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16. Abstract

The mandates of the Clean Air Act Amendments (CAAAs) and Intermodal Surface Transportation Efficiency Act (ISTEA) Congestion Mitigation and Air Quality (CMAQ) Improvement Program require the evaluation and monitoring of transportation control measure (TCM) emission impacts.

The objective of the research documented herein was to investigate issues related to the evaluation and monitoring of TCM impacts. Researchers reviewed the advantages and limitations of TCM evaluation methods currently available, and identified two critical issues which influence their capabilities and accuracy. The TCM evaluation methods reviewed include the use of comparative empirical data, network-based models, and sketch-planning tools. The structure of TCM monitoring programs was also studied. Monitoring programs are presented for four TCMs: transit plazas, intersection improvements, ridesharing, and park-and-ride lots.

In general, researchers concluded that the TCM evaluation methods currently available require improvement, but that sketch-planning tools hold the most promise given the amount of input data available. None of the methods available can evaluate all the TCMs. This fact, and the difficulties with TCM participation rate estimation and TCM program evaluation, limits the ability to evaluate the regional impacts of TCMs.

This study also concluded that more TCM information needs to be collected, and that properly designed TCM monitoring programs are essential to meet legislative mandates and improve current TCM evaluation methods. Recommendations include the initiation of a standardized data collection and monitoring program.

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THE EVALUATION AND MONITORING OF TRANSPORTATION CONTROL MEASURES

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IMPLEMENTATION STATEMENT

This report focuses on the evaluation and monitoring of transportation control measures (TCMs). The contents will assist metropolitan planning organizations and state departments of transportation that must evaluate and monitor the impacts of TCMs. The research includes a review of three approaches that can be used in the evaluation of TCM travel and emission impacts. The report concludes that sketch-planning tools are the most comprehensive and cost-effective methods currently available. The report also discusses two critical issues which have a significant influence on TCM evaluation results: the estimation of TCM participation rates, and the evaluation of programs with multiple TCMs. Chapter IV identifies the essential components of TCM monitoring programs, and provides examples for four TCMs. Overall, sketch-planning methods appear to have the most promise, but the research described herein supports the improvement of all current TCM evaluation methods. The research also supports the initiation of comprehensive data collection and monitoring programs, and the proper design of TCM monitoring programs to collect the type of data that are useful to current evaluation tools.

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 (FHWA) or the Texas Department of Transportation (TxDOT). 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. (#66413), was the Principal Investigator for the project.

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SUMMARY

The purpose of the research documented in this report was to investigate methods for evaluating and monitoring the impacts of TCMs. The report reviews and evaluates the TCM evaluation methods currently available, and identifies and describes two issues that influence their capabilities. The report also discusses the general components of an effective monitoring program, and provides examples for four specific TCMs. The proper design of these programs is important because of legislative mandates and because the information collected, if appropriate, can be used to improve the validity and reliability of TCM evaluation methodologies.

Overall, the review of TCM evaluation methods and discussion of TCM monitoring programs yielded the following conclusions: 1) all TCM evaluation methods have advantages and limitations, and none can evaluate the air quality impacts of all the TCMs identified in the Clean Air Act Amendments (CAAAs) of 1990; 2) sketch-planning methods hold the most promise for cost-effective TCM impact evaluation given the level of input data available; 3) there are at least two factors which significantly influence the results of current TCM evaluation and require more consideration; and 4) a properly designed TCM monitoring program is necessary to meet legislative mandates, and to collect data that can be used to improve current TCM evaluation methods.

In general, the research described herein supports the implementation of a nationwide standardized data collection and monitoring program, and the study and improvement of current TCM evaluation methods. New or altered TCM evaluation methods may be necessary to account for the critical issues identified in this report. Evaluation methods that consider more of the TCMs that could be implemented are needed. In addition, this report recommends more research into the influences and estimation of TCM participation rates, and the evaluation of interactions among TCMs implemented at the same time.

CHAPTER I

INTRODUCTION

BACKGROUND

The Clean Air Act Amendments (CAAAs) of 1990 and the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 had a major impact on the transportation planning process in the United States. The mandates of the CAAAs and the Congestion Mitigation and Air Quality (CMAQ) Improvement Program established in ISTEA require careful consideration of the air quality impacts of transportation facilities and services. The influence of these mandates has been especially apparent in areas that have been designated as nonattainment in the CAAAs.

Sixteen general categories of transportation control measures (TCMs) are identified in the CAAAs. These measures can be applied to either the supply or demand sides of a transportation system in order to help the area improve its air quality. Their implementation is required in areas the CAAAs have designated as serious or extreme ozone nonattainment, and/or serious, severe, or extreme carbon monoxide nonattainment. The sixteen TCM categories are the following:

- Trip Reduction Ordinances,
- Employer-Based Transportation Management Programs,
- Work Schedule Changes,
- Areawide Rideshare Incentives,
- Improved Public Transit,
- High-Occupancy Vehicle Facilities,
- Traffic Flow Improvements,
- Parking Management,
- Park-and-Ride/Fringe Parking,
- Bicycle and Pedestrian Programs,
- Special Events,

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- Vehicle Use Limitations/Restrictions,
- Accelerated Retirement of Vehicles,
- Activity Centers,
- Extended Vehicle Idling, and
- Extreme Low-Temperature Cold Starts.

Each TCM category includes a number of measures that can be applied in a particular situation. Appendix A lists the specific measures included within each TCM category.

Houston/Galveston is the only nonattainment area in Texas required to implement TCMs. The Dallas/Fort Worth, Beaumont/Port Arthur, and El Paso nonattainment areas must only consider the implementation of TCMs if they cannot demonstrate reasonable progress toward meeting the CAAAs mandates. Stephenson and Dresser addressed the transportation-related requirements of the CAAAs for each of these areas (1).

The CAAAs and ISTEA (CMAQ program) require the evaluation and/or monitoring of TCM emission impacts. The CAAAs specifically require the estimation of TCM emissions, and the use of CMAQ program funds is contingent upon the same type of evaluation. The emission impacts of a TCM must also be evaluated in order for it to be included within, and to check its conformity with, the State Implementation Plan. Compliance with the milestones designated in the CAAAs also requires the monitoring of TCM emission impacts. Serious ozone nonattainment areas (e.g., Houston/Galveston) must initiate a monitoring program to ". . .demonstrate whether current aggregate vehicle mileage, vehicle emissions, and congestion levels are consistent with those assumed for the area's demonstration of attainment" (2).

The evaluation and monitoring of TCM emission impacts is very important. When properly implemented, the results of these processes can be used to analyze the effectiveness of a planned or implemented TCM, expand the TCM impact database compiled as part of this project, improve the reliability and validity of TCM evaluation methods, and allow more effective and knowledgeable decisions about the implementation of TCMs.

The evaluation and monitoring of TCMs are interrelated. For example, an improvement in the quality of the data collected by a monitoring program may be used to improve the validity of TCM evaluations tools. Monitoring data can be used to alter default input values in evaluation methods and subsequently represent local conditions more closely. In turn, an improvement or upgrade in evaluation methods may result in more relevant data being collected. Thus, the interrelationship of the evaluation and monitoring of TCMs may result in the improvement of both processes.

PROBLEM STATEMENT

The evaluation and monitoring of TCM emission impacts are important and interrelated tasks that metropolitan planning organizations (MPOs), state departments of transportation, or other responsible agencies in urban areas must accomplish. Unfortunately, the TCM evaluation methods that are currently available are often incapable of accurately or effectively estimating the emission impacts of a TCM. In addition, due to a lack of data on the impacts of implemented TCMs, the results they produce are rarely verified or validated.

The assessment of TCM evaluation methods that is summarized in Chapter II uncovered two issues critical to the improvement of these methods. The first issue is the estimation of TCM participation rates—e.g., the number of people who would carpool if a ridesharing program were implemented or who would shift from auto to transit if a transit improvement were implemented. Estimated emissions benefits are highly sensitive to the participation rates assumed in evaluations. Unfortunately, it is difficult to estimate participation rates accurately prior to implementation of a TCM. The second critical issue is estimating emissions benefits when programs of multiple TCMs are implemented. Measures may be interrelated, and the benefits of a particular TCM may be different when implemented as part of a program than if implemented individually. Current methods generally ignore these interrelationships. Chapter III explores these issues in more detail.

The TCM evaluation methods and tools currently used, and the validity and reliability of their outcome, could be improved in the future by the implementation of properly designed and effective TCM monitoring programs. The availability of a nationwide database on the

characteristics and impacts of implemented TCMs would also be invaluable. A database of this type was started as part of this project, and is included and discussed in Texas Transportation Institute (TTI) Report 1279-6, *The Use and Evaluation of TCM Measures (3)*.

OBJECTIVES/SCOPE

The primary objective of the research documented in this report was to investigate the state-of-the-art capabilities of current TCM impact evaluation and monitoring approaches. The study included a review of the advantages and limitations of three TCM evaluation methodologies, and the identification and analysis of two critical issues which significantly influence the results of TCM evaluations. The issues identified include the estimation of TCM participation rates, and the evaluation of the emission impacts when more than one TCM is implemented. Finally, the general content and components of a properly designed TCM monitoring program were identified, and the monitoring programs of four specific TCMs designed. A framework was constructed to monitor the impacts of transit plazas, intersection improvements, ridesharing programs, and park-and-ride lots. Specific case studies for the first two TCMs were designed, but programs for the other two were more general in nature.

This report is organized into five chapters. The first chapter provides a general overview of why the evaluation and monitoring of TCM impacts have become increasingly important. Chapter II is a summary of the advantages and limitations of the TCM evaluation methods currently available. Chapter III is a discussion of two critical issues which currently have a significant influence on the accurate evaluation of TCMs. Chapter IV describes the general components of an effective TCM monitoring program, and also discusses the approach which should be taken to monitor TCMs. Finally, Chapter V presents the conclusions and recommendations reached from the review and investigation of TCM evaluation methods, the issues that limit their capabilities, and TCM monitoring programs.

