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Research Study Title: Congestion Management and Air Quality Benefits of Transportation Improvements

16. Abstract

The TTI CM/AQ Evaluation Model was originally developed for the Denver Regional Council of Governments (DRCOG) by JHK & Associates. After reviewing it, the Texas Transportation Institute (TTI) sought enhancements to this model for use in Texas and other nonattainment states. The resulting model is called the TTI CM/AQ Evaluation Model. The TTI CM/AQ Evaluation Model evaluates potential projects based on the following criteria: eligibility, travel impacts, emission impacts, and cost-effectiveness. To compare independent projects within a region during the decision process for CM/AQ funding, each project evaluated with this model is given an overall score based on the project's effects for the criteria listed above.

Training workshops were held by TTI in the first quarter of 1995 to teach metropolitan planning organization, state department of transportation, and regional air quality organization staff how to use this model. Basics of sketch-planning applications were also taught.

The DRCOG and TTI CM/AQ Evaluation Models represent significant steps toward the development of analytical methodologies for selecting projects for CM/AQ funding. Because the needs of nonattainment and attainment areas change over time, this model is particularly useful as key evaluation criteria can be modified to reflect the changing needs of a metropolitan area. Further enhancements are being made to the model and future versions will be made available to MPO and DOT staff.

17. Key Words Congestion Mitigation/Air Quality, Transportation Control Measures, Mobile Source Emissions, Analysis Tools, Sketch-Planning Tools	18. Distribution Statement No Restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161		
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TTI CM/AQ EVALUATION MODEL USER'S GUIDE AND WORKSHOP TRAINING MATERIALS

Software and User's Guide
developed by

JHK & Associates
for the
Denver Regional Council of Governments

Workshop presented by

Jason A. Crawford and William E. Knowles
Texas Transportation Institute

IMPLEMENTATION STATEMENT

The work documented in this report is intended to assist metropolitan planning organization (MPO) and state department of transportation (DOT) staffs in determining how to allocate Congestion Mitigation/Air Quality (CM/AQ) Improvement Program funding to proposed transportation projects. The Texas Transportation Institute (TTI) CM/AQ Evaluation Model was originally developed for the Denver Regional Council of Governments by JHK & Associates with assistance from Balloffet & Associates. TTI recognized the importance of this model to applications in Texas and sought enhancements to the original model to produce the TTI CM/AQ Evaluation Model. Workshops on the use of this model and basic applications of sketch-planning tools were held. Training materials used by students in these workshops are included as appendices.

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

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation. Additionally, this report is not intended for construction, bidding, or permit purposes. George B. Dresser, Ph.D. and Carol Walters P.E. (TX 51154) were the Principal Investigators for the project.

REGISTERED TRADEMARKS

Paradox is a registered trademark of Borland.

ACKNOWLEDGMENTS

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SUMMARY

JHK & Associates has developed an analytical model for evaluating and recommending local transportation projects for Congestion Mitigation/Air Quality (CM/AQ) funds available through the Intermodal Surface Transportation Efficiency Act (ISTEA). The model was originally developed for the Denver Regional Council of Governments (DRCOG) to assist them in their decision-making process for allocating CM/AQ funding throughout their nonattainment area. The model was enhanced for the Texas Transportation Institute (TTI) and Texas Department of Transportation so that the model would be more applicable to local jurisdictions in Texas. The enhanced model is called the TTI CM/AQ Evaluation Model. This model was also modified by TTI to satisfy requests by the sponsor.

The TTI CM/AQ Evaluation Model is able to evaluate 59 different CM/AQ strategies for four pollutants. The four key pollutants are carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxides (NOx), and particulate matter (PM-10). At the time of this report, El Paso is a nonattainment area for CO and PM-10. Nonattainment areas for ozone in Texas include Houston, Dallas-Fort Worth, and Beaumont-Port Arthur. VOC and NOx are included in the model because both are precursors to ozone formation. The model evaluates projects based on an average 24-hour day; however, analysis is separated into peak and off-peak periods where the peak period represents the combined AM and PM peaks.

The model is designed to evaluate projects quickly and effectively while providing a means of comparing results across different types of projects. The model does include some simplifying assumptions, which are described in the report, to ensure that comparisons could be made across different modes of travel and project benefits. Analysis of proposed projects proceeds through five modules: eligibility, travel impacts, emission, cost-effectiveness, and criteria weighting. The final model output for each eligible project evaluated is a single project rating supplemented by absolute and relative changes in travel and emission criteria resulting from the implementation of the proposed project.

TTI conducted workshops to teach potential model users basic techniques of sketch-planning applications and how to use this particular model. The training materials used for these

workshops are included as appendices to this report.

The DRCOG and TTI CM/AQ Evaluation Models represent significant steps toward the development of analytical methodologies for selecting projects for CM/AQ funding. The needs of nonattainment and attainment areas change over time which makes this model particularly useful because key evaluation criteria can be modified to reflect the changing needs of a metropolitan area.

SECTION 1
INTRODUCTION

JHK & Associates, with assistance from Balloffet & Associates, has developed an analytical model to be used in evaluating and recommending projects for the Congestion Mitigation/Air Quality (CM/AQ) funds available from the Intermodal Surface Transportation Efficiency Act (ISTEA). The CM/AQ Evaluation Model was originally developed for the Denver Regional Council of Governments (DRCOG) and was revised for the Texas Transportation Institute (TTI) to increase the applicability of the model to local jurisdictions in Texas. Further enhancements were made to the model by TTI. The model was designed so that projects could be evaluated quickly and efficiently while providing a comparable basis for evaluation across different types of projects. To ensure that comparisons can be made across different modes of travel and encompass varied project benefits, the screening process applied does include some simplifying assumptions that are described in this report.

The final output of the TTI CM/AQ Evaluation Model is a project rating for each project eligible for CM/AQ funds. Project eligibility is determined according to guidelines distributed by the Federal Highway Administration. The project rating reflects weighted criteria, which are described in the next section. The project rating developed by the TTI CM/AQ Evaluation Model may be used as one factor in the decision-making process for distributing CM/AQ funds. Other factors that may be taken into account include the geographic distribution of funds, a maximum percentage of available funding to be spent on capital improvements projects, or a minimum percentage of available funding to be spent on innovative projects. The qualitative nature of these factors prevented their incorporation directly into this model.

A primary objective of the development of the TTI CM/AQ Evaluation Model was to provide an analysis tool to evaluate and compare the wide range of transportation strategies that may be submitted as projects requesting CM/AQ funding. The strategies included in the TTI CM/AQ Evaluation Model range from employer-based strategies such as providing a transit pass subsidy, to technological changes such as providing alternatively-fueled vehicles in the public vehicle fleet. A listing of all strategies is provided in Table 1-1. The model was also designed

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to accommodate projects that do not correspond to one of these predefined strategies so that the evaluation process can still be conducted on a comparable basis. Included in the model are four types of pollutant emissions: carbon monoxide (CO); volatile organic compounds (VOC) (a precursor to ozone); nitrogen oxides (NOx) (also a precursor to ozone); and particulate matter less than ten microns (PM-10).

