Critical Analysis of Sketch-Planning Tools Used To Evaluate Benefits of Transportation Control Measures

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Two premier sketch-planning tools used to evaluate transportation control measures (TCMs)—the San Diego Association of Governments (SANDAG) TCM tools method and the Systems Applications International (SAI) method—are examined. A critical analysis and sensitivity analysis were performed on the SANDAG and SAI methods. Data collected for the El Paso, Texas, nonattainment area were used to evaluate the sensitivity results. The sensitivity analysis examined several variables in five TCMs: flextime, ridesharing, transit fare decrease, transit service increase, and parking management. Results of the sensitivity analysis showed that the tools are most sensitive to the TCM project descriptors and work-related variables. The report concludes that (a) recent work in the field has advanced the state of the practice and (b) although sketch-planning tools are gross estimating techniques, they are currently the best TCM analysis tools. Areas identified for improvement include (a) developing procedures for estimating TCM participation rates; (b) developing indirect trip effects and latent demand estimation procedures; (c) evaluating synergistic, additive, and negative effects of TCM programs; and (d) incorporating modal emission analysis.

Motor vehicles are an important part of modern society. Significant trends in automobile use have become apparent during the past 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. 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.

The main transportation-related pollutants are carbon monoxide (CO), hydrocarbons (HC), and nitrous oxides (NO_x). The Environmental Protection Agency (EPA) has reported that 78 million Americans live in the 41 metropolitan areas that exceed CO standards (*1*). 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 (*2*), 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."

Before TCMs can be used to reduce mobile source 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, which has been used since the late 1970s in metropolitan areas throughout the United States. Several sketch-planning tools for TCM evaluation have been devised over the years. Most have built on past work, whereas others have strived to break new ground through their own methodologies. The two most current methodologies are the San Diego Association of Governments (SANDAG) methodology developed by Sierra Research, Inc., with support from JHK & Associates, and the Systems Applications International (SAI) methodology prepared for EPA.

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

This study had one primary objective and several secondary objectives. The primary objective was to analyze critically sketch-planning methods that evaluate the mobile source emission benefits of TCMs. This analysis examined each method's logic, data requirements, and results. The secondary objectives were to assess each methodology's sensitivity to specific data inputs, identify areas for improvement, and suggest possible solutions to enhance the current models.

The scope of the study was limited to the SANDAG and SAI methods. This study used data gathered from El Paso, Texas. El Paso is categorized as a serious ozone nonattainment area and a moderate CO nonattainment area.

LITERATURE REVIEW

Several TCM evaluation 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." (*3*)

The methods reviewed as part of this study were NCHRP Report 263, Air Quality Analysis Tools version 3 (AQAT-3), Turnbull method, Sacramento Metropolitan Air Quality Management District (SMAQMD), San Luis Obispo Air Pollution Control District (SLOAPCD), SANDAG TCM Tools, SAI, North Central Texas Council of Governments (NCTCOG), Houston-Galveston Area Council (HGAC), and the Texas Department of Transportation (TxDOT). The AQAT-3, SMAQMD, SLOAPCD, and SANDAG methods were developed in California.

Many of the California-based methods were not developed with out-of-state use in mind. Specifically, these methods incorporate

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California emission factor models that are not appropriate to use outside of California.

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. Obtaining estimated changes in VMT and speeds is important when estimating the mobile source emission benefits from TCMs.

No method reviewed is capable of fundamental demand estimation. SANDAG and SAI are the only methods reviewed that evaluate the effects of latent demand and indirect trips on the total performance of a TCM. SAI estimates latent demand and indirect trip effects through social and economic parameters, which fall away from fundamental demand estimation. Other methods neither estimate these factors nor document that they are a concern. Induced demand through latent demand and indirect trips can negate some of the benefits gained from TCMs.

The basic mobile source emission components of a vehicle trip are start emissions, running emissions, hot soak emissions, and diurnal emissions. Very few methods reviewed accounted for start emissions. Start emissions are an important component of the vehicle trip because most vehicle emissions occur when the vehicle is started. A vehicle produces more emissions when it has been at rest for some time (cold start) than when it is started within a few minutes of the engine being turned off (hot start). The SANDAG and SAI methods account for all of the basic mobile source emission components. Other methods account for only some of the components.