Ten other reports have also been produced as part of this project, and should be referenced for a more detailed discussion of the subjects mentioned in this summary document. These reports are:

- *An Outline of Transportation-Related Requirements for Compliance with the Clean Air Act Amendments of 1990 (1);*
- *User's Guide for the Texas Mobile Source Emission Estimation Software: PREPIN, POLFAC5A, COADJ, IMPSUM, and SUMALL (4);*
- *State-of-the-Practice Report on Mobile Source Emissions Models (5);*
- *State-of-the-Practice Report on Mobile Source Emissions Models (Revised) (6);*
- *The Sensitivity of the UAM to Mobile Source Emissions (7);*
- *A Critical Analysis of Sketch-Planning Tools for Evaluating the Emission Benefits of Transportation Control Measures (8);*
- *The Use and Evaluation of Transportation Control Measures (3);*
- *TCM Analyst 1.0 and Users Guide (9);*
- *An Annotated Bibliography of Transportation-Related Air Quality Documents: 1989-1994 (10);* and,
- *Texas Mobile Source Emissions Software Version 2.0: User's Manual (11).*

CHAPTER II

TCM EVALUATION METHODS

The accurate estimation, evaluation, and documentation of TCM emission impacts is required by the CAAAs and for the use of CMAQ program funds. In fact, the CAAAs contain detailed requirements for the estimation of these impacts, and for the evaluation of a TCM's conformity with the State Implementation Plan. Only the Houston/Galveston area in Texas is required to include TCMs in its transportation improvement plan, estimate their impacts, and evaluate their conformance. The other nonattainment areas in Texas (i.e., Dallas/Fort Worth, El Paso, and Beaumont/Port Arthur) are only encouraged to plan and implement TCMs if they cannot demonstrate reasonable progress toward meeting the CAAAs mandates. However, all of the nonattainment areas in Texas have included TCMs in their transportation improvement plans. Therefore, the MPOs in these areas must adopt a TCM evaluation method. Alternative methods include the use of comparative empirical data, network-based modeling, and sketch-planning tools. This chapter summarizes the advantages and limitations of the TCM impact evaluation methods and tools currently available. A more detailed discussion is found in TTI Report 1279-6, *The Use and Evaluation of Transportation Control Measures (3)*.

COMPARATIVE EMPIRICAL DATA

A Manual of Transportation-Air Quality Modeling for Metropolitan Planning Organizations suggests the use of empirical data from the observed performance of TCMs implemented in similar locations as one method of impact analysis by (*12*). This method applies TCM emission or travel impacts experienced in similar areas to locally implemented programs. The major advantage to this method is its simplicity. However, this simplicity is also its major disadvantage, and the limited value of this method must be kept in perspective.

There are several limitations to the use of comparative empirical data as a TCM evaluation method. First, the area from which the empirical data are taken must be similar enough to the local area for comparable results to be expected from the implementation of

the TCM. Second, the accuracy and reliability of the data that are used must be scrutinized and validated. Third, published data on TCM impacts are limited. Finally, public and private agencies interested in the evaluation of TCMs are unlikely to accept the results of an analysis method based solely on the use of experiences from another region.

NETWORK-BASED MODELING

This approach to TCM evaluation includes network-based traffic simulation and travel demand models. The use of these modeling tools has been recommended for TCM impact evaluation, and they are generally preferred over methods involving manual calculations or spreadsheet analysis when the number and complexity of TCMs to be evaluated is large (*12, 13*). These models are usually large, complex programs whose proper use requires considerable expertise. In addition, the use of these models to evaluate the regional impacts of TCMs poses technical challenges, because they are not typically designed for this type of analysis, and neither traffic simulation nor travel demand models can evaluate TCMs directed at controlling emissions from off-highway vehicles. The advantages and limitations of these models are discussed in the following paragraphs.

Traffic Simulation Models

TCMs aimed at improving traffic flow conditions can be reasonably evaluated by the use of traffic simulation models. Traffic simulation models have several advantages over other TCM evaluation tools. First, a properly calibrated traffic simulation model can produce traffic flow conditions (i.e., vehicle speeds) that are generally comparable to actual field measurements. Second, traffic simulation models can explicitly represent most traffic control devices (e.g., traffic signals, stop signs, and yield signs); however, not all traffic simulation models are capable of simulating all traffic control devices. Third, traffic simulation models can represent the transportation network in more detail than a travel demand model. This advantage facilitates the simulation of traffic interaction between various levels of roadway (e.g., freeways and arterials). Fourth, many microscopic traffic simulation models can

generate vehicle speed profiles and idling times. A knowledge of these factors allows better estimation of mobile source emissions.

Despite these advantages, the use of traffic simulation models as a TCM analysis tool is not an obvious choice because they have several limitations. For instance, not all traffic simulation models are capable of simulating all traffic control devices, nor can they analyze all the TCMs identified in the CAAAs. Therefore, if a metropolitan area is considering implementation of several TCMs it may have to use several different traffic simulation tools. Such an analysis would require considerable time and resources.

Traffic simulation models are not responsive to shifts in travel demand. These models use traffic volumes that are provided by the analyst, but demand patterns change over time due to the influence of the implemented TCM(s). Therefore, traffic simulation models are not able to evaluate both the spatial and temporal demand impacts necessary to completely understand the air quality improvement potential of a TCM.

Generally, traffic simulation models have limited emissions estimation capabilities. In fact, some traffic simulation models do not provide emissions estimates, and those that do often use outdated emissions data that are not specifically applicable to the characteristics, vehicle-miles-traveled (VMT), or vehicle fleet mixture of the local area.

Finally, one of the most significant limitations to the use of network-based traffic simulation models, at least from the point of view of the analyst, is the considerable amount of calibration they require to obtain reasonable estimates of traffic operations. For example, one traffic simulation model has almost 20 embedded parameters that can be changed at the user's option in order to calibrate the model to local conditions. This is one disadvantage to the use of these models for TCM evaluation.

Travel Demand Models

Many metropolitan areas develop travel demand models for regional planning purposes. The availability of these models is one advantage to their use as a TCM evaluation tool because no additional modeling effort is necessary except for that required for the estimation of regional mobile source emission impacts. Travel demand models can also

redistribute vehicular demand on a network due to the traffic flow improvements produced by the implementation of a TCM. Traffic simulation models do not have this capability.

Travel demand models can analyze the impact of most TCMs, and are frequently suggested as the method to use for the evaluation of TCMs that modify trip demand dimensions (e.g., frequency, mode, route). For example, they can represent TCMs involving transit extensions, HOV lanes, parking cost changes, and toll changes. However, other TCMs, including the implementation of bicycle facilities, rideshare programs, and traffic flow improvements, may be represented within the model only indirectly through changes in surrogate variables (e.g., increases in travel time or cost) (13). Unfortunately, representing TCMs through this indirect means is subjective because the relationship between the actual variable and its surrogate is generally difficult to quantify.

There are several additional limitations to the use of travel demand models for TCM impact evaluation. One disadvantage is their scale. Traditional travel demand models are designed to study the regional and corridor level impacts of major infrastructure developments. The scale of TCM impacts, on the other hand, is generally small in terms of area and shifts in travel demand. Therefore, the scale of regional travel demand models may be too gross for TCM impact evaluation.

In addition, the speeds estimated by travel demand models are actually impedance measures used for traffic assignment purposes. They are not intended as direct estimates of actual speeds. Therefore, the output of these models does not represent the actual variations and magnitude of the speeds and densities on those links. In fact, it is common for even the best procedures to make estimation errors of over 30 percent on link volumes and over 50 percent on speeds (14). The magnitude of these errors by themselves greatly exceeds the size of the travel impacts of most TCMs, and significantly limits the ability of these models to accurately estimate the emission impacts of TCMs.

One additional disadvantage to the use of travel demand models is that they can only evaluate those TCM activities that uniformly alter modal availability or change the time and cost of a travel mode over all the users of a particular trip class (e.g., all service employees).

Therefore, shifts in demand due to employer-based transportation management programs, for example, cannot be predicted by travel demand models.

SKETCH-PLANNING TOOLS

Sketch-planning tools are estimation techniques that use either manual or computerized methods to predict the impacts of TCMs. They typically use the data generated by the travel demand modeling process and combine it with the characteristics of a TCM to predict its travel and emission impacts. One of the advantages of these tools is their relative simplicity. A disadvantage is that they have not been validated, and the accuracy of their results is unknown.

Some sketch-planning tools recently developed include the TDM Evaluation Model (TDM Model) developed by the COMSIS Corporation, TCM Tools developed by Sierra Research, Inc. and JHK & Associates for the San Diego Association of Governments (SANDAG), and a methodology developed by Systems Applications International (SAI) for the Environmental Protection Agency (EPA). In addition, a computerized spreadsheet version of the SAI method, called TCM Analyst, was created as part of this study (9). The advantages and limitations of these sketch-planning tools are summarized in the following paragraphs.

TDM Model

In general, the TDM Model procedure is based on a disaggregate logit mode choice model (i.e., the pivot point model), but the developer of the method has also provided look-up tables based on empirical data for TCMs that cannot be analyzed using this approach (15). The model estimates changes in vehicle trips, VMT, and modal split resulting from demand management measures.

One advantageous characteristic of the TDM Model is that the default coefficients of its logit equation are based on values from approximately 20 metropolitan areas of varying location, character, and size. Therefore, these default coefficients are national averages, and the model can be used in all regions of the United States. These default values can also be

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modified if more relevant local data are available. The TDM Model can also be used for regional, sub-regional, or site specific analysis of demand management TCMs, but it does require trip tables by purpose and mode, and highway distance matrices as input. Fortunately, the TDM Model has been structured to read the trip tables of the travel demand models used in most metropolitan areas.