The CM/AQ Evaluation Model Workshop was designed and taught by the Texas Transportation Institute as part of Project 0-1358 to educate transportation professionals involved in the analysis of CM/AQ projects on the capabilities of this model. Topics covered in the workshops were an overview of the CM/AQ program, introduction to the TTI CM/AQ Evaluation Model, discussion of data requirements and potential data sources, and hands-on application with the model. The workshops were taught on the Texas A&M University campus. Included in Appendix A are the training slides used in the workshops.

The remainder of this report is organized into three sections. Section 2 describes the methodology used in developing the TTI CM/AQ Evaluation Model. Section 3 provides an overview of how the model operates and step-by-step instructions for using the model. A summary is provided in Section 4. More detailed, supplemental information for the TTI CM/AQ Evaluation Model is provided in technical appendices.

Table 1-1
Strategies Included in the TTI CM/AQ Evaluation Model

Improved Public Transit
Increased Transit Service
Express Buses
Paratransit Programs
Light Rail
Bus Signal Pre-emption
Activity Center Shuttles
Transit Advanced Traveler Information System
Transit Shelters

HOV Facilities
Freeway HOV Lanes
Arterial HOV Lanes
Ramp Meter Bypass for HOVs

Employer-Based Strategies
Transit Pass Subsidy
Employee Transportation Coordinator
Education/Information Dissemination
Guaranteed Ride Home
Trip Reduction Ordinances

Traffic Flow Improvements
Traffic Signal Timing & Coordination Improvements
Traffic Operations Center
Courtesy Patrol
Other Incident Detection & Response Programs
Motorist Information
Intersection Improvements (widening)
Ramp Metering
Reversible Lanes

Park-n-Ride Lots
Transit-oriented
Car/Vanpool-oriented
Bike to Park-n-Ride Program

Auto/Truck Restrictions
Restricted Times for Goods Delivery
Auto Restricted Zones

Congestion Pricing
VMT Tax
Tolls

Rideshare Programs/Services
Regional or Neighborhood Based Rideshare Program
Transportation Management Associations
Vanpool Programs

Non-Motorized Facilities
Pedestrian Improvements
Bicycle Lanes, Paths
Bicycle Amenities (lockers, showers, secure storage)
Public Education Campaign
Bicycle/Pedestrian Coordinator Positions

Vehicle Idling Controls
Drive-thru restrictions
Curb-side idling restrictions
Vehicle idling restrictions by buses and trucks

Alternative Work Schedules
Compressed Work Week
Flexible Work Hours
Staggered Work Hours

Alternative Fuel Incentive Programs
Public Fleet Compressed Natural Gas
Reformulated Gasoline/Diesel

PM10 Reduction Measures
Enhanced Street Sweeping
Road Sanding/Salting Alternatives
Diesel Control Programs

Telecommuting
Home-based Telecommuting
Satellite Work Centers
Teleconferencing

Parking Management
Restricted Parking Supply
Parking Charges (commute and all trips)
Preferential Parking for Carpools and Vanpools

Other Transportation Projects
Promising Technologies
Feasible Approaches
Projects not in strategy listing

SECTION 2
METHODOLOGY FOR THE CM/AQ MODEL EVALUATION MODEL

2.1 OVERVIEW OF MODEL STRUCTURE AND METHODOLOGY

The TTI CM/AQ Evaluation Model was developed in Paradox 4.5, a PC-based database management software package, and can be operated in later DOS-based versions as well. For ease of reference and for organizing the calculations, the model was developed as five separate modules:

1. Eligibility
2. Travel Impacts
3. Emissions
4. Cost-Effectiveness
5. Criteria Weighting

The overall structure of the TTI CM/AQ Evaluation Model and an illustration of the data flows between the modules are provided in Figure 2-1.

The analytical methodology developed for the TTI CM/AQ Evaluation Model reflects a sketch-planning-oriented approach that is based on project-specific data. This approach combines the need to analyze projects that are location-specific or regional in their impacts with the requirement that MPO staff be able to evaluate projects quickly and efficiently. While Figure 2-1 illustrates a single structure for the entire model, unique calculations were developed for each strategy to reflect the individual ways in which projects impact travel, emissions, and cost-effectiveness. In developing the individual sets of equations, it was important to determine how each strategy impacts a number of key characteristics, including:

- type of area (e.g., CBD, urban, rural)
- trip type (e.g., commute, non-commute)
- time of day (e.g., peak, off-peak)
- vehicle type (e.g., light duty auto, heavy duty truck, etc.)
- transportation measures (e.g., trips, VMT, speed, idling)

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- pollutants (e.g., carbon monoxide, volatile organic compounds, oxides of nitrogen, particulate matter)

- start type (e.g., cold starts, hot starts)