The SANDAG and SAI methodologies are at the forefront of the sketch-planning methods to evaluate mobile source 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.

The SANDAG methodology has three modules: travel impacts, emission impacts, and cost-effectiveness. The method is designed to predict the effect of individual TCMs (*4*). The method includes 25 TCMs; user-defined TCMs can also be evaluated. These TCMs are

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

The method was developed using LOTUS 1-2-3 and FORTRAN. The emission module uses two California emission factor models: EMFAC7 and BURDEN7C. The cost-effectiveness module uses output from the travel and emission modules and computes daily costs for pollutant mass removed.

The SAI methodology is EPA's most recent attempt to estimate the potential emission benefits from the implementation of TCMs. Its basic structure consists of two modules: travel effects and emission effects. The method provides analysis procedures for seven TCMs: telecommuting, flextime, compressed work week, ridesharing, transit improvements, HOV lanes, and parking management. The documentation of the methodology provides step-by-step instructions on how to estimate the effects on trips, VMT, and speeds from selected TCMs. The emission module can be used with any emission factor model. A limitation of this method is that no computer software is available to implement the method, and it would be very cumbersome to use with pencil and paper.

STUDY DESIGN

Conversion of SANDAG and SAI Methodologies to Spreadsheet

Both methods were programmed or imported, or both, into an available spreadsheet. The SAI method was programmed in its entirety. The SANDAG method was imported and modified to the available spreadsheet's standards. The SANDAG method was further modified so that emission estimates could be compared between the two methods.

The SANDAG method estimates emission reductions using the California-specific emission factor models (EMFAC7E and BURDEN7C). The SANDAG emission module could not be modified to allow MOBILE emission factors to be used. Thus, the SANDAG emission module could not be used to directly compare those results obtained from the SAI method. To overcome this problem, the SAI emission module was adapted for use with the SANDAG method's travel estimates to calculate a mobile source 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. Therefore, the two methods should produce comparable emission estimates given similar travel effects.

Description of Study Region

El Paso is located in west Texas and borders New Mexico and the Republic of Mexico. During the past decade, the city's population has increased steadily to a 1990 census population of 561,965, the fourth largest in Texas. The city is 4,000 ft above sea level and has several mountains around the perimeter of the central business district, forming an air basin. Because El Paso is classified as a serious ozone nonattainment area and a moderate CO nonattainment area, El Paso officials were interested in evaluating TCM options that could be used to reach attainment.

Data Collection

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

The data sources included TxDOT, the El Paso Metropolitan Planning Organization, Sun Metro (El Paso's transit authority), 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 United States were used, and other values were calculated from published sources. 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 Texas travel survey 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 scenarios. Control flags and additional data developed by the Texas Air Control Board (now the Texas Natural Resource Conservation Commission) were used in this study.

Sensitivity Analyses

Sensitivity analyses were performed on several of the methods' variables for two reasons: (a) to determine their impact on the methods and (b) 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 used to evaluate five TCMs: flextime, ridesharing, transit fare decrease, transit service increase, and parking management. These TCMs were selected because El Paso officials showed interest in them.

Key travel results from the TCM evaluation (vehicle trip and VMT changes occurring in the peak and off-peak periods) were used in the sensitivity analysis. Emissions were not compared for two reasons: (a) the use of the SAI emission model in both spreadsheet models would not allow for a unique comparison between the two methods, and (b) emission estimates are calculated on the basis of the travel effects. The following equations were used to identify the methods' sensitivity to each variable:

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

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

These equations allow comparison between variables because each ratio has a common denominator. Variables were compared with other variables within a TCM and with the same variable in other TCMs. Each variable examined was changed by 10 percent of the baseline value where possible to simplify and standardize the analysis process across all variables.