A major disadvantage of the TDM Model is that it does not directly estimate emissions. However, its output can be used in other software to accomplish this task. Other disadvantages to the use of this model are that it can only analyze demand-based TCMs that affect commute trips, and its structure does not readily allow the addition of TCMs that are not already coded into the software.

TCM Tools

TCM Tools was developed to estimate the travel, emissions, and cost-effectiveness of several TCMs that may be used by regional planning and air pollution agencies in California (16). The inputs required by the model include baseline travel characteristics, TCM-specific parameters, and any underlying assumptions.

There are several advantages to the use of TCM Tools. It is simple to use and requires only a rudimentary knowledge of a common spreadsheet program. In addition, it requires only regional averages of certain travel variables rather than regional trip tables or highway distance matrices. Finally, the structure of the model allows new TCMs to be added when necessary.

The use of TCM Tools also has its limitations. First, the method relies heavily on default values based on empirical data from California; however, these default values can be changed if local data are available. The emission rates used by TCM Tools, on the other hand, which are based on California emission factor models, cannot be changed by the user to better represent the local situation. TCM Tools is applicable only on an areawide basis, and the regional information it requires is not always easily understood and can be difficult to obtain. For instance, TCM participation rates must be provided by the user, and this type of information is not always available or easy to estimate.

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SAI Method

The SAI method was developed for use by transportation planning agencies across the country (*17*). It is partially based on the concepts of TCM Tools, but does not estimate TCM cost-effectiveness. Overall, it provides a step-by-step procedure to estimate TCM impacts on trips, VMT, and vehicle speed.

The use of this tool for TCM impact evaluation has several advantages. For example, although its input variables are similar to TCM Tools, they are more understandable and provide a better description of the overall scope of a TCM. The method also requires fewer variables to describe the regional averages it uses. In addition, unlike TCM Tools, the SAI method does not require that its input variables be programmed or entered into any supporting software.

Two other advantages of the SAI method are that it is applicable in all regions of the country, and that its structure and methodology can be applied to additional TCMs. In addition, the SAI method can use any emission rates. It also provides a process to estimate the combined impacts (not necessarily additive) of several TCMs. Typically, TCMs are evaluated independently and selected for implementation based on individual performance.

The SAI method has some of the same limitations as TCM Tools. For example, both require TCM participation rates as input, and are both applicable only on an areawide basis.

TCM Analyst

As part of the research summarized in this report, the SAI method was enhanced. The resulting sketch-planning tool was programmed into a computer spreadsheet environment and called TCM Analyst. This tool has the ability to evaluate the regional travel and emissions impacts of more TCMs than the SAI method, and it can also calculate TCM cost-effectiveness.

There are several advantages to the use of TCM Analyst. First, the spreadsheet framework of this model allows the instantaneous evaluation of the effects produced by changes in its required inputs and assumptions. The spreadsheet structure of TCM Analyst also includes several tools that can lessen the work of an analyst. In addition, the enhanced

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methodology also attempts to account for the trip-making effects of the increase in automobile availability at the home of ridesharing program participants. As previously mentioned, TCM Analyst also has the capability to estimate TCM cost-effectiveness.

Unfortunately, TCM Analyst has some of the same disadvantages as other sketch-planning tools. For instance, its need for large amounts of regional travel data as input may force users of the methodology to rely heavily on assumptions and default values. Currently, TCM Analyst can evaluate only a limited number of TCMs, and the addition of other measures would be labor intensive because of the required formatting and internal programming. This model, like the SAI Method, is limited to regional analyses, and it cannot estimate point-specific or sub-area benefits of TCM implementation. However, the failure to analyze TCMs on all three levels is common for most sketch-planning tools, and the most relevant level of TCM air quality analysis is often regional.

Sketch-Planning Tools Summary

None of the sketch-planning tools discussed can evaluate the impacts of all the TCMs identified in the CAAAs. However, this limitation is not unique to sketch-planning tools.

All of the sketch-planning tools discussed are relatively straight-forward. This characteristic is one of their advantages over the use of network-based models. Unfortunately, sketch-planning tools also require extensive input data to establish baseline travel characteristics, and this requirement negates some of the advantages to their use. In fact, the TCM Tools, SAI method, and TCM Analyst requirement of TCM participation rates as input can reduce the applicability of these methods to a "what-if" analysis. This type of analysis is dependent upon the judgment of the analyst.

Finally, indirect changes in demand due to the implementation of a TCM are not considered sufficiently, if at all, by the methods. The SAI method does calculate latent demands caused by some TCMs, but does not use these calculations in its results.

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TCM EVALUATION METHODS SUMMARY

In summary, the emission impacts of a TCM can be evaluated using a number of methodologies. The TCM evaluation methods used in a metropolitan area are dependent upon the TCMs that it is considering for implementation. This is due to the fact that the TCM evaluation methods currently available are limited in their capabilities, and none of them can analyze all TCMs. The validity of the results produced by these methods is also limited due to the lack of data on the characteristics and impacts of currently operating TCMs. More of this type of data could improve the results of these methods.

In general, the use of empirical data comparison is not considered an adequate evaluation method, and a network-based modeling approach is regarded as too labor intensive. Sketch-planning tools, on the other hand, because of their simplified evaluation methods, are easy to use. These methods are also more appropriate to the levels of TCM impact data currently available. Therefore, it appears that the use of sketch-planning tools is currently the most promising approach for the evaluation of TCMs.

CHAPTER III

CRITICAL ISSUES IN TCM EVALUATION

Several critical issues must be considered in the evaluation and assessment of TCM regional impacts. The research done as part of this project has shown that two issues, in particular, currently have a significant influence on the accuracy and validity of TCM evaluation results. These two issues are the estimation of TCM participation rates, and the impact evaluation of TCM programs (i.e., the implementation of more than one TCM at a time). The methods used to complete these tasks, and the influence these issues have on the evaluation of TCM impacts, are discussed in this chapter.

TCM PARTICIPATION RATE ESTIMATION

The results produced by current TCM evaluation methods are particularly sensitive to the participation rate used. Unfortunately, the actual participation in a TCM is rarely known in advance and can be very difficult to estimate. This is especially true when the scope of a TCM, and therefore its potential participation rate, is dependent upon human behavior (e.g., mode choice decisions). In addition, it is commonly accepted that the participation rate of a TCM is influenced by how it is marketed. The following paragraphs discuss two methods of TCM participation rate estimation and the potential influence of marketing on these estimations.

Methods of Estimation

The strategy employed to estimate the participation rate of a particular TCM is dependent upon the evaluation method used. The use of comparative empirical data indirectly assumes that the participation rate of the TCM being evaluated is equal to that of the TCM for which the data were originally collected. Network-based approaches, on the other hand, model some TCM participation rates through the adjustment of surrogate variables such as travel time or cost. Finally, sketch-planning tools typically require TCM participation rates as a direct input. This section evaluates alternative methods available for improving the

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estimation of participation rates, including modeling, and the use of employee trip reduction (ETR) databases.

Participation Rate Modeling

The proper evaluation of a TCM requires an accurate estimation of its participation rate or demand. One approach is to use a TCM participation rate estimation model. The results of these models may be used to improve the participation rates estimated, and help fulfill the input requirements of most sketch-planning tools.

There are undoubtedly a large number of locally-developed models that can be used to estimate the participation rates of what are now called TCMs. However, the validity of the results produced by these models is dependent upon the data used for their development. Therefore, they have limited applicability unless they are spatially and temporally calibrated to local conditions.

For example, models to estimate the demand or utilization of vanpooling programs and park-and-ride lots (both TCMs) have been developed or calibrated from data collected in the Houston area (*18, 19*). First, a model was developed for the "ballpark" estimation of vanpooling demand (*18*). Guidelines were provided for the estimation of the number of vanpools per capita and per bus on a HOV lane. Second, data from Houston were also used to calibrate and develop several park-and-ride lot demand models (*19*). The existing models which were calibrated to local conditions included the Institute of Transportation Engineers (ITE) method, GOPARK, and GOPARK II. In general it was found that none of the calibrated models improved upon those specifically developed for the Houston area. In addition, both the vanpooling and park-and-ride documents specifically noted that the models developed for Houston may not be applicable in other areas (*18, 19*).

In current practice, participation rate estimation models are not used to provide input to TCM evaluation methods. A literature review and telephone conversations with practicing TCM evaluation professionals indicated that the use of locally collected data is currently the best approach to estimate TCM participation rates.

The estimation of accurate TCM participation rates, or the adequate calibration of an existing model, often requires large amounts of data. For this reason, many MPOs use data from other areas for the evaluation of TCM impacts.

Empirical Data Use

Another approach to the estimation of TCM participation rates is the use of empirical data. As previously discussed, a TCM database was initiated as part of this project, but a general lack of useful data was found (*3*). However, there is another significant source of data which has recently become more readily available. The mandates of the ETR program established in the CAAAs require all large employers (i.e., those that have at least 100 employees) in extreme and severe ozone nonattainment areas (e.g., Houston/Galveston) to collect and report the travel patterns and alternative mode preferences of their employees. This requirement applies to approximately 1,600 worksites in the Houston/Galveston area.

A database was created from approximately 1,200 ETR program plans submitted to the Texas Natural Resources Conservation Commission (TNRCC). These plans meet the CAAAs requirements by documenting the number of employee trips per week by mode (e.g., drive alone, carpool/vanpool, transit, and bicycle/walk). They also indicate the number of trips that are avoided by the implementation of a compressed workweek or telecommuting program. The usefulness of this database as a participation rate estimation tool was investigated.