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┌──────────┐                    ┌──────────────┐
│ Strategy │───────────────────►│   Strategy   │
│Description│                   │Characteristics│
└────┬─────┘                    │and Baseline Travel│
     │                          │     Data     │
     ▼                          └──────────────┘
┌──────────┐    ┌──────────┐
│Eligibility│──►│  Travel  │
│  Module  │    │  Module  │
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     │               │
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┌──────────┐    ┌──────────┐        ┌──────────┐   ┌─────────┐
│Listing of│    │Change in │        │ Emissions│◄──│Emission │
│ Projects │    │• Trips   │───────►│  Module  │   │  Rates  │
│Not Eligible│  │• VMT     │        └────┬─────┘   └─────────┘
│for CM/AQ │    │• Speed   │             │
│  Funds   │    │• Idling  │             ▼
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                     │   ┌──────────┐│Change in │
                     │   │ Project- ││• CO      │
                     │   │ Specific ││• VOC     │
                     │   │Cost Data ││• NOx     │
                     │   └────┬─────┘│• PM10    │
                     │        ▼      └──────────┘
                     │   ┌──────────┐
                     │   │  Cost-   │
                     │   │Effectiveness│
                     │   │  Module  │
                     │   └────┬─────┘
                     │        ▼      ┌─────────┐
                     │   ┌──────────┐│Weighting│
                     │   │  Cost-   ││ Factors │
                     │   │Effectiveness│└────────┘
                     │   └────┬─────┘
                     │        ▼
                     │   ┌──────────┐
                     └──►│ Criteria │◄──
                         │Weighting │
                         │  Module  │
                         └────┬─────┘
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                         ┌──────────┐
                         │ Project  │
                         │  Rating  │
                         └──────────┘
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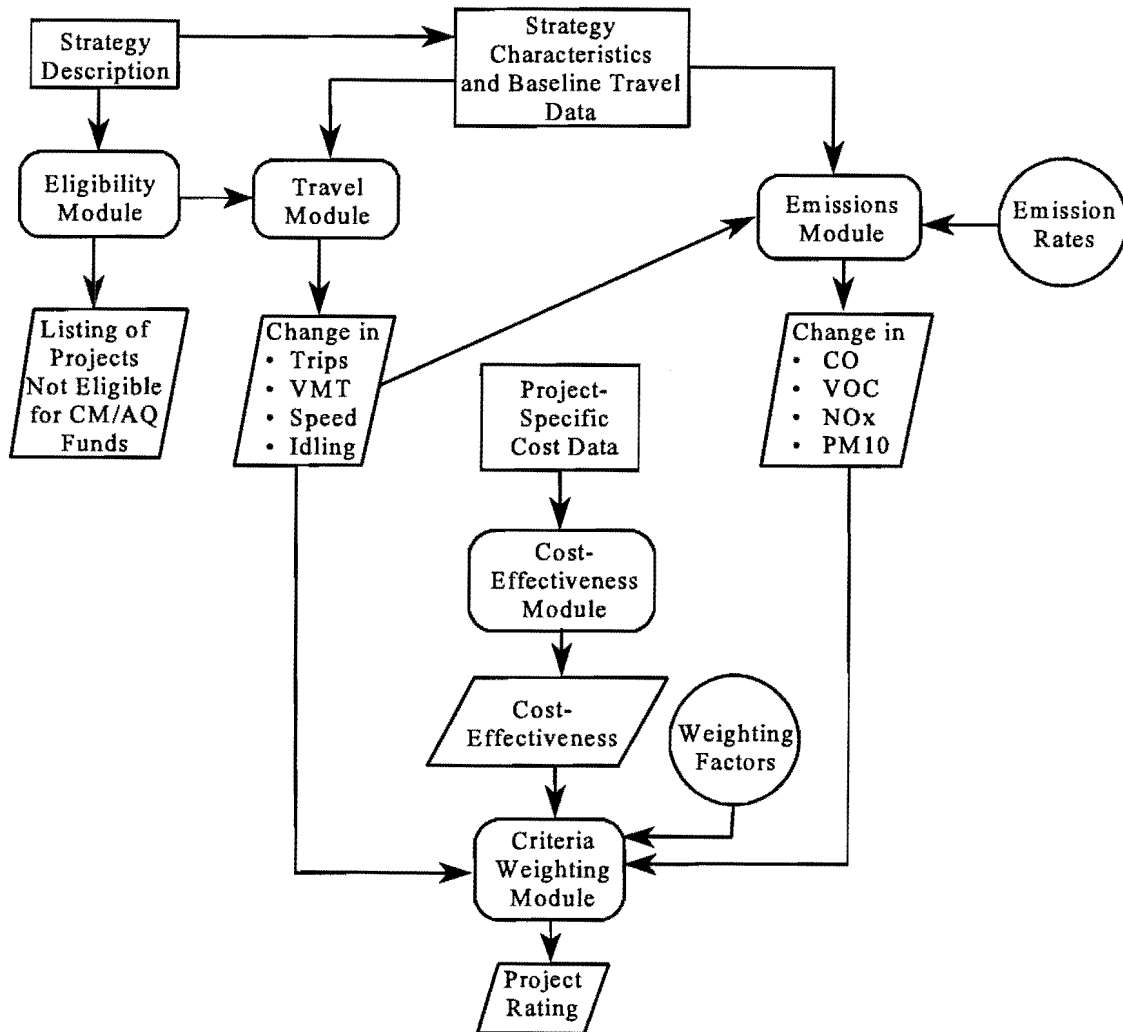
Figure 2-1.   TTI CM/AQ Evaluation Model Structure.

The remainder of this methodology section is organized by module. For each module in each of the five remaining sections, the following information is provided:

- purpose of the module

- module methodology

- input data required

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• outputs developed

More detailed, supplemental information is provided in appendices as indicated throughout this report.

2.2 ELIGIBILITY MODULE

Module Purpose

The Eligibility Module determines whether a project is eligible for CM/AQ funds under current federal law and U.S. DOT/Federal Highway Administration (FHWA) guidelines. The general criteria for determining eligibility are based on an FHWA memorandum dated July 13, 1995, as well as discussions between JHK & Associates and FHWA staff, and additional input from regional planning agencies actively implementing CM/AQ projects and programs. These criteria are summarized in Table 2-1.

The fundamental prerequisite is that a project or program be part of a transportation plan and Transportation Improvement Program (TIP) that conforms to the requirements of the federal Clean Air Act Amendments (CAAA) of 1990. A project that would otherwise be eligible but has not been incorporated into a conforming regional or state transportation plan and TIP cannot receive CM/AQ funding.

The restrictions on CM/AQ funding are aimed at ensuring that projects and programs are publicly controlled and that they are used to establish new or expanded transportation projects, programs, and services. For example, transit operating subsidies are considered ineligible because they are viewed as merely sustaining existing service.

Module Methodology

The methodology applied to determine each project's eligibility is based upon the listing of potential strategies provided in Table 1-1 and the eligibility criteria in Table 2-1. Based on the project description provided by the applicant, the module proceeds through the steps shown in Figure 2-2. A project may be included in this model's listing of strategies, but still needs to meet additional (secondary) criteria listed in Table 2-1. A project not in the listing of strategies must meet the general criteria in Table 2-1. If a project is found to be ineligible for CM/AQ funding,

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the processing of this project through the module will cease and an indicator of ineligibility will be assigned. It is expected that the TTI CM/AQ Evaluation Model user would run an entire set of proposed projects through the Eligibility Module before proceeding to the subsequent modules. An overview of the data flows for this module is provided in Figure 2-3.
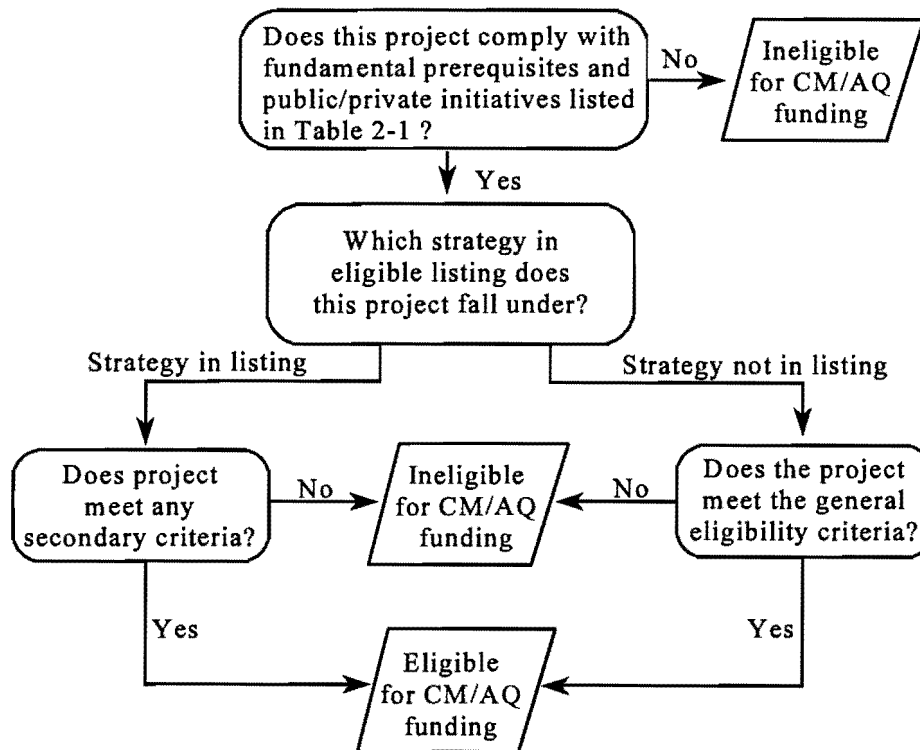
Figure 2-2.   Steps for Eligibility Module.