The variables examined in the sensitivity analysis for each method were grouped according to defined categories: base travel variables, TCM scope descriptors, supplemental TCM descriptors, work-related variables, nonwork-related variables, and peak-period-related variables. Each of the categories is described as follows:

- Base travel variables are defined as those variables that describe the current condition of the region's transportation system. An example of the variables in this category is the fraction of trips made via shared mode.
- TCM project descriptors include scope descriptors and supplemental inputs used to determine the TCM's effectiveness. Scope descriptors are variables used to define the TCM's operation when implemented. Examples of scope descriptors are number of participants, frequency of participation, and average percentage of fare decrease. Examples of supplemental TCM descriptors are the new work trip length and elasticity of transit use with respect to cost.
- Work-related variables define characteristics of the work trips in the region. An example is the work trip generation rate for SOV users.
- Nonwork-related variables would include variables such as the fraction of nonwork trips during the peak period. Nonwork-related variables define the region's nonwork trip characteristics.
- Peak-period-related variables are variables about trip characteristics in the peak periods. An example is the fraction of the work (nonwork) trips during the peak period.

COMPARISON AND EVALUATION OF SANDAG AND SAI METHODOLOGIES

The comparison of the SANDAG and SAI methods covers several areas. The structure of each method is presented and reviewed. The outputs and data requirements of the two methods are also discussed. Unique and interesting areas in travel and emission change estimates are present. The discussion concludes with an evaluation of the methods' abilities to assess the benefits of TCM packages.

Method Structures

The SANDAG method can analyze a variety of TCMs. Its TCM selection covers a broad range of transportation actions that may be used in metropolitan areas to improve air quality.

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 SANDAG emission module is California specific and does not allow analysis for areas outside California. The regional limitation of this method is being corrected through FHWA funding and was expected to be available in fall 1994 for use throughout the nation. Documentation provided with the software did not clearly present the processes used to estimate mobile source emission reduction estimates.

The SAI method is consistent and straightforward. The method is limited in its selection of TCMs to analyze; however, a good base has been established in the documentation for future development of additional procedures to analyze additional TCMs.

The SAI travel module consists of nine steps. The first step is to calculate the number of person trips affected. Next, person trips are transformed into a reduction in vehicle trips based on the person trips affected. The change in vehicle trips is calculated for work and nonwork trips. The method then determines the indirect trip effects for each TCM for work and nonwork-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: (a) work, peak; (b) work, off-peak; (c) nonwork, peak; and (d) nonwork, off-peak. This organization of trips provides a good accounting system of trips that occur in a region. Next, 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, the initial VMT levels, and elasticities. Changes in emissions are estimated based on the results from travel changes.

The emission module consists of four steps. First, mobile source emission changes are calculated from vehicle trip changes. Second, mobile source emission changes associated with VMT changes are determined. Next, changes in mobile source emissions are calculated from fleet speed changes. Finally, the values from the previous steps are summed to yield a total mobile source emission change associated with a TCM.

Outputs

Reports of estimated mobile source emission changes are important because the objective of the CAAA is to influence mobile source emissions. Reports of travel changes are equally important because they are used to estimate mobile source emission changes.

The SANDAG and SAI methods both provide output in absolute terms. The SANDAG and SAI travel outputs are changes in vehicle trips, VMT, and regional speed (this is reported as a percentage of increase or decrease). The emission changes in the SAI method cover HC, CO, and NO_x. These pollutant reductions are reported in grams per day. The units of the emission output can be easily converted to other acceptable units (kilograms per day or tons per day). The SANDAG method provides emission change estimates for reactive organic gases, CO, NO_x and particulate matter. Before-and-after regional emission levels, as well as the percentage of reduction in emissions, are supplied to the user.

Data Requirements

Both methods have extensive data requirements. Three concerns with these data requirements are the user-supplied TCM participation rates, the use of defaults, and an inconsistency in the definition of work trips with traditional planning models.

User-Supplied TCM Participation Rates

Both methods require the TCM analyst to enter target participation rates; however, MPOs cannot confidently provide participation rates for TCMs. Therefore, the tools provide a means for testing "what if" scenarios for TCM participation and require the TCM analyst to design a program to reach the target participation rate.