The information contained in the ETR database pertains to the simultaneous implementation of more than one TCM (i.e., a TCM program). The employee travel mode distribution at a particular worksite is dependent upon the content of the TCM program implemented, worksite characteristics (e.g., location, number of employees, and work done) and area characteristics (e.g., access to transit and parking availability). An investigation of the travel mode distribution at worksites implementing identical TCM programs found that the average passenger occupancy (APO) levels at the site varied from 1.0 to 1.83. Further analysis of these worksites segmented by zip code and number of employees also showed a large variation in APO levels.

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In general, researchers concluded that the ETR database cannot currently be used to accurately estimate TCM participation rates. There are obviously other factors, possibly unmeasurable, which impact the APO levels at a worksite. Some possibilities include the current informal nature of ETR programs, and a lack of alternative travel mode information dissemination and publicity. The influence of these factors may grow smaller over time, but the impact of TCM marketing is currently uncertain. The following paragraphs discuss the effect of marketing on the participation rate of TCMs.

Marketing Impacts

It is commonly accepted that the marketing of TCMs significantly affects their participation rates and subsequent travel and emission impacts. However, the exact impact of marketing on the participation rates of a TCM is usually unsubstantiated and/or undocumented. In fact, the influence of marketing on the impacts of TCMs is almost completely based on professional judgment. It cannot be estimated using any of the TCM evaluation methods currently available.

Several studies have evaluated the effects of different marketing approaches on the use (i.e., participation rate) of public transit. The findings of these studies could contribute to the more accurate evaluation of TCMs related to improved public transit service. Unfortunately, the studies have produced inconsistent results. One study found that the marketing of public transit through direct mailings targeted at new residents was cost effective in attracting and retaining transit riders (20). However, another study found that neither the dissemination of transit service information nor its combination with free-ride coupons increased transit ridership (21). In fact, it has generally been concluded that in ". . .spite of the many claims made for both informational and promotional programs, there is little evidence that [either] measure brings any increase in ridership or system revenue" (22). Overall, the inconsistent results produced by the studies limit their usefulness.

There are several possible causes for the inconsistent results presented above and the general lack of research into the influences of marketing on the impacts of TCMs. First, many TCMs have only recently been implemented, and their participation rates may not have been

measured. Therefore, it is unlikely that the influence of marketing on these rates has been considered. Second, differentiation of the effects of marketing on TCM participation rates from the effects of other factors is difficult. Third, the measurement of marketing influences (both short-term and long-term) on the accurate evaluation of TCMs is not currently a top priority. Many of the other issues discussed in this report, particularly this chapter, are considered to be more important.

In summary, it can be assumed that the marketing of a TCM has a significant influence on its participation. However, the quantification of its actual effect is difficult to estimate. This factor contributes to the difficulties encountered in the estimation of TCM participation rates, and affects the validity of current TCM evaluation methods.

TCM PROGRAM IMPLEMENTATION

A second critical issue which must be considered in the evaluation of TCM impacts is the accurate estimation of TCM program impacts. It is typical for a metropolitan area to implement more than one TCM at a time (i.e., a TCM program) to maximize the potential air quality benefits of each measure. Unfortunately, there are a number of TCM combinations which may have the opposite outcome.

Table 1 is an example of the number and variability of TCMs that might be planned for implementation within a metropolitan area (in this case Houston/Galveston, Texas). Obviously, the estimation of the regional travel and emission impacts for each project listed, if possible with the evaluation methods currently available, would be complex and data intensive. An estimation of their combined regional impacts is even more difficult. In fact, there are currently ". . .no clear and unambiguous methodologies for predicting the combined impact of [transportation control] measures. . ." (23).

The study of TCM program evaluation has largely been limited to the qualitative categorization of the impacts of some TCM combinations (9, 13, 24). The interrelationships between the travel and emission impacts of individual TCMs can be negative, additive, or synergistic. A negative relationship between impacts occurs when the TCMs compete for a single market (e.g., telecommuting and ridesharing). An additive relationship, on the other

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Table 1. TCMs Identified in the Houston/Galveston 1995 TIP (25)

General TCM Category	Specific Project
Traffic Flow Improvements	Arterial Traffic Management Systems Signal Installation Signal Upgrades Signal Coordination Intersection/Roadway Widening and Improvements Motorist Assistance Program Grade Separation Accident Investigation Sites Highway Advisory Radio Port of Houston Access Intelligent Highway Systems
Areawide Rideshare Incentives	Vanpool Program Rideshare Computer
Improved High-Occupancy Vehicle (HOV) Facilities	HOV Lanes/Ramps HOV Interchange HOV Interconnectivity Program HOV Safety Enhancements
Employer-Based Transportation Management Programs	Employer Trip Reduction Program Education and Training Employer Trip Reduction Special Project
Improved Public Transit	Ozone Advisory Day Transit Program Downtown Transit Superstop Transit Control Facility Pedestrian/Transit Way Railway Station Renovation Bus Operating Facilities Transit Center/Streets Bus Shelters Advanced Scheduling System Automated Telephone Information System Geographic Information System/Automatic Vehicle Locator Trolley Extension Bus Annunciator Pilot Program Best Bus and Next Generation Bus Program
Park-and-Ride/Fringe Parking	Park-and-Ride Lots
Bicycle and Pedestrian Programs	Pedestrian/Transit Way Bike and Pedestrian Facilities

hand, occurs when TCMs do not compete for market share, and their individual impacts can be summed. Finally, a combination of synergistic TCMs results in an impact greater than the sum of the individual impacts. For example, a guaranteed ride home and ridesharing programs have a synergistic relationship.

The negative and additive relationships of several TCM combinations have been defined as part of the research documented herein (9). Figure 1 shows these relationships. They are based on information from the negative, additive, and synergistic relationships identified in two previously published documents (13, 24).

In addition to the identification of these relationships, researchers attempted to develop a methodology that accounted for the common assumption that the impacts of combined TCMs should be summed. The goal was to incorporate such a method into the TCM Analyst. However, the attempt was not successful, and it was concluded that sufficient data are not currently available to permit accurate quantification of the interrelationships among TCMs.

SUMMARY

This chapter has focused on two issues that must be considered in the evaluation of TCMs. The first issue discussed was the accurate estimation or modeling of TCM participation rates. These rates have a large influence on the predicted impacts of a TCM, but their estimation is difficult without the collection of local data. Unfortunately, very few metropolitan areas have the resources to collect such data. It is also commonly accepted that the magnitude of TCM participation is affected by how the measure is marketed. None of the TCM evaluation methods currently available account for the impact of marketing. The second issue discussed was the lack of a quantitative method to estimate TCM program impacts. The interrelationships between some TCM impacts have been qualitatively identified, but in practice they are generally only summed. The assumption of a additive relationship may not be true. Researchers concluded that there is currently not enough data to adequately quantify the interrelationships of TCMs.

	Telecommuting	Flextime	Compressed Work Week	Ridesharing	Transit Fare Decrease	Transit Service Increase	Transit Plazas	Parking Management	HOV Lanes	Traffic Signalization	Intersection Improvements
Telecommuting	■	-	-	-	-	-	-	-	-	-	-
Flextime	-	■	-	-	+	+	+	+	-	+	+
Compressed Work Week	-	-	■	-	+	+	+	+	-	+	+
Ridesharing	-	-	-	■	-	-	-	+	+	-	-
Transit Fare Decrease	-	+	+	-	■	+	+	+	+	-	-
Transit Service Increase	-	+	+	-	+	■	+	+	+	-	-
Transit Plazas	-	+	+	-	+	+	■	+	+	-	-
Parking Management	-	+	+	+	+	+	+	■	+	-	-
HOV Lanes	-	-	-	+	+	+	+	+	■	-	-
Traffic Signalization	-	+	+	-	-	-	-	-	-	■	+
Intersection Improvements	-	+	+	-	-	-	-	-	-	+	■

KEY
+ = Positive Relationship
- = Negative Relationship

Figure 1. TCM Interaction Matrix (*Adapted from 9*)

The two issues discussed in this chapter limit the validity, reliability, and accuracy of current TCM evaluation methods. The impact of these issues, therefore, must be considered when the results of a TCM evaluation are reported or reviewed. More research is necessary to better understand the effects of both issues.

The issues identified in this chapter also emphasize the need to collect more standardized data on the impacts of existing TCMs. This task can be more easily accomplished with properly designed TCM monitoring programs. The following chapter discusses monitoring programs for four TCMs.

CHAPTER IV

TCM MONITORING PROGRAMS

Better monitoring of implemented TCMs is needed. The information gathered from a properly designed TCM monitoring program can be used to help address the critical issues discussed in Chapter III, and to improve the validity and reliability of TCM evaluation methods.

This chapter presents general guidelines for monitoring TCMs. These guidelines identify the general objectives of a TCM monitoring program and specify what data should be collected. By way of example, the following paragraphs also discuss the monitoring programs for four specific TCMs (i.e., improved public transit , traffic flow improvements, areawide rideshare incentives, and park-and-ride/fringe parking).

GENERAL GUIDELINES

Overall, monitoring programs should be designed to measure the traffic and environmental characteristics that are modified by the TCM. Unfortunately, this may not be possible in many cases. TCMs, for example, typically have regional travel and/or emission impacts. It may not be possible to measure directly these regional impacts due to the complexity and costs, both of time and resources, involved in this task. Therefore, it may be necessary to measure surrogate variables, such as traffic speed or volumes, to reach conclusions on the effectiveness of a TCM.

In general, the development of an effective TCM monitoring program requires three steps. The first step involves the determination of objectives for each evaluated and/or implemented TCM. These objectives should be translated into hypotheses that can be tested statistically.

