Urban Freeway Congestion Problems and Solutions: An Update. *ITE Journal*, Vol. 59, No. 12, December 1989, pp. 21-23.

3. G. Hawthorn. Transportation Provisions in the Clean Air Act Amendments of 1990. *ITE Journal*, Vol. 61, No. 4, April 1991, pp. 17-24.

4. *Mobility Facts. 1992 Edition*. Institute of Transportation Engineers. 1992.

5. J. Horowitz. *Air Quality Analysis for Urban Transportation Planning*. MIT Press, Cambridge, MA, 1982.

6. Metropolitan Transportation Commission. *Draft Environmental Impact Report, Regional Transportation Plan, Environmental Analysis Sensitivity Test: Transportation Control Measures*. San Francisco, CA. April 1991.

7. Sacramento Metropolitan Air Quality Management District. Vol. V, Transportation Control Measures Program. *Sacramento 1991 Air Quality Attainment Plan*. Sacramento, CA. July 24, 1991.

8. B.S. Austin, J.G. Heiken, S.B. Shepard, and L.L. Duvall. *Methodologies for Estimating Emissions and Travel Activity Effects of TCMs*, Draft Final Report. Prepared for Office of Air Quality Planning and Standards and Office of Mobile Sources, U.S. Environmental Protection Agency. Prepared by Systems Applications International: San Rafael, CA, July 27, 1992.

9. P.C. Randall and A. Diamond. *AQAT-3: Air Quality Analysis Tools*. California Air Resources Board. 1990.

10. K.F. Turnbull, R.H. Pratt, J.R. Kuzmyak, and L.L. Duvall. Development of a Short-Range Travel Demand Management Program: the I-35W Experience. *Transportation Research Record 1280*. Transportation Research Board, Washington, D.C. 1990, pp. 30-38.

11. San Luis Obispo Air Pollution Control District. *Clean Air Plan San Luis Obispo County. Appendix D. Transportation Control Measures*. San Luis Obispo County, CA. December 1991.

12. Telephone conversation with Ron Mertis, Sacramento Air Quality Management District. Sacramento, CA. March 2, 1993.

13. W. R. Loudon and D. A. Dagang. Predicting the Impact of Transportation Control Measures on Travel Behavior and Pollutant Emissions, presented at Transportation Research Board 1992 Annual Meeting. Washington, D.C. January 1992.

14. *Highway Capacity Manual, Special Report 209.* Transportation Research Board, National Research Council, Washington, D.C., 1985.

15. Sierra Research, Inc. *Methodologies for Quantifying the Emission Reductions of Transportation Control Measures.* Prepared for San Diego Association of Governments. Report No. SR91-10-03. San Diego, CA. October 8, 1991.

APPENDIX

MOBILE5A CONTROL FLAG SETTINGS AND INPUT VALUES

Table A-1
MOBILE5A Control Flag Setting Summary

Record Number	Variable Name	Control and Code Used
1	PROMPT	1 = No prompting; vertical format
2	PROJID	80 characters for title
3	TAMFLG	1 = Use MOBILEA tampering rates
4	SPDFLG	1 = One speed for all vehicle types
5	VMFLAG	3 = One user input VMT mix for all scenarios
6	MYMFRG	3 = MOBILEA annual milage accumulation rates, user input registration distributions
7	NEWFLG	1 = Use MOBILE5A basic exhaust rates
8	IMFLAG	2 = I/M program assumed
9	ALHFLG	1 = No additional correction factors
10	ATPFLG	2 = ATP for 1980 to 2020 model years assumed
11	RLFLAG	1 = Use uncontrolled refueling emission rates for all gasoline-fueled vehicles and for all model years
12	LOCFLG	2 = One LAP record input for all scenarios
13	TEMFLG	1 = MOBILE5A calculates temperatures to be used in correction of emission rates from input values of average minimum and maximum daily temperatures; calculated values override ambient temperature input
14	OUTFMT	3 = 112 column descriptive format
15	PRTFLG	4 = Calculate and output emission factors for all three pollutants
16	IDLFLG	2 = Idle emission factors calculated and printed (in addition to exhaust emission rates)
17	NMHFLG	1 = HC emission factor comprised of THC
18	HCFLAG	3 = Print sum and component emission factors for HC