Neither method covers the total TCM planning process by requiring the user to input target participation rates. The TCM planning process includes governmental or employer actions, traveler reactions, and transportation system changes. There are three steps in the TCM planning process: (a) estimate the number of travelers who will participate in the TCM, (b) estimate the change in travel demand resulting from this level of participation, and (c) estimate the change in traffic conditions resulting from this change in demand. The SANDAG and SAI sketch-planning tools require the TCM analyst to perform the first step (i.e., estimate TCM participation rates) and provide the results as input for the second step. The sketch-planning tools perform the second and third steps.

Use of 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. Default values are generally used for elasticities and data that are difficult to obtain.

Both methods use elasticities to predict traveler behavior and travel characteristics. Elasticities for predicting traveler behavior estimate the travel responses to cost increases. Elasticities used to predict travel characteristics estimate the changes in travel speed with respect to volume. 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 volume-to-capacity ratio on the transportation network.

Both methods stress that TCM analysts should develop regional data inputs to accurately model the effects of TCMs on the regional transportation system. The TCM analyst must understand that results can be substantially different if regional data are used in place of default data.

Inconsistent Work Trip Definition

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 ABC, as shown in Figure 1, regardless of the number of intermediate stops. 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: AB and BC. These two trips cannot be reassembled once they are broken into its components. Users cannot obtain complete trip information in the study region once the trips have been segmented in the traditional planning models.

Travel Change Estimations

Vehicle trip reduction is estimated after the affected person trips are calculated. The SANDAG method 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, com-

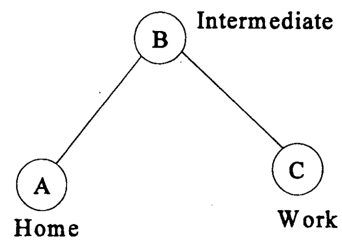

FIGURE 1 Work-Trip Schematic.

bined in the step that determines the reduction in the number of vehicle trips associated with a particular TCM. SAI has two distinct steps that determine reduction in person and vehicle trips.

The SANDAG vehicle trip changes are categorized in a different process 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 nonwork trips. The SAI method categorizes vehicle trip changes by work and nonwork before splitting these categories into time periods (peak and off peak).

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.

The SAI method is the only method to estimate indirect vehicle trip effects. The method estimates vehicle trip increases related to work and nonwork travel based on several variables including the fraction of the population that does not own a vehicle and the work and nonwork trip generation rates for SOV users. The estimated increase in work and nonwork vehicle trips are combined with the overall trip changes to yield a net change in vehicle trips.

Latent Demand

Latent demand is the demand attracted to a roadway because of improved conditions. This phenomenon is not completely understood, and research is ongoing to determine its processes. SANDAG and SAI were the only methods reviewed that recognized latent demand as a factor that influences the overall effectiveness of a TCM. As a result from the lack of conclusive research on the attraction and effects of latent demand, both methods lack a quantitative completeness needed in this area.

SANDAG estimates the latent demand effects associated with TCMs differently from SAI. First, SANDAG does not evaluate latent demand effects for all TCMs. Where it is used, SANDAG requires the user to enter the increase in volume.

SAI is the first model to attempt to calculate latent demand. It does not, however, use its latent demand results in subsequent calculations to assess its impact on the transportation system.

Emission Change Estimations

The SANDAG and SAI methods include many mobile source emission components that are small contributors to total vehicle emissions. These components include running exhaust, start exhaust, and evaporative and diurnal emissions. Evaporative emissions in the SANDAG method cover running, hot soak, and diurnal breathing. The SAI method's evaporative emissions do not include diurnal breathing but do account for crankcase and refueling emissions.

A unique step in the SAI emission analysis is the estimation of emission changes 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 are the other two pollutants (HC and NO_x) because a decrease in recurrent congestion decreases the amount of vehicle idling, which is a direct and major contributor to CO hot spots. The assumption for this step is 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. In many cases, a TCM project may experience additional mobile source emission benefits if the regional fleet speed is increased by only 1.61 or 3.2 km/hr (1 or 2 mph).