The second step is to prepare a data collection plan to measure the effects of each TCM. For example, if a flextime program is planned for an employment center, the data collection plan would include a study of employee arrival times to determine the impact of their shifting commute periods. The data collection plan should also control for the effect of

extraneous variables. For example, temporal variability in traffic volume data can be controlled by scheduling the pre- and post-TCM implementation data collection efforts to occur on the same days of the week and during the same period of the year. Automatic traffic recorder data may be used to identify trends in traffic volumes and/or travel patterns. The identification of these extraneous variables allows the analyst to control for them in the monitoring program.

The third step is the establishment of statistical procedures to determine whether the measured changes are significant, or simply the result of random variations. A statistical analysis of the data collected in step two to test the hypothesis defined in step one is an important element of an effective TCM monitoring program.

These steps are the basic components of an effective TCM monitoring program. The results of a monitoring program that incorporates these steps can be very useful. The impacts of a TCM can be effectively evaluated, and the data collected can be used to validate and/or improve the TCM impact estimation capability of the evaluation methods currently available. By way of example, the following paragraphs describe the monitoring programs for four TCMs.

SAMPLE TCM PROGRAMS

To illustrate how the general guidelines might be implemented for specific TCMs, sample monitoring plans are presented for four measures: improved public transit (transit plazas), traffic flow improvements (intersection improvements), areawide rideshare incentives (ridesharing), and park-and-ride/fringe parking (park-and-ride lots). These are some of the more commonly implemented TCMs in Texas. Detailed case studies are provided for transit plazas and intersection improvements. The monitoring programs for ridesharing and park-and-ride lots, on the other hand, are discussed only in general terms.

Improved Public Transit: Transit Plazas

A monitoring program was designed for a public transit improvement in El Paso, Texas. The monitoring program considered the impacts of the City Hall Transit Plaza which

is currently in preliminary engineering. The project is included within the El Paso transportation improvement program (fiscal years 1995-1999), and it is planned as a major transit plaza with bus pullouts, turn-arounds, shelters, benches, lighting, landscaping, and a transit information center. Figure 2 shows the location of this proposed transit plaza. The proposed monitoring program may be used as a reference in the design of programs for similar TCMs.

TCM Objective

The objective of the proposed transit plaza is to increase the amount of transit access to downtown El Paso. The construction of the transit plaza will be combined with additional rubber-tired trolleys for CBD trips to meet this objective. Eventually, the transit plaza will also be the final destination of the west El Paso express transit routes. The transit plaza will provide a central location for these transit riders to transfer to the intra-downtown trolleys, and provide access to the major employment, governmental, and shopping centers in the downtown area. Recreational trips are unlikely to be influenced by the existence of express bus service.

Researchers have identified several hypotheses about the possible effects of the El Paso transit plaza construction. Table 2 shows the hypotheses that should be statistically evaluated.

Data Collection Plan and Controls

A large amount of data should be collected in order to measure the effectiveness of the transit plaza in fulfilling its objective. In general, data should be collected around the transit plaza area on three mid-week days: Tuesday, Wednesday, and Thursday. Specifically, information on vehicle and person traffic volumes/patterns, average vehicle occupancy, transit loadings, and travel times should be gathered. Data should be collected before and after the transit plaza is constructed.

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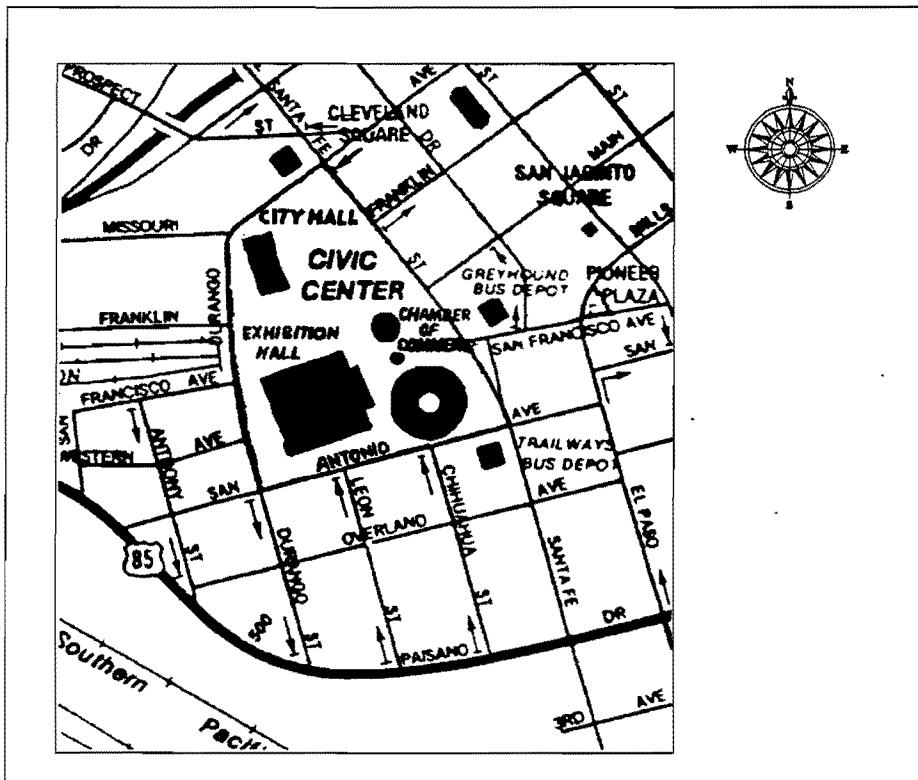
Figure 2. Map of El Paso Transit Plaza Location

Table 2. Transit Plaza Hypotheses

Measured Variable	Hypothesis[1]
Vehicle Volumes (Overall)	$X_b > X_a$
Transit Volumes	$X_b < X_a$
Passenger Car Volumes	$X_b > X_a$
Person Volumes (Overall)	$X_b = X_a$
Transit Vehicle Occupancy	$X_b < X_a$
Passenger Car Occupancy	$X_b > X_a$
Travel Times	$X_b > X_a$

[1]X_b = mean of variable before transit plaza construction.
X_a = mean of variable after transit plaza construction.

Information on traffic volumes and patterns should be gathered on all roadways that access the transit plaza area (see Figure 2):

Santa Fe Street	North of Missouri Avenue
Durango Street	South of San Antonio Avenue
Leon Street	South of San Antonio Avenue
Chihuahua Street	South of San Antonio Avenue
Santa Fe Street	South of San Antonio Avenue
Missouri Avenue	East of Santa Fe Street
Franklin Avenue	East of Santa Fe Street
Main Street	East of Santa Fe Street
San Francisco Avenue	East of Santa Fe Street
Missouri Avenue	West of Durango Street
Franklin Avenue	West of Durango Street
San Francisco Avenue	West of Durango Street
Western Avenue	West of Durango Street
San Antonio Avenue	West of Durango Street

Traffic volumes should be collected from Monday at 12:00 PM to Friday at 12:00 PM during a typical week. The volumes should be segmented into 15 minute intervals for the entire week and used to determine the volume of vehicles entering and exiting the transit plaza area at different times of the day (especially during the AM and PM peak travel periods). The volume counts can also be used to identify where the majority of the traffic enters and/or exists the area.

Person volume and travel patterns should be estimated through sample measurements of average vehicle occupancy (AVO), the results of the automatic traffic recorder (ATR) counts, and the transit load data discussed later in this report.

AVO should also be measured around the transit plaza area. This information can be used to estimate changes in person movement due to its construction. Information that should be collected includes the number of passengers per vehicle and the type of vehicle. The AVO samples should be collected during three time periods: AM peak, off-peak, and PM peak. A sample schedule to accomplish this task in one week is shown below.

Tuesday	Wednesday	Thursday
7:30 AM - 8:30 AM	7:30 AM - 8:30 AM	9:30 AM - 11:00 AM
9:30 AM - 11:00 AM	4:30 PM - 5:30 PM	4:30 PM - 5:30 PM

The change in transit loading/unloading should be evaluated at the major bus stops in the area. In this case study there are three major bus stop locations: west of the City Hall on Durango St., Franklin Ave at Santa Fe Ave, and east of the Chamber of Commerce on Santa Fe St. (see Figure 2). The loading and unloading checks should be performed on Tuesday, Wednesday, and Thursday from 7:00 AM to 6:00 PM for all bus routes stopping at the noted locations. Transit vehicle occupancy should also be estimated at each stop.

Travel times on the main routes into and out of the City Hall area should also be sampled. Increases in transit access should increase transit ridership and decrease travel times for non-transit vehicles. The floating car method is one method of collecting travel time data. Travel times should be collected along Santa Fe Street , Durango Street , and the Missouri Avenue-Durango Street corridor to evaluate the effects of the El Paso transit plaza construction. Travel data collection routes should include the boundaries of the study area, as well as street sections outside of and connecting to the boundary streets. For example, the travel time route for the Durango Street-Missouri Avenue corridor should be bounded by Paisano Drive and Mesa Street. Significant changes in travel times were not expected to occur on the south side of the City Hall area on San Antonio Avenue.

All the travel time runs begin and end at the intersection of Santa Fe Street and Corto Way. They should be collected on Tuesday, Wednesday, and Thursday during travel periods which are similar to the times the previously discussed data was collected (i.e., AM peak, noon, off-peak, and PM peak).

Data collection controls are necessary to increase the validity of the information gathered and the statistical tests that are applied. In El Paso, for example, data should not be collected when special events occur in the City Hall area. The vehicular and passenger volumes collected would not represent a typical situation.

The traffic volumes recorded by ATR stations in the El Paso region should be reviewed to identify any significant volume changes regionwide. These changes can then be taken into account when recording, evaluating and testing the traffic volumes counted in the downtown area.

Control data should also be checked with respect to transit ridership. Total transit ridership information on non-affected routes should be collected and examined for any significant changes. These changes, like that of traffic volumes, can then be taken into account when evaluating and testing the transit ridership volumes measured in the transit plaza area.