Table 2-1
Project Eligibility for CM/AQ Funding per
FHWA Memorandum, July 13, 1995

FUNDAMENTAL PREREQUISITES
All projects and programs eligible for CM/AQ funds must come from a conforming transportation plan and TIP and be consistent with the conformity provisions contained in Section 176(c) of the Clean Air Act. The project must also comply with National Environmental Policy Act (NEPA) requirements.

ELIGIBLE PROJECTS/PROGRAMS AND RESTRICTIONS

Transportation Activities in an Approved SIP

Transportation Control Measures Included in the CAAA of 1990
- (I) public transit;
- (ii) high-occupancy vehicle facilities (HOV);
- (iii) employer-based transportation management plans, including incentives;
- (iv) trip-reduction ordinances;
- (v) traffic flow improvement programs that achieve emission reductions;
- (vi) park and ride facilities;
- (vii) programs to limit or restrict vehicle use in congested areas;
- (viii) programs for shared-ride services;
- (ix) programs to limit roads and areas to nonmotorized use;
- (x) bicycle facilities;
- (xi) programs to control extended idling of vehicles;
- (xii) programs to permit flexible work schedules;
- (xiii) programs and ordinances to facilitate nonautomobile travel;
- (xv) new construction and reconstruction of paths for nonmotorized transportation.

Other Bicycle and Pedestrian Facilities and Programs
- Nonconstruction projects related to safe bicycle use.
- Establishment and funding of state bicycle/pedestrian coordinator positions.
- Provision of bicycle amenities must primarily be used for transportation.

ISTEA Management Systems
Eligible if projects are required to develop and establish three ISTEA management systems (traffic congestion, public transportation facilities and equipment, and intermodal transportation facilities and systems).

New Traffic Monitoring, Management and Control Operations
Operating expenses are eligible for a period of only three years from the inception of the new or additional service.

New Emission Inspection and Maintenance Programs
- Eligible only for new or expanded programs, satisfies EPA requirements, and funding does not displace existing funding.
- If for operating expenses, eligible only for three years.

Table 2-1 (continued)
Project Eligibility for CM/AQ Funding per
FHWA Memorandum, July 13, 1995

ELIGIBLE PROJECTS/PROGRAMS AND RESTRICTIONS - continued

Transit Project Funding Limitations
In general, the capital costs of system/service expansions are eligible, and transit operating and maintenance costs are not eligible. In limited cases, operating costs for new transit service are eligible for CM/AQ funding. The main criterion is that the project must be for new service which supports a discrete, new project or program having documented air quality benefits. CM/AQ funds cannot be used to replace existing funding sources for transit operations and cannot be used to further subsidize existing operations.

Highway and Transit Maintenance and Reconstruction Project Ineligible
Routine maintenance on existing facilities is ineligible since it merely maintains and does not improve air quality.

Planning and Air Quality Monitoring Projects
Projects planning activities that lead directly to construction of facilities or new services and programs that have an air quality benefit, such as preliminary engineering or environmental documents.

Public/Private Initiatives
Initiatives that are owned, operated, or under the primary control of the public sector. If privately owned or operated, they must be shown to be cost-effective; and the state is responsible for protecting the public interest and investment, and must normally be a public sector responsibility.

Limitation on Construction of Single-Occupant Vehicle Capacity
Eligible if the project consists of an HOV facility only available to single-occupant vehicles at off-peak travel times.

Employer Trip Reduction Ordinances
Vehicle purchases for a private firm must be excluded from the program.

Alternative Fuels Incentives
If a vehicle conversion program, then it must respond to a specific Clean Air Act requirement or be specifically identified in the SIP as an emission reduction strategy.

PM-10 Reduction Measures
All CO and ozone nonattainment parties must be satisfied with the program.

Telecommunications
- Project can be a planning, technology, or feasibility study; or it can be for training, coordination or promotion, plus
- The project must exclude physical establishment of telecommuting centers, computer/office equipment purchases or related activities.

Other Transportation Projects
Projects based on promising technologies and feasible approaches to improve air quality will also be considered for funding if AQ benefits can be demonstrated and have concurrence of Federal and State transportation agencies and MPOs.

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**Table 2-1 (continued)
Project Eligibility for CM/AQ Funding per
FHWA Memorandum, July 13, 1995**

ELIGIBLE PROJECTS/PROGRAMS AND RESTRICTIONS - continued

Outreach Activities
Eligible if project is a communication service that is critical to successful implementation of transportation measures. May be funded for an indefinite period.

Rideshare Programs
- New or expanded rideshare programs are eligible and may be funded for an indefinite period if the project is an outreach program.
- Vanpool activities must be for new or expanded services.
- Operating expenses are eligible for only three years.
- Not eligible for public services that would be in direct competition with and impede private sector initiatives.

Establishing/Contracting with TMAs
Establishment of TMAs and start-up costs for three years and must be sponsored by a public agency.

Attainment Deadline Restrictions
Projects (or phases thereof) programmed in the first two years of the TIP that is in effect at the time of redesignation.

Maintenance Areas
Projects (or phases thereof) programmed in the first two years of the TIP that is in effect at the time of redesignation.

Fare/Fee Subsidy Programs
Eligible if offered as a component of a comprehensive, targeted program to reduce SOV use.
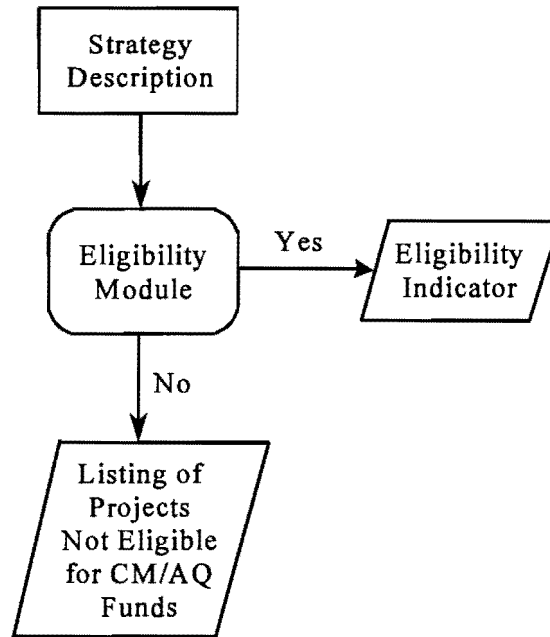
Figure 2-3.   Data Flows for Eligibility Module.

Input Data Required

Information describing the submitted project is required to determine eligibility for CM/AQ funding. Specifically, these questions are:

1. Does this project comply with fundamental prerequisites and public/private initiatives listed in the FHWA memorandum?

2. Under which strategy in the eligible listing does the project fall?

3. Does the project meet any secondary criteria?

The specific questions can be included in the application forms submitted for each project.

Outputs Developed

Based on the determination of whether or not a project is eligible for CM/AQ funding, an indicator is assigned to each project that will allow only eligible projects to proceed through the

remainder of the TTI CM/AQ Evaluation Model. A report is generated that lists the projects that are determined to be ineligible and the step at which this determination was made.