Neither method was able to incorporate modal emissions in their analysis. Modal emissions are currently being researched by EPA as a part of understanding the mobile source emission interrelationships within the acceleration, cruise, deceleration, and idle cycle. Numerous acceleration and deceleration cycles have been known to increase fuel consumption, which in turn leads to increased automotive emissions. Once results are available on this topic, modal emissions should be included in the SANDAG and SAI methods as part of the total emission analysis.

TCM Packages

Neither method has the complete ability to assess TCM packages. The methods can evaluate the additive effects of TCMs but cannot assess 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 with other TCMs to increase further the mobile source emission benefits from a TCM program. Conversely, many TCMs compete for the same traveler market. Analyzed separately, the TCM package may indeed exhibit sizable benefits, but once implemented, the program may not be cost effective because of competing TCM actions.

SENSITIVITY ANALYSIS OF SANDAG AND SAI METHODOLOGIES

A sensitivity analysis was performed on many variables for each of the TCMs studied to determine their effect on the estimated TCM's benefits. The sensitivity analysis was based on changes from base scenarios. In each sensitivity test, base scenario values were used in the TCM, except for the variable being tested. The variables were then categorized by type and the sensitivity for the variable category was summarized.

Qualitative sensitivity ratings were based on the percentage of changes between the set of variables examined within each TCM. If a variable exhibited a significantly higher percentage of change than other variables within the TCM, it was ranked as possessing a high sensitivity.

The relationship between sensitivity and data reliability is important to understand. Table 1 shows possible combinations of sensi-

TABLE 1 Potential Error in TCM Evaluation

	Sensitivity		
Reliability	High	Moderate	Low
High			MINIMUM
Moderate			
Low	MAXIMUM		

tivity and data reliability. 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 evaluation increases as the sensitivity increases and the reliability decreases.

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.

Tables 2 and 3 summarize the sensitivity analysis performed for this study. Several pages of tables document the complete sensitivity analysis in a TTI Research Report 1279-5 (*5*). Table 2 shows the average sensitivity results for the SANDAG and SAI methods. The sensitivity of vehicle trip and VMT changes to the variable categories is shown for the peak and off-peak periods, as well as a total average. Table 3 displays the qualitative assessment of the sensitivity results obtained from the results of individual TCM evaluations and the averages shown in Table 2. Three variable categories were not represented in the sensitivity analysis from the SANDAG method: work, nonwork, and peak period.

The variable categories yielding the highest sensitivity on the outputs are the TCM project descriptors (scope descriptors and supplemental descriptors). These are the most critical variables to estimate or enter. These variables define the extent of the TCM and which trips will be affected.

The word "estimate" is used in this discussion for cases in which TCM participation rates are input, because accurate values cannot be used in the analysis. TCM analysts must provide the sketch-planning tools with their best guess of TCM participation. TCM analysts may decide to test a range of participation, which would yield an estimated range of emission reduction.

Work-related and base travel variables were found to have a moderate sensitivity effect on the methods' results. This is a logical ranking considering that the focus of TCMs is on work-related travel. Very few TCMs are designed to affect travel for nonwork trips.

Nonwork-related and peak-period-related variables yielded moderate to low output sensitivities. Nonwork-related variables do not pose significant problems in TCM analysis because TCMs do not focus on affecting this travel type.

CONCLUSIONS

Recent work on sketch-planning tools has advanced the state of the practice. The two methods examined in this report are evidence of this progress. 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.

TCM analysts must realize that sketch-planning tools are techniques for gross estimation of TCM benefits. Although these tools provide TCM analysts with only a first look at the potential benefits of TCMs, they are the best tools for analysis at this time. Network-based travel demand and traffic simulation models do not have the capability at this time to estimate benefits of a wide range of TCMs.