Finally, control is necessary with respect to the after-construction data collection. The after-study should be undertaken, if possible, at the same time of the year (month, week, days of week) as the before-study was undertaken. This timing should account for seasonal, monthly, and daily variations of traffic volumes and travel patterns. If the after-study cannot be conducted at the same time of the year as the before-study, seasonal, monthly, and daily adjustment factors should be used.

Statistical Procedures

One of the most important steps in a TCM monitoring program is identification of hypotheses and statistical procedures to evaluate the significance of measured changes from the implementation of the TCM. The hypotheses made for this case study are identified in Table 2. They should be tested through the use of standard parametric and non-parametric hypothesis testing procedures.

Transit Plaza Monitoring Program Summary

The previous discussion is an example of what should be contained in a properly designed TCM monitoring program for a transit plaza construction project. The important components of TCM monitoring programs are the identification of the project objectives, the design of a data collection plan, the recognition of what data control procedures should be followed, and the establishment of the hypotheses to be tested and statistical test to be used. The specifics discussed in this section may be used as a reference for other similar TCMs.

Traffic Flow Improvements: Intersection Improvements

Traffic flow improvements include TCMs such as intersection and arterial street geometry improvements, signal retiming, and the installation of advanced traffic control systems. These TCMs have been used as a means of reducing congestion and air pollution in several nonattainment areas.

Intersection geometric improvements are the focus of the monitoring program discussed in the following paragraphs. More than 200 sites have been proposed for geometric improvements in Dallas/Fort Worth over a span of seven years. The monitoring program described in this section of the report is designed to monitor the effects of five proposed intersection improvements. Table 3 lists these intersections and their proposed improvements. Similar monitoring programs can be applied to comparable intersection improvement sites.

Table 3. Intersection Improvement Study Sites

Major Street	Minor Street	Proposed Improvements
Inwood Road	Maple Avenue	Addition of left-turn lane on both approaches of Maple Avenue
Inwood Road	Cedar Springs Road	Addition of left-turn lane on both approaches of Cedar Springs Road
Lemmon Avenue	Inwood Road	Widening all four approaches to expand from one to two left-turn lanes
Lemmon Avenue	Oak Lawn Avenue	Widening eastbound Oak Lawn Avenue to expand from one to two left-turn lanes
Greenville Avenue	University Boulevard	Addition of left-turn lane on both approaches of University Boulevard

TCM Objective

In general, the objective of the intersection improvements identified in Table 3 is to reduce mobile source emissions by reducing vehicular travel times and delays. In the case of the five study intersections, the expected reductions in both travel time and delay would be

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due to the separation of turning vehicles from the through traffic by the addition of left-turn lanes.

The regional air quality effects of these TCMs are not easily measured or monitored; however, data can be collected on traffic volumes, stopped delay, and travel times. The regional air quality impacts of these improvements can be estimated through the use of appropriate models and emission factors.

Several hypotheses should be tested to evaluate whether the implemented intersection improvements have met or at least advanced toward their declared objectives. Table 4 identifies the hypotheses that should be statistically evaluated to test the significance of the measured changes in data collected (e.g., travel times).

Table 4. Intersection Improvement Hypotheses

Measured Variable	Hypothesis[1]
Turning Volumes	$X_b < X_a$
Stopped Delay	$X_b > X_a$
Travel Times	$X_b > X_a$

[1]X_b = mean of variable before intersection improvement.
X_a = mean of variable after intersection improvement.

Data Collection Plan and Controls

MPOs and other responsible agencies need to collect information on several operational characteristics in order to evaluate the effects of intersection improvements. Specifically, data on vehicle turning movements, stopped delay, and travel times need to be monitored. The agencies should collect this data at locations that are expected to be affected by the intersection improvements of interest. Data should be collected before and after the improvements.

Data on turning movements provide information on the changes in traffic demand that may occur due to intersection improvements, and is also necessary for estimating delay. Peak period turning movement counts at five minute intervals should be made on all approaches

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of each intersection. Peak travel periods are from 7 AM to 9 AM in the morning, and from 4 PM to 6 PM in the evening. The peak periods may vary between intersections and cities. Turning movement data should be collected on at least two typical weekdays (e.g., Tuesday, Wednesday, or Thursday). If several days of turning movement data are collected, meaningful statistical analysis can be performed to determine the significance of any variations in the volumes. Both morning and afternoon peak period data should be collected. Standard traffic data collection methods are described in the ITE *Manual of Transportation Engineering Studies (26)*.

Data also should be collected to evaluate the expected changes in stopped delay. Stopped delay information should be recorded at 15-second intervals for all approaches of each intersection. Data should also be collected on at least two typical weekdays during both peak periods. Preferably, the stopped delay data should be collected at the same time as turning movement data.

Several travel time samples (at least five for each peak period) should also be collected for each approach of a study intersection. As noted above, these data should also be collected on at least two typical weekdays during both morning and evening peak periods.

The travel time of interest in the case of intersection improvements is that between the center of the adjacent upstream signalized intersection and the center of the subject intersection (on each approach). The assumptions here are that the travel time improvements will only be experienced by traffic traveling between the two adjacent intersections, and that there is no effect on the travel times of vehicles beyond them. This assumption is necessary to estimate the vehicle-miles-of-travel affected by the speed changes due to intersection improvements.

Several factors should be controlled as much as possible when traffic volume, stopped delay, and travel times are collected. Care should be taken to collect data only on days with acceptable weather conditions. Adverse weather conditions, such as rain, ice or snow, can produce non-typical driving conditions. Collection of data under these conditions should be avoided.

The controls used to collect valid data for the transit plaza case study described previously should also be exercised with respect to intersection improvements. The data collected before and after the intersection improvements should be during the same months of the year. This will balance any seasonal variations in traffic volumes. Any special events or construction in the city that may effect the operation of study intersection should also be taken into account. Care should also be taken to ensure that all the proposed intersection improvements, such as signal retiming, placement of traffic control devices and detectors, are completed before the after-improvement data is collected. Geometric improvements, without the implementation of signal retiming plans to take advantage of the improvements, may not show any significant benefits.

Statistical Procedures

If enough data are collected for these variables, the hypotheses listed in Table 4 can be tested (i.e., the means compared) using standard parametric and non-parametric techniques. However, it is more typical to have situations where the amount of data collected is not large enough for any type of meaningful statistical test to be performed because resources (e.g., time or money) to collect the required amount of data may not be available. In these cases, standard traffic engineering practices and judgment should be employed to determine the significance of the difference between the pre- and post-improvement data.

Intersection Improvement Monitoring Program Summary

The objectives of the case study intersections described are fairly typical of intersection improvement TCM projects. The implementation of a monitoring program similar to the one described should allow the effective evaluation of whether these objectives have been furthered by the intersection improvements.

The geometric intersection improvement case study monitoring program described in this section identifies the type and amount of data that needs to be collected. This type of program can be used for other similar traffic flow improvement TCMs. Similar data would need to be collected for other traffic flow improvements like signal retiming. After the data are collected it can be used to model the emissions impacts of traffic flow improvements.

Ridesharing

The following paragraphs describe a typical monitoring effort for a ridesharing program. They illustrate how the three steps in the general guidelines can be used as reference for the proper design of a ridesharing monitoring program.

TCM Objective

Ridesharing can be implemented as a region-wide or a site-specific program. The objective of either program is to increase the AVO for the region or the site. This is achieved through implementation of carpool/vanpool programs often aided by computer-based rideshare matching. Several other measures, including guaranteed ride home, preferential parking, flextime, park-and-ride facilities, and HOV lanes, are generally implemented to encourage commuters to rideshare. Since all these measures contribute to ridesharing, monitoring a ridesharing program is a means of measuring the combined impact of these individual measures.

Several hypotheses can be made about the effects of a ridesharing program. Table 5 shows these hypotheses.

Table 5. Ridesharing Hypotheses

Measured Variable	Hypothesis[1]
Person Volumes (Overall)	$X_b = X_a$
Vehicle Volumes (Overall)	$X_b > X_a$
Travel Times	$X_b > X_a$

[1]X_b = mean of variable before ridesharing program.
X_a = mean of variable after ridesharing program.

The primary hypothesis for ridesharing is that average AVO will increase. AVO is a function of the number of persons and vehicles. If the number of people in carpools/vanpools and using transit increases, the AVO will increase. As a result of increased AVO, speeds on affected corridors or routes should increase.

Data Collection Plan and Controls

Rideshare programs can be either regional, sub-regional (e.g., downtown or major employment centers) or site specific. Based on the nature of the program, the particular area of program influence should be targeted for data collection.

Detailed information on the commute behavior of employees in the region or sub-region of interest should be collected in order to measure accurately the ridesharing activity (e.g., AVO). Large employer sites (>100 employees) in several ozone nonattainment areas, including the Houston-Galveston area in Texas, developed and administered surveys and questionnaires to comply with the employee commute options program mandated by the CAAA. These surveys resulted in detailed information on the commute trip-making behavior of the employees for a typical week. Much of the data necessary for monitoring employee ridesharing activity is available from the plans that employers submitted to the TNRCC. Similar surveys should be conducted for all worksites in a region or sub-region to determine the overall commute patterns for all employees.

MPOs and other responsible agencies should also collect data on the travel times along affected corridors. Major arterials and freeways traveled by commuters to the region or sub-region should be monitored. The reduction in vehicle trips may result in increased speeds on the affected arterials and freeways if traffic does not redistribute itself in the corridor. Travel time data should be collected, in accordance with the ITE specifications, for at least two typical weekdays.

Surveys, questionnaires, and travel time measurements should be administered during typical weeks, and not during major holiday seasons or at the beginning of a school year. Data should only be collected on days with acceptable weather conditions. Adverse weather conditions, such as rain and ice or snow, and special events can produce non-typical driving conditions. Collection of data under these conditions should be avoided.