2.3 TRAVEL IMPACT MODULE

Module Purpose

The purpose of the Travel Impact Module is to determine the impacts of each submitted project on the four key transportation characteristics: vehicle trips, vehicle miles traveled (VMT), average travel speed, and vehicle idling time. Average travel speed refers to total travel time which includes delays and idling, not running speed. This is consistent with the definition used to estimate emission factors. These measures will be used to represent the travel-related impacts; however, congestion mitigation is not directly assessed. It is necessary to calculate the impact of each project on travel behavior as the critical input into the emissions and cost-effectiveness calculations. It is important to note that projects with regionwide impacts as well as projects that impact smaller areas can be evaluated with this model; however, the model is best suited to determine regionwide impacts of projects because the model uses an aggregate analysis technique.

Module Methodology

For each strategy included in the TTI CM/AQ Evaluation Model, a separate set of parametric equations was developed to reflect the unique ways that each strategy impacts travel behavior. The general approach used in developing the parametric equations combines the effects of five factors to evaluate trip reduction as shown in Figure 2-4. A brief description of each of these factors included in the parametric equation approach is provided in Table 2-2. Included in the description is an example of how each factor was applied in developing the equations for evaluating an employee transit pass subsidy. As an example, the commute trip reduction equation for an employee transit pass subsidy is:

Reduction in Commute Trips = (Percent subsidy of cost of monthly transit pass) *
  (-(Elasticity of transit use with respect to fare for commuters)) * (Total commute
  person trips) * (Percent of commute trips that are transit) * (Percent of employees
  offered transit passes) * (Percent of transit ridership that equals the trip reduction)

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Based on the appropriate factors (i.e., Percent of Travel That Occurs in the Peak), peak and off-peak trip reduction can also be calculated. In general, VMT reduction is calculated by combining the estimated reduction of trips with the affected average trip length. Average speed changes for the specified area are based on the estimated VMT reduction and a sensitivity factor. Those measures that impact idling are evaluated based on input data directly related to vehicle idling characteristics. An overview of the data flows for this module is provided in Figure 2-5.

The previous paragraphs describe the *general* approach used in developing the specific equations for each strategy. Almost every strategy included in the TTI CM/AQ Evaluation Model affects travel behavior in a way that requires customizing this general approach. A description of how the travel equations have been customized for each strategy and detailed equations for all strategies is provided in Appendix B. These are the equations that are used directly in the model. For each strategy, a listing of the baseline, travel, and emission variables used within the equations are provided.

Some of the strategies included in the TTI CM/AQ Evaluation Model do not impact travel behavior but impact vehicle pollutant emissions directly by reducing the rate of pollutant emissions on a grams per mile basis. These strategies include:

- Alternative fuels incentive programs
- Enhanced street sweeping
- Road sanding/salting alternatives
- Diesel control programs

The methodology used to evaluate the emissions impact of each of these strategies is described in the Emissions Module section (Section 2.4).

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│  Changes in a│  │  Sensitivity │  │   Current    │  │  Portion of  │  │    Other     │
│   Strategy   │  │    Factor    │  │   Share of   │  │    Travel    │  │  Modifying   │
│  Parameter   │  │              │  │    Market    │  │   Affected   │  │   Factors    │
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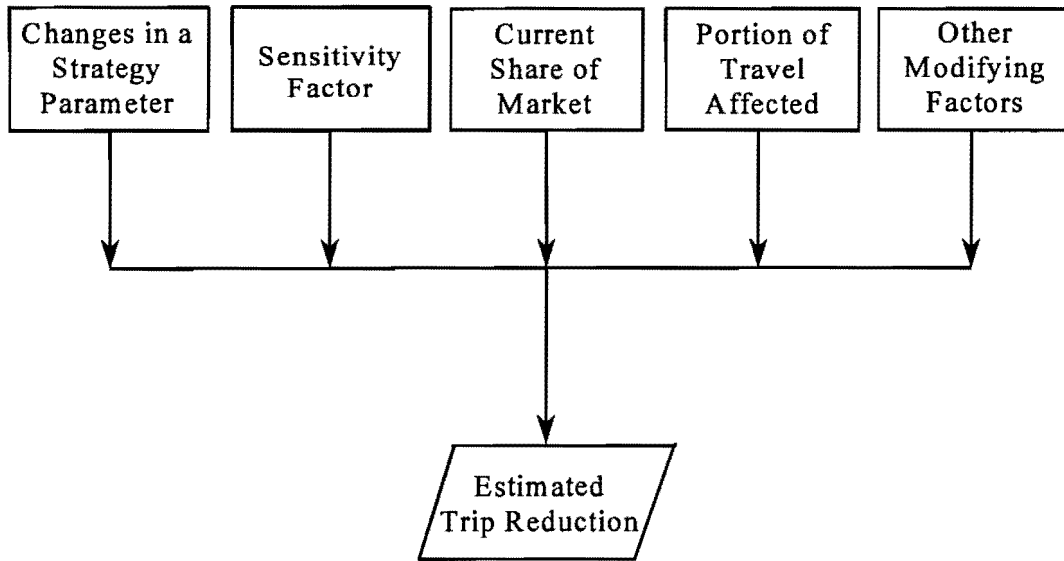
Figure 2-4.   Parametric Equation Approach for the Travel Impact Module.

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                              ┌────────────────────┐
                              │     Strategy        │
                              │ Characteristics and │
                              │ Baseline Travel Data│
                              └─────────┬───────────┘
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        ╱────────────────╲      ╭────────────────╮
       ╱   Eligibility    ╲     │     Travel     │
      ╱    Indicator      ╱────▶│     Impact     │
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                               ╱   Change in        ╲
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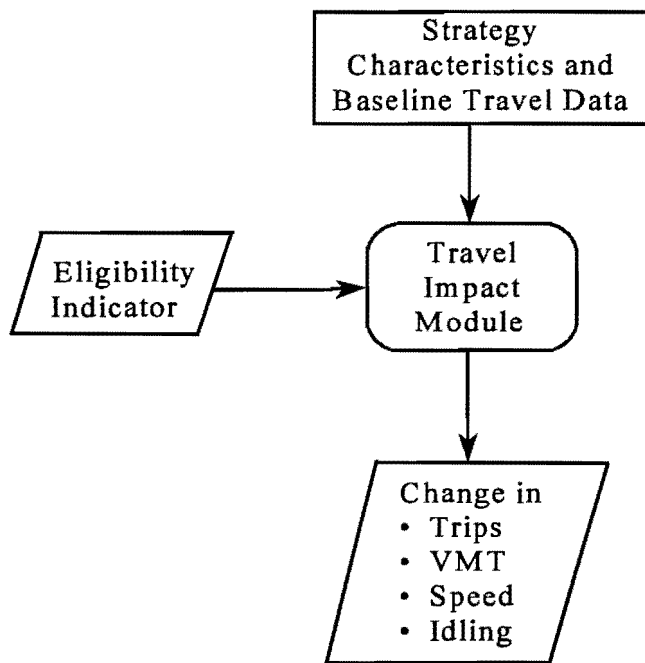
Figure 2-5.   Data Flows for Travel Impact Module.