Several areas of the sketch-planning tools were identified for improvement. Data requirements could be improved by assisting

TABLE 2 Average Sensitivity Results for SANDAG and SAI Methods

		Vehicle Trips (%)			VMT (%)		
Method	Variable Category[a]	Peak	Off-Peak	Total	Peak	Off-Peak	Total
SANDAG	Base Travel	-0.00050	-0.00020	-0.00035	-0.00040	-0.00020	-0.00030
	TCM Scope Descriptors	-0.00646	-0.00793	-0.00720	-0.00604	-0.00545	-0.00574
	Supp. TCM Descriptors	-0.00024	-0.00021	-0.00023	-0.00023	-0.00016	-0.00019
	Work Related[b]						
	Non-Work Related[b]						
	Peak Period Related[b]						
SAI	Base Travel	0.00045	0.00023	0.00034	0.00047	0.00020	0.00034
	TCM Scope Descriptors	-0.03639	-0.01001	-0.02320	-0.03043	-0.01291	-0.02167
	Supp. TCM Descriptors	-0.00184	-0.00075	-0.00129	-0.00179	-0.00052	-0.00116
	Work Related	0.00054	0.00031	0.00042	0.00058	0.00026	0.00042
	Non-Work Related	0.00001	0.00014	0.00008	-0.00005	0.00010	0.00006
	Peak Period Related	-0.00013	0.00010	-0.00002	-0.00012	0.00006	-0.00003

[a] Average variable changes were 10%
[b] No variables tested with this designation

TABLE 3 Qualitative Sensitivity Results for SANDAG and SAI Methods

Method	Variable Category	Sensitivity		
		High	Moderate	Low/None
SANDAG	Base Travel		X	
	TCM Scope Descriptors	X		
	Supp. TCM Descriptors		X	
	Work Related[a]			
	Non-Work Related[a]			
	Peak Period Related[a]			
SAI	Base Travel Variables		X	
	TCM Scope Descriptors	X		
	Supp. TCM Descriptors		X	
	Work Related		X	
	Non-Work Related			X
	Peak Period Related			X

[a] No variables tested with this designation

analysts in (a) estimating TCM participation, (b) developing regional data for the model and not relying on defaults developed elsewhere, and (c) finding some consistency in the work trip definition between sketch-planning tools and traditional planning models. Travel change estimates may be improved by continuing to develop procedures to estimate the effects of indirect trips and latent demand. Mobile source emission changes estimated in the methods do not account for modal emissions. Once research is completed on modal emissions, efforts should be undertaken to include modal emissions in the sketch-planning tool analysis. TCM packages are unable to be evaluated with sketch-planning tools. These tools currently can only evaluate TCMs individually, thus not accounting for any synergistic, additive, or negative effects TCM actions may cause.

The sensitivity analysis showed that TCM project descriptors are the most sensitive when analyzing a TCM. Descriptors that define the scope of the TCM being evaluated are also extremely important to obtain accurate representations of regional benefits from a TCM. The base travel and work-related variables have a moderate sensitivity. Accurate data collection for the sketch-planning tools should focus on variables that define the base travel characteristics of the region as well as work-related variables. The work-related variables are more sensitive than nonwork- and peak–period-related variables.

RECOMMENDATIONS

Four recommendations were made based on the results of this study:

- Develop procedures for estimating TCM participation rates. The sketch-planning tools currently require the TCM analysts to enter target TCM participation rates. However, procedures do not exist to assist in defining the scope of TCM programs. Therefore, procedures designed to predict traveler reactions to TCM actions must be developed.
- Develop indirect trip effects and latent demand estimation procedures. The SAI method provides a good first attempt to quantify indirect trip effects and latent demand; however, the procedure should be refined and in the case of latent demand should be used in the analysis. Indirect trip effects and latent demand have a potential to counter the benefits from a TCM program. Therefore, research results from these areas should be incorporated into TCM analysis.
- Incorporate modal emission analysis. Modal emission analysis may provide insight on which TCMs can most effectively reduce these types of emissions. Fewer accelerations and decelerations made by a vehicle decrease fuel consumption and tailpipe emissions. Although 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.
- 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 with other TCMs. 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 individually, which is inadequate.

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