Statistical Procedures

The hypotheses that can be made for ridesharing programs are identified in Table 5. They should be tested through the use of standard parametric and non-parametric hypothesis testing procedures.

Ridesharing Monitoring Program Summary

The previous paragraphs discussed a monitoring plan for rideshare programs. Unlike the two previous examples, no specific site was used to demonstrate the plan. The data collection is expected to remain similar irrespective of the site. Some plan components such as the specific areas and roadways affected by a park-and-ride lot should be identified based on the location. It should be noted that ridesharing is the result of several individual measures like HOV lanes, computer matching, carpool/vanpool subsidies, preferential parking, flextime, etc. The changes in AVO are a combined effect of all the individual measures implemented in the region/sub-region.

Park-and-Ride Lots

Park-and-ride lots are common additions to transit systems and ridesharing programs. Their proper placement is intended to encourage the use of transit services and the formation of carpools/vanpools. Typically these lots are adjacent to major freeways and/or have connections to an HOV system.

TCM Objective

The primary objective of a park-and-ride lot is to increase the AVO of the transportation corridor within which it is located. This objective is achieved through providing a location, usually adjacent to major freeways and HOV facilities in the fringe areas of a metropolitan area, where solo drivers can park their vehicles and carpool, vanpool, or use transit to complete their commute trip.

Several hypotheses should be tested with respect to park-and-ride lots. Table 6 shows these hypotheses.

The primary hypothesis for park-and-ride lots is that AVO will increase in the corridor. As a result, speeds in the corridor may also increase. Regionally, a decrease in VMT is hypothesized, with a majority of the decrease witnessed in the affected corridor.

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Table 6. Park-and-Ride Lot Hypotheses

Measured Variable	Hypothesis[1]
Vehicle Volumes (Overall)	$X_b > X_a$
Transit Volumes	$X_b < X_a$
Passenger Car Volumes	$X_b > X_a$
Carpool/Vanpool Volumes	$X_b < X_a$
Person Volumes (Overall)	$X_b = X_a$
Transit Vehicle Occupancy	$X_b < X_a$
Passenger Car Occupancy	$X_b > X_a$
Carpool/Vanpool Occupancy	$X_b < X_a$
Travel Times	$X_b > X_a$

[1]X_b = mean of variable before park-and-ride lot construction.
X_a = mean of variable after park-and-ride lot construction.

Data Collection Plan and Controls

The ability of park-and-ride lots to increase AVO can be monitored through the collection of several types of data.

Utilization rates are the ratio of the number of parking spaces occupied to the number of parking spaces available. The number of spaces occupied may vary daily since some commuters may rideshare two or three days per week. The utilization rate for one typical week should be observed and the average occupancy computed. As an input to analysis, this rate would have to be predicted before the lot is constructed and verified in the post-analysis.

Mode splits describe the use of transit and car/vanpools for the trip from park-and-ride lot to worksite. The actual emission benefits depend on the mode for the second leg of the commute trip. A 6-person vanpool is more beneficial than a 2-person carpool. Data on mode splits should be collected on all days of a typical week.

Information from origin-destination surveys can be used to compute the average distance to the park-and-ride lot as well as the average distance to worksites from the lot. The total VMT reduction as a result of the park-and-ride lot can be estimated based on the

average distance to and from the park-and-ride lot. This information should be collected on a typical week day from the users of the park-and-ride lot.

MPOs and other responsible agencies should also collect data on the travel times along the affected corridor. Park-and-ride lots are generally aimed at reducing vehicle trips on some major arterials and freeways traveled by commuters. The reduction in vehicle trips may result in increased speeds on the affected arterials and freeways. Travel time data should be collected, in accordance with the ITE specifications, for at least two typical weekdays.

The data collection should be performed during a typical week. Care should be exercised so that data are not collected during holidays or periods when large number of people are likely to take vacations.

Statistical Procedures

Table 6 identifies the hypotheses that can be made for park-and-ride lots. They should be tested using standard parametric and non-parametric hypothesis testing procedures.

Park and Ride Lot Monitoring Program Summary

A typical monitoring plan for park-and-ride lots was discussed in the previous paragraphs. No specific site was used to demonstrate the plan. The data collection is expected to remain similar irrespective of the site. Some plan components such as the specific areas and roadways affected by the park-and-ride lot should be identified based on the location.

SUMMARY

This chapter discussed general guidelines for monitoring TCMs including the objectives of a TCM monitoring program and data collection needs. Monitoring programs for four TCMs (i.e., improved public transit, traffic flow improvements, rideshare programs, incentives, and park-and-ride/fringe parking) were discussed based on the general guidelines. The monitoring plans for public transit and intersection improvement measures were prepared for specific sites, which could serve as an example for developing similar plans at other sites.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The evaluation and monitoring of TCMs are two distinct but interrelated components of the transportation planning process. This report summarized the advantages and limitations of the TCM evaluation methods currently available, discussed two issues that influence their results, and presented the three essential components of a TCM monitoring program.

The TCM evaluation methods summarized in this report include the use of comparative empirical data, network-based models, and sketch-planning tools. These methods are discussed in more detail within TTI Reports 1279-6 and 1279-7 (3, 9). The ability of these methods to accurately evaluate TCM impacts is significantly influenced by at least two factors. The factors discussed in this report include the estimation of TCM participation rates and the evaluation of TCM programs.

The results of the current TCM evaluation methods, although influenced by a number of factors (including the two critical issues discussed in this report), can be improved through the proper monitoring of TCM impacts. This report identifies general guidelines for the monitoring of TCMs, and presents the monitoring programs for four specific TCMs (i.e., transit plazas, intersection improvements, ridesharing, and park-and-ride lots). These guidelines and the content of these programs can be used as a reference in the design of similar TCM monitoring activities.

CONCLUSIONS

Several conclusions were reached based on the research documented in this report:

1. None of the TCM evaluation methods currently available are capable of estimating the regional impacts of all sixteen TCMs identified in the CAAAs. Each method has its own advantages and limitations.

2.	The use of sketch-planning tools currently appears to hold the most promise with respect to the cost-effective evaluation of TCM impacts. This approach is well suited to the current level of TCM impact data available. The gross nature of these tools allows their input data to be more easily collected and results in a less labor intensive TCM evaluation. In addition, more time can be spent on the analysis of TCMs rather than on the construction and implementation of the evaluation model.

3.	The accuracy and validity of TCM evaluation results are influenced by a number of issues. Two issues with a significant impact are the estimation of TCM participation rates and the evaluation of TCM programs. The results of a TCM evaluation are highly sensitive to the assumed participation rate, and the evaluation of TCM programs is generally only considered on a quantitative basis.

4.	The validity and reliability of current TCM evaluation methods can be improved, and more standardized TCM impact data collected, through the application of properly designed TCM monitoring programs.

5.	A TCM monitoring program or plan should contain at least three components. First, the objectives of the TCM must be defined and translated into hypotheses that can be statistically tested. Second, a data collection plan must be developed and data collection controls identified. Finally, appropriate statistical procedures (with respect to the type of hypotheses and data collected) must be established to determine whether the measured changes are significant, or simply the result of random variations. All three of these components are essential for the effective monitoring of a TCM.

RECOMMENDATIONS

The research documented in this report has led to the following recommendations:

1.	New and/or improved TCM evaluation methods are necessary to adequately meet current legislative mandates and to increase the number of TCMs a metropolitan area

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can consider and evaluate. Two critical issues which must be addressed are the estimation of TCM participation rates and the evaluation of TCM programs.

2. A standardized data collection and TCM monitoring program should be initiated nationwide. The implementation of this type of program should make the TCM data collected more useful, and help improve the results of all TCM evaluation methods. A national database of TCM impacts was started as part of this project, and should be continually updated. The implementation of a standardized data collection and TCM monitoring program becomes more relevant as more TCMs are implemented.

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APPENDIX A

TCM TYPOLOGY[1,2]

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TRIP REDUCTION ORDINANCES

- Special Use Permits
- Negotiated Agreements
- Trip Reduction Goals Program
- Mandated Ridesharing and Activity Programs
- Transportation Management Funds and Districts
- Requirements for Adequate Public Facilities
- Conditions of Approval for New Construction

EMPLOYER-BASED TRANSPORTATION MANAGEMENT PROGRAMS

- On-site Employer Transportation Coordinator
- Transit/Rideshare Services
    - Provide HOV Shuttle Services between Company Facilities
    - Centralized Vanpool/Carpool Matching Service
    - Rideshare/Transit Marketing/Information Programs
    - Designated Transportation Coordinator
    - HOV Priority Parking
    - Vanpool/Subscription Bus Financing
    - Subscription Buses or Buspooling
    - Midday and Park-and-Ride Shuttles
    - Guaranteed Ride Home
    - Use of Employer's Fleet
- Bicycling and Walking
- Employee Financial Incentives
    - Subsidize Transit Use
    - Transportation Allowances
    - Eliminate Employee Parking Subsidies
    - Charge for Drive-Alone Parking
    - Reduced Fares for HOV

Complementary Measures

- Trip Reduction Ordinances
- Parking Management
- Park-and-Ride Lots
- HOV Facilities
- Pricing Strategies
- Indirect Source Review/Permit Program

WORK SCHEDULE CHANGES

- Telecommuting
    - Home
    - Satellite Work Center
    - Neighborhood Work Center
- Flextime
    - Daily Start/End Time
    - Number of Hours Worked
        - Per Day
        - Per Week
        - Per Pay Period
- Staggered Work Hours
- Compressed Work Week
    - 4-Day Week (10 Hour Work Days)
    - 5/4 Plan (80 Hours in 9 Days)