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Table 2-2
Description of Factors in the Parametric Equation Approach

Parametric Equation Factor	General Description	Employee Transit Pass Subsidy Example
Change in Strategy Parameter	Each strategy can be defined in terms of specific parameters, which are used directly in the developed equations.	Percentage subsidy of cost of monthly transit pass
Sensitivity Factor	A measure of the impact the change in a strategy parameter has on travel behavior. Often expressed as an elasticity.	Elasticity of transit use with respect to fare for commuters
Current Share of Market	Many sensitivity factors "pivot" off the portion of the travel market using a particular mode.	Percentage of commute trips that are transit
Portion of Travel Affected	Many strategies will impact only a specified piece of the entire travel market.	Percentage of employees offered transit passes
Other Modifying Factors	Any other factors that should be taken into account so that the impact on travel behavior is not overstated.	Percentage of transit ridership increase that equals the trip reduction[1]

[1] This factor allows the trip reduction to take into account the fact that all new transit riders do not affect a vehicle trip reduction due to factors such as the percent of new transit riders that used to be in carpools and the percent of new transit riders that drive to the transit station.

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Input Data Required

As indicated in the equations contained in Appendix B, a significant number of variables are required to analyze the transportation impacts of each strategy. The variables consist of baseline travel characteristics (e.g., number of commute person trips), strategy-defining parameters (e.g., the percentage of employees receiving a transit pass subsidy), and assumptions (e.g., elasticity of transit use with respect to cost).

Potentially, the user could be required to input many values. To streamline this process, the TTI CM/AQ Evaluation Model has been designed so that the user is asked to input data on a strategy-by-strategy basis. Some baseline variables are used for more than one strategy. Where this occurs, the user will be asked to input the value only once; and then it will be reported in the data input screens for subsequent strategies. A benefit of this approach is that it ensures consistency throughout the evaluation period across different strategies.

To minimize the effort required to provide the input data, default values are included in the model for the baseline travel characteristics, assumptions, and many of the strategy-defining parameters. These default values were specified for the Denver region where available; otherwise national averages were used. The default values included in the model are for the selected analysis year of 1998. Input data **must** be customized for the user's particular region. The model is designed so that the user can override the default value with a specified input value. Enhancements providing the capability to overwrite the baseline values included in the model were included. Steps for editing the baseline travel defaults are:

Step 1. Select *Data I/O* option from the main menu of the TTI CM/AQ Evaluation Model.

Step 2. Select *Baseline Defaults*.

Step 3. Enter baseline travel data when prompted by the model. The "Page Up" and "Page Down" keys are used to move between baseline travel variables.

Step 4. Click on "Do_It!" to save the updated data.

Outputs Developed

For each project evaluated, the travel impact module produces changes in trips, VMT, speed, and idling time in both absolute terms and as a percentage change from baseline values. These changes are output by both peak and off-peak period for trips, VMT, and speed.

2.4 EMISSIONS MODULE

Module Purpose

The primary goal of the TTI CM/AQ Evaluation Model is that evaluated projects have a beneficial impact on air quality. The Emissions Module quantifies the emissions impact of each CM/AQ project by first establishing a baseline estimate of emissions in kilograms per day (kg/day) by pollutant type and comparing it to the estimated incremental change in emissions from implementing specific CM/AQ-funded projects. Emissions for CO, VOC, NOx and PM-10 are estimated for every CM/AQ project unless that project will have no impact on a specific emission type. Hydrocarbon emissions are measured in the form of VOC, because this form is considered a primary precursor to ozone formation. Only pollutant emissions are evaluated, as opposed to the air quality of a region, in relation to the National Ambient Air Quality Standards.

The final product of the Emissions Module is the change in emissions by pollutant for each project analyzed and the resulting percentage change in emissions from the baseline emissions measurement. The data required to estimate these changes primarily come from two sources. One source, the Travel Impact Module, produces the information on changes in travel characteristics such as change in vehicle trips. The second source is the emission rates that were developed using the U.S. Environmental Protection Agency's (EPA) emission rate model MOBILE5a for CO, VOC, and NOx emissions data and EPA's PART5 particulate model for PM-10. The user is asked to supply certain information for specific CM/AQ strategies and provided the opportunity to override default values.

Module Methodology

The Emissions Module performs a series of calculations to first estimate the baseline level of emissions (before implementing any CM/AQ projects) and then estimates the reduction in

emissions for each project. Appendix C contains the emissions equations used in this module. The Travel Impact Module provides the data required on the changes in number of vehicle trips, VMT, average travel speed, and idling time for each CM/AQ project. Separate emission rates for trip-based emissions, running emissions, and idling emissions are used to estimate the different impacts of changes in travel characteristics rather than simply measuring changes in VMT. Measuring changes in VMT would not demonstrate the effectiveness of projects that reduce idling time or change average speed. For projects of this type, specific emission-type rates for CO, VOC, NOx, and PM-10 were developed outside the module. New sets of emission rates can be used if required, such as for different analysis years, by editing the emission factors used in the model.

The Travel Impact Module produces the estimates of total daily vehicle trips, total daily VMT, and average daily speed that are necessary to estimate the baseline emissions for CO, VOC, NOx, and PM-10. The number of vehicle trips are divided into cold starts and hot starts based on percentages obtained from the Air Pollution Control Division (APCD) of the Colorado Department of Health. Individual metropolitan areas are encouraged to develop localized percentages to describe the unique characteristics of that region. Separate emission rates for cold starts and hot starts in grams per trip (g/trip) are applied to the factored number of vehicle trips to obtain trip-based emissions for CO, VOC, and NOx that are applied to daily VMT. Combining these trip-based emissions and running emissions established the baseline emission measurement for CO, VOC, and NOx. The emission rates for PM-10 are segmented by fugitive dust and vehicle source emissions. Fugitive dust emissions are further divided into unpaved and paved road emission rates. The fugitive dust emission rates are applied to each vehicle type rather than differentiated by vehicle type. These PM-10 emission rates are applied to daily VMT to estimate total PM-10 emissions. The number of vehicle trips and VMT are disaggregated into eight vehicle types based on default factors supplied by the APCD (which can be modified by the user) to correspond to the emission rates that are also separated into eight vehicle types for the TTI CM/AQ Evaluation Model as shown in Table 2-3.

Table 2-3
Vehicle Type Comparison

TTI CM/AQ Evaluation Model	MOBILE5a
Light Duty Gasoline Vehicle	Light Duty Gasoline Vehicle
Light Duty Gasoline Truck 1	Light Duty Gasoline Truck 1
Light Duty Gasoline Truck 2	Light Duty Gasoline Truck 2
Heavy Duty Gasoline Vehicle	Heavy Duty Gasoline Vehicle
Light Duty Diesel Vehicle	Light Duty Diesel Vehicle
Light Duty Diesel Truck	Light Duty Diesel Truck
Heavy Duty Diesel Vehicle	Heavy Duty Diesel Vehicle
Buses	Heavy Duty Diesel Vehicle equivalent
No Equivalent	. Motorcycles

A similar process is used to estimate the change in emissions that result from implementing CM/AQ transportation strategies, but not all four travel characteristics (i.e., changes in vehicle trips, VMT, speed, and idling time) are affected by every type of strategy. Approximately three quarters of the strategies in this model affect vehicle trips, VMT, and average travel speed.[1] Roughly one quarter of the strategies in this model, such as traffic signal improvement or staggered work hours, change average travel speed without affecting trips or VMT. Idling time is reduced in one quarter of the model's strategies, usually without changes to the other travel characteristics. (Changes in idling time as a result of a change in average travel speed are incorporated into the emission rates, which are based on driving cycles, and are not calculated separately). Four of the model's strategies do not affect any of the travel characteristics but directly reduce the emission rates.