Table A-2
I/M Program Settings

Field	Content	Value
1	Program start year	87
2	Stringency level	18
3	First model year covered	75
4	Last model year covered	20
5	Waiver rate - pre-1981 model year vehicles	0.
6	Waiver rate - 1981 and later model year vehicles	0.
7	Compliance rate	073
8	Program type	2 (decentralized)
9	Inspection frequency	1 (annual)
10	Vehicle types[1] subject to inspection 2 = yes 1 = no	2 (LDG) 2 (LDGT-1) 2 (LDGT-2) 1 (HDGV)
11	Test type	1 (idle test)
12	Flags controlling use of alternate I/M credits	11 = Do not read alternate credits

[1]Vehicle Types
Light-duty gasoline vehicles (LDG)
Light-duty trucks (LDGT-1) under 6,000 pounds (2,722 kilograms)
Light-duty trucks (LDGT-2) over 6,000 pounds (2,722 kilograms)
Heavy-duty gasoline powered trucks (HDGT) over 8,500 pounds (3,856 kilograms)

Table A-3
ATP Program Settings

Field	Content		Value
1	Program start year		86
2	First model year covered		80
3	Last model year covered		20
4	Vehicle types[1] subject to inspection 2 = yes 1 = no		2 (LDG) 2 (LDGT-1) 2 (LDGT-2) 1 (HDGT)
5	Program type/Inspection frequency		2 (decentralized) 1 (annual)
6	Compliance rate		073.
7	Inspections performed 2 = yes 1 = no	Air pump system	2
		Catalyst	2
		Fuel inlet restrictor	2
		Tailpipe lead deposit test	2
		EGR system	2
		Evaporative control system	2
		PCV system	2
		Gas cap	2

[1]Vehicle Types
Light-duty gasoline vehicles (LDG)
Light-duty trucks (LDGT-1) under 6,000 pounds (2,722 kilograms)
Light-duty trucks (LDGT-2) over 6,000 pounds (2,722 kilograms)
Heavy-duty gasoline powered trucks (HDGT) over 8,500 pounds (3,856 kilograms)

Table A-4
CO Season Local Area Parameter Record

Field	Content	Value
1	Scenario name	Optional
2	ASTM class	blank
3	Minimum daily temperature	26.0
4	Maximum daily temperature	63.0
5	Period 1 Reed vapor pressure	11.6
6	Period 2 Reed vapor pressure	11.6
7	Period 2 start year	90
8	Oxygenated fuels flag	blank
9	Diesel sales fraction flag	blank

Table A-5
Ozone Season Local Area Parameter Record

Field	Content	Value
1	Scenario name	Optional
2	ASTM class	blank
3	Minimum daily temperature	66.0
4	Maximum daily temperature	97.0
5	Period 1 Reed vapor pressure	07.7
6	Period 2 Reed vapor pressure	07.7
7	Period 2 start year	90
8	Oxygenated fuels flag	blank
9	Diesel sales fraction flag	blank

Table A-6
CO Season Scenario Record

Field	Content	Value		
1	Region for which emission factors are to be calculated	1 = low altitude		
2	Calendar year of evaluation	90		
3	Speed	3 to 65 mph at increments of 1 mph		
4	Ambient temperature	50.7		
5	Operating mode fractions in percentage of VMT accumulated by:	100 CST	100 HST	100 STB
	PCCN - Non-catalyst vehicles in cold-start mode	100	0.0	0.0
	PCHC - Catalyst vehicles in hot-start mode	0.0	100	0.0
	PCCC - Catalyst vehicles in cold-start mode	100	0.0	0.0
6	Month	1 = January		

Table A-7
Ozone Season Scenario Record

Field	Content	Value		
1	Region for which emission factors are to be calculated	1 = low altitude		
2	Calendar year of evaluation	90		
3	Speed	3 to 65 mph at increments of 1 mph		
4	Ambient temperature	86.6		
5	Operating mode fractions in percentage of VMT accumulated by:	100 CST	100 HST	100 STB
	PCCN - Non-catalyst vehicles in cold-start mode	100	0.0	0.0
	PCHC - Catalyst vehicles in hot-start mode	0.0	100	0.0
	PCCC - Catalyst vehicles in cold-start mode	100	0.0	0.0
6	Month	7 = July		