AREAWIDE RIDESHARE INCENTIVES

- Areawide Commute Management Organizations (Third Party Brokerages)
    - Carpool Matching Programs
    - Vanpool Programs
    - Shared Ride Taxi
    - Guaranteed Ride Home
- Transportation Management Associations (TMAs)
    - Operation of Ridesharing and Other Transportation Management Programs
    - Education
    - Informational Materials
    - Advocacy
    - Transportation Services Coordinators
    - Employee Surveys
    - Organization
        - Independent, Non-Profit Corporation
        - Existing Business Organization
- Tax Incentives and Subsidy Programs
    - State/Local Tax Exemptions for Vanpool or Transit Subsidies
    - Exemption of Ridesharing Vehicles from 'Common Carrier' Status
    - Safety Regulations for Vanpools, Buspools, Subscription Buses
    - Insurance Coverage
    - Liability Responsibility
    - Accelerated Depreciation Allowance for Employer-Provided Vanpools and Bicycling Facilities
    - State/Local Gas Tax Exemptions for Provision of Vanpool Benefits

Complementary Measures

- Park-and-Ride Lots
- Preferential Carpool/Vanpool Parking
- Transportation Management Associations
- HOV Facilities
- Employer-based Transportation Management Programs
- Trip Reduction Ordinances
- Pricing Strategies
- Public Awareness Programs

IMPROVED PUBLIC TRANSIT

- System/Service Expansion
    - Fixed Guideway Transit
    - Fixed Route and Express Bus Services
    - Circumferential and Local Bus Service
    - Paratransit Programs
- System/Service Operational Improvements
    - Feeder Bus Service
    - Express Bus Service
    - Bus Route and Schedule Modifications
    - Improved Transfers
    - Schedule Coordination
    - Bus Traffic Signal Preemption
    - Road Operational Changes
    - Operations Monitoring
    - Maintenance Improvements
    - Park-and-Ride Service
    - Subscription Bus Service
- Demand/Market Strategies
    - Employer Offered Incentives
    - Marketing and Information Programs
    - Peak/Off-Peak Transit Fares
    - Simplified Fare Collection
    - Reduced Fares
    - Monthly Passes
    - Unticket Programs
    - Passenger Amenities
    - Joint Development Activities

Complementary Measures

- Park-and-Ride Facilities
- Signal Timing/Preemption
- Pricing Strategies
- HOV Facilities
- Parking Restrictions

IMPROVED HIGH-OCCUPANCY VEHICLE FACILITIES

- Freeway
    - Exclusive (Separate Right-of-Way)
    - Barrier or Buffer Separated
    - Concurrent-flow
    - Contra-flow
    - · Queue Bypass
- Arterial
    - Concurrent-flow
    - Contra-flow
    - Reversible Flow
    - Median Lane
    - Bus Street
    - Bus Tunnel
- Entrance Ramp Priority
- Parking Facilities

Complementary Measures

- Park-and-Ride/Fringe Parking Lots
- Transit Transfer Centers
- Transit Improvements
- Priority Access/Egress for Buses and Carpools
- Areawide Ridesharing
- Parking Management

TRAFFIC FLOW IMPROVEMENTS

- Traffic Signalization
    - Local Intersection Signal Improvements
    - Interconnected Arterial Signal Systems
    - Area Signal System
    - Equipment or Software Updating
    - Eliminate Unnecessary Signals and Stop Signs
- Traffic Operations
    - Additional Lanes Without New Construction
    - Intersection and Roadway Widening
    - One-Way Streets
    - Turn Lane Installation
    - Turning Movement and Lane Use Restrictions
    - Reversible Traffic Lanes
    - Strengthen Curb Cut Controls
    - Improved Traffic Control Devices
    - Grade Separation
- Enforcement and Management
    - New Freeway Lane Using Shoulders or Reduced Lane Widths
    - Incident Detection and Management Systems
    - Freeway Diversion and Advisory Signing
    - Ramp Metering
    - Mainline Metering
    - Integrated Surveillance and Control
    - Enforcement
- Intelligent Vehicle and Highway Systems (IVHS)

Complementary Measures

- Restricting Movements and/or Cross Traffic
- Removing or Restricting Parking to Off-Peak Periods
- Removing Unnecessary Stop Signs
- Removing Recurrent Bottlenecks from Congested Roadways
- Implementing Motorist Advisory
- Programs to Expedite Removal of Disabled Vehicles
- Provide Pull-Outs for Disabled Vehicles
- Peak Period Pricing

PARKING MANAGEMENT

- Preferential Parking for High-Occupancy Vehicles
    - Garages and Lots
    - Metered Spaces
    - Rate Reduction
    - Reserved Spaces
- Public Sector Parking Pricing
    - Alter Rates
    - Long- vs. Short-Term Parking
    - Impose New Prices
    - Tax the Provision of Free Private Parking
- Parking Requirements in Zoning Codes
    - Revise Maximum and Minimum Requirements
    - Allow Reductions in Minimum Requirements for Traffic Mitigation Actions
- On-Street Parking Controls
    - Curb Parking Restrictions
    - Residential Parking Controls
    - Peak Hour Parking Ban and Enforcement
    - Reduced Legal Parking Spaces in High Congestion Areas
    - Increased Meter Fees
    - Increased Enforcement and Towing
- Commercial Vehicles
    - On-Street Loading Zones
    - Off-Street Loading Areas
    - Peak Hour On-Street Loading Prohibition
- Control of Parking Supply
    - Limit Construction of New Parking Facilities in Areas Served by Mass Transit
    - Limit Number of On- and Off-Street Parking Spaces in Designated Areas
    - Use of Zoning and Parking Regulations to Limit Capacity

PARK-AND-RIDE/FRINGE PARKING

- Construct New/Enlarged Dedicated Facilities on Public Property
- Use of Direct Ramps to Connect Park-and-Ride Lot with Freeway System
- Locate Personal Business Support Services at Park-and-Ride Lots Including Day-Care Centers, Financial Services, Convenience Stores, and Dry Cleaners
- Joint Use of Theater, Shopping Center, Church, and Stadium Parking Facilities, as Available
- Parking at all Major Transit Stations
- Locate Fringe Parking to Serve Major Highway Facilities/Interchanges Near Central Business District
- Provide Transit/Shuttle Services to Park-and-Ride/Fringe Parking
- Priority Parking for HOVs at Major Parking Facilities
- Provide Bicycle Lockers/Storage at Parking Facilities

Complementary Measures

- HOV Lanes
- Parking Management Programs
- Improved Public Transit
- Employer-based Transportation Management Programs
- Areawide Ridesharing
- Automobile Use Restriction in the CBD
- Work Schedule Changes

BICYCLE AND PEDESTRIAN PROGRAMS

- Bicycle Facilities
  - Routes, Lanes, and Paths
    - Supportive Route Signalizations
    - Lane Striping
    - Repaving
    - Signing
  - Bicycle Plans and Maps
  - Bicycle Coordinators
  - Lockers, Racks, and Other Storage Facilities
  - Showers and Clothing Lockers
  - Integration with Transit
  - Ordinances
  - Education
  - Media and Promotion
- Pedestrian Facilities and Programs
  - Sidewalks and Walkways
  - Safe Facilities
    - Crosswalks
    - Walk Signals
    - Median Strips
    - Speed Ramps
    - Lighting
    - Clear Sight Lines
  - Sidewalk Environment/Furniture
    - Benches
    - Street Level Shops
    - Amenities
  - Connections with Transit
  - Education

TRAFFIC MANAGEMENT FOR SPECIAL EVENTS

- Remote Parking with Shuttle Service
- Public Transportation
- Highway Improvements
- Signage, Communication and Public Education/Information
- Traffic Flow Improvements
- Parking Management
- Pedestrian Access/Circulation
- Public and Private Coordination Committee
- Operations Response Teams
- Alternative Travel Schedules
- Rescheduling of Truck Travel

VEHICLE USE LIMITATIONS/RESTRICTIONS

- Route Diversion
  - Automobile Free Zones
  - Pedestrian Malls
  - Traffic Controls
- No-Drive Days
  - Voluntary
  - Required
- Control of Truck Movement
  - Designated Truck Routes
  - Truck Management Strategies
      - Sign Placement
      - Changeable Message Signs
      - Speed Restrictions
      - Additional Lanes
      - Lane Restrictions
  - Scheduling of Shipping/Receiving
  - Peak Period Truck Bans on Freeways or Major Arterials
  - Freight and Delivery Consolidation

ACCELERATED RETIREMENT OF VEHICLES

- Vehicle Eligibility
- Dollar Value of Payment
- Program Duration
  - Length of Buy-Back Period
  - One Time Program
  - Sequential Program
- Limitations on Number of Vehicles Bought
  - None
  - Maximum Number
- Retirement -vs- Tune Up
- Administration
  - Public Sector
  - Private Sector
  - Use of Credits in Emissions Banking and Trading

ACTIVITY CENTERS

- Design Guidelines/Regulations
  - Transit
  - Carpooling and Vanpooling
  - Pedestrians
  - Bicycling
- Parking Regulations and Standards
- Mixed Use Development Ordinances and Zones
- Site Plan Review Ordinances

EXTENDED VEHICLE IDLING

- Controls on Drive-Through Facilities
  - New Facilities
  - Existing Facilities
- Limitations on Idling of Heavy-Duty Vehicles
  - Trucks
  - Buses
  - Locomotives and Other Mobile Sources
- Vehicle Modifications

EXTREME LOW-TEMPERATURE COLD STARTS

- Vehicle Modifications
  - Block Heaters
  - Intake Manifold Heaters
  - Monolithic Fuel Injection Systems
  - Start or Warm-up Catalysts
  - Multipoint Fuel Injection Systems
- Parking Facility Electrical Outlets
  - Public Facilities
  - Private Employers
- Transit Use Incentives
- No-Drive Days
- Vehicle Fleet Operations