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[1] Emission reductions from the user-defined measures are estimated based on changes in vehicle trips and VMT.

Trip-based emission reductions are estimated separately for hot starts and cold starts, requiring information on the percentage for each type of vehicle start. Default percentages are used in the module **unless** the user chooses to override them. The percentages of cold starts and hot starts are estimated for peak and off-peak periods as well as for the daily average. All factors are used for strategies that affect specific time periods. The reduction in trip-based emissions for a strategy is estimated as the number of vehicle trips are eliminated, multiplied by the cold start percentage for that strategy and the cold start emission rate for CO, VOC, and NOx. The same calculation is performed with the hot start percentage and hot start emission rate replacing the cold start percentage and emission rate.

Estimation of running emission reductions from implementation of CM/AQ strategies is based on changes in VMT and changes in average travel speed. The emission rates used in estimating this emission reduction are based on the new average travel speed and are multiplied by the change in VMT. For strategies that affect only average travel speed without altering VMT, the product of the emission rate based on the new average travel speed and the baseline VMT is subtracted from the baseline emission measurement.

Reductions in idling time emissions are the product of the idle emission rate in grams per hour (g/hr) and the number of hours per day in reduced idling time. Certain strategies, such as drive-through restrictions, increase the number of hot starts because drivers must turn off their engines for relatively short periods of time. The user enters the number of increased hot starts, and this value is used to lessen the emission reductions as a result of decreased idling time.

Four of the transportation strategies identified for CM/AQ evaluation affect only the rate of emissions and do not change any of the travel characteristics. The alternative fuels program reduces CO and VOC emissions according to the number of vehicles affected by the program and the percentage reduction in the emission rates for these alternative fuels. Enhanced street sweeping and use of sanding alternatives reduces the PM-10 emission rate for sanding during the winter time. The diesel control program reduces emissions from sulfur dioxide, a contributor to PM-10, but not to a level that has a measurable impact on PM-10.

Cold start and hot start emission rates are estimated for CO, VOC, and NOx using information from MOBILE5a, which does not directly provide these rates. The incremental

difference between 100 percent cold starts or hot starts and 100 percent hot stabilized emission rates are performed using an average speed of 25.6 mph. Developers of the MOBILE model used the Federal Test Procedure to estimate basic emission rates. The average speed from this procedure for vehicles in cold or hot start conditions was 25.6 mph for 505 seconds, or for 3.59 miles. The incremental difference between the emission rate for 100 percent cold starts or hot starts and 100 percent hot stabilized conditions is multiplied by 3.59 miles to estimate the additional emissions when starting the vehicle. Only the difference between these two rates is used; because the hot stabilized portion of emissions is estimated elsewhere as running emissions, which is the product of VMT and the hot stabilized emission rate.

Cold start emission rate =[(100% cold start @ 25.6 mph) - (100% hot stabilized @ 25.6 mph)] * 3.59 miles
Hot start emission rate = [(100% hot start @ 25.6 mph) - (100% hot stabilized @ 25.6 mph)] * 3.59 miles

The emission rates used in estimating the baseline level of emissions and the change in emissions for CM/AQ strategies are based on the worst-case scenario for a particular emission type. The emission rates for CO are based on conditions during the winter months when these rates are highest; while the rates for VOC and NOx, as precursors to ozone, are based on summertime conditions when ozone formation is the highest. Previously, this model used PM-10 emission rates which included emission rates for sanding that are applicable only to winter time. The revised TTI CM/AQ Evaluation Model does not incorporate sanding effects because this event occurs infrequently in Texas areas. A few of the transportation strategies may be applicable only to certain seasons, such as bicycle measures that apply only to warmer months. If these measures affect CO, VOC, and NOx or PM-10 emissions, the rates are adjusted to avoid overestimating the benefits of the strategy.

Input Data Required

Three types of data are required to perform the calculations in the Emissions Module, and two of these types are supplied from other modules or are included in this module. Emission rates are one type of information required and are contained in an external file that will not be changed

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by most users of the module. Generally, a new set of emission rates will be supplied to the model only when analysis for a different year is being performed. The second type of data needed for this module is the output from the Travel Impact Module on changes in vehicle trips, VMT, average travel speed, and idling time. This output is automatically transferred between the two modules. The third type of data requires the user to supply information needed to estimate the impacts on emissions. For some information, such as facility type and the percentage of cold starts, default information is always used unless the user changes the database tables that contain this information. Figure 2-6 illustrates this flow of input data to the Emissions Module.
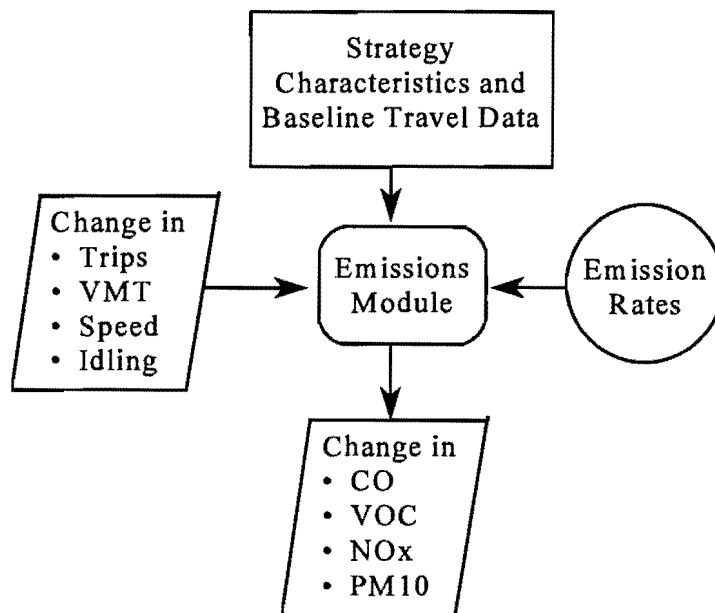
Figure 2-6.   Data Flows for Emissions Module.

The emission rates for CO, VOC, and NOx are contained in a Paradox database (MOBILE5A.DB) and are for the year 1998. The Emissions Module reads the MOBILE5A.DB file to obtain emission rates for cold starts, hot starts, and running emissions by speed increments of 2.5 mph from 2.5 mph to 65.0 MPH, and idle emissions.

Emission rates for PM-10 are contained in two Paradox databases (PARTEMIS.DB and FUGITIVE.DB). The Emissions Module also reads the PARTEMIS.DB file to obtain PM-10

rates by speed increments of 2.5 MPH for 2.5 MPH to 55.0 MPH. Emission rates for fugitive dust from roadways are read from the FUGITIVE.DB file.

The Emissions Module is designed to interpolate between speeds when required. As necessary, new emission rates can be developed outside the module and input into the emission rate database through the TTI CM/AQ Evaluation Model or Paradox.

The TTI CM/AQ Evaluation Model includes a procedure to enter emission rate data from MOBILE and PART5. The steps for entering emission rates from MOBILE are:

Step 1. Run MOBILE5a with the desired inputs.

Step 2. Calculate cold start, hot start, and idle emission factors.

Step 3. Select *Data I/O* option from the main menu of the TTI CM/AQ Evaluation Model.

Step 4. Select *Edit Emission Rates*, then *Emission Rates* (a warning message has been added to ensure that these rates are not accidentally changed).

Step 5. Use the provided data entry screens to update the emission rates with the MOBILE5a output from Step 1. User can modify 21 sets of emission rates (seven vehicle types and three pollutant types). "Page Up" and "Page Down" keys are used to move between the sets of emission rates.

Step 6. Click on "Do_ It!" to save the updated data.

The steps for entering emission rates from PART 5 are:

Step 1. Run PART5 with desired inputs.

Step 2. Select *Data I/O* option from the main menu of the TTI CM/AQ Evaluation Model.

Step 3. Select *Edit Emission Rates*, then select either *Fugitive Dust Rates* (a warning message has been added to ensure that these rates are not accidentally changed).

Step 4. Use the provided data entry screens to update the emission rates with the PART5 output from Step 1. "Page Up" and "Page Down" keys are used to move between the sets of emission rates.

Step 5. Click on "Do_It!" to save the updated data.

Step 6. Repeat Steps 3 through 5 for the *PM10* option.

The change in travel characteristics from the CM/AQ projects is estimated by the Travel Impact Module. For instance, changes in idling time due to intersection widening is based on values supplied by the user of the Travel Impact Module. Once the user has supplied transportation information in the travel module, it does not have to be entered again for the Emissions Module.

The user has the opportunity to supply specific characteristics for some strategies and in some cases is required to enter information before emission reductions can be estimated. Certain transportation strategies may affect only certain area types, such as the Central Business District. In these cases, the choice affects the use of the vehicle type distribution. Some strategies may have a more pronounced effect on CO or PM-10 reductions for a known "hot spot" or "hot grid" area. The boundaries of hot spots and grids will change over time and should be defined by MPO or DOT staff. If the strategy has a particular effect on a hot spot or grid, this information is used in the Criteria Weighting Module. Certain strategies require the user to input information that was not required in the Travel Impact Module, such as the number of vehicles involved in the alternative fuels program.

Outputs Developed

The Emissions Module estimates the baseline level of emissions (before any CM/AQ strategies are implemented) and the change in emissions that result from implementing each transportation strategy. The baseline emissions are required to assess the magnitude of the change in emissions and whether this change is an increase or decrease in emissions. When only the average travel speed changes, the baseline emissions are needed to estimate the change in emissions and to determine whether this change is an increase or decrease in emissions. The output from the Emissions Module is the reduction or increase in CO, VOC, NOx, and PM-10 emissions for each strategy analyzed in both kilograms per day (kg/day) and percentage change

from the baseline measurements. These outputs are used as inputs for the Cost-Effectiveness Module and the Criteria Weighting Module.

Testing the PM-10 enhancements revealed that emission baseline and benefit estimates are extremely sensitive to fugitive dust rates. Extreme care should be taken in developing and using fugitive dust rates with this model. Because PART5 generates these rates on a g/mi basis, all VMT is affected, whether on paved or unpaved roadways. If concerns over PM-10 emissions are raised, it is suggested that the fugitive dust rates be zeroed out, thereby accounting for only tailpipe and wear-generated particulate matter.

2.5 COST-EFFECTIVENESS MODULE

Module Purpose

While the Travel Impact and Emissions Modules indicate the effectiveness of the submitted projects, these modules do not distinguish the difference in cost between the projects. Two projects that have relatively equal effectiveness may vary greatly in their costs. For this reason, the Cost-Effectiveness Module has been included in the TTI CM/AQ Evaluation Model to calculate the cost of each project and the cost-effectiveness of each project in terms of the cost per kilogram of pollutants reduced. Emissions impacts, rather than travel impacts, were used as the effectiveness measure to emphasize that the primary goal for CM/AQ funding in a nonattainment area is to improve air quality by reducing mobile source emissions.

Module Methodology

There are two primary components in cost-effectiveness calculations: the cost value used in the numerator and the measure of effectiveness to use in the denominator of the equation. The units of the cost-effectiveness values calculated for the CM/AQ Evaluation Model are dollars spent per kilogram of pollutant reduced ($/kg).

For the TTI CM/AQ Evaluation Model, two types of costs are of potential interest: total costs to the public sector and amount of CM/AQ funding requested. To calculate the total costs to the public sector, five cost categories are taken into account. The categories are described

below. All cost estimates are for the incremental costs due to the strategy and are costs incurred by public sector agencies only.

Daily Labor Cost: The total amount spent on labor per day for a particular strategy. Because this is a fully-burdened labor cost, it includes employee benefits. Program administration costs fall into this category. Costs for already-employed personnel should be included for the amount of time they spend related to the strategy.

Daily Capital Cost: The cost of capital facilities and equipment, such as vehicles purchased and bicycle storage lockers installed, amortized over the expected life of the facilities and equipment. FTA assumptions regarding amortizing periods for capital equipment should be referenced, and the Office of Management and Budget (OMB) has recently released a 7 percent interest rate to be used in these calculations.

Daily Direct Operational Cost: The daily cost incurred to perform any operational tasks required for the strategy. An example is the cost of fuel for additional bus miles.

Daily Overhead Cost: The daily overhead cost incurred for the strategy. For example, extending hours of operation for transit service may result in central facilities remaining open longer, which in turn results in increased energy usage for lighting.

Daily Revenues: The daily revenues that the public sector may realize as a result of implementing the strategy. Additional revenues from increased transit use would be included in this category.

Applicants should provide this information in their submittal for CM/AQ funding to the MPO, and the costs for each strategy are highly dependent on the specific definition of the strategy. The total cost to the public sector is calculated by adding together the first four cost categories and subtracting the cost savings. The amount of CM/AQ funding requested should be available on the application form and does not need to be calculated in the model.

Four pollutants are examined in the TTI CM/AQ Evaluation Model: CO, VOC, NOx and PM-10. The cost-effectiveness calculations are performed separately for each of the four

pollutants. In the TTI CM/AQ Evaluation Model, a combined cost-effectiveness calculation was not developed because each of the four pollutants represents unique issues; and any attempt to combine their reductions in a cost-effectiveness equation would lead to an assumption that the pollutant benefits are additive. In addition, the relative importance of each pollutant may change over time, which would be difficult to reflect if a combined cost-effectiveness value was calculated.

After the costs are calculated and the pollutant emission reductions are input from the Emissions Module, cost-effectiveness is calculated by dividing the total costs by the emission reductions. In cases where emissions increase, cost-effectiveness will not be estimated because the project is not effective. Where there is an overall cost savings, the cost-effectiveness value will be negative. The data flows for the Cost-Effectiveness Module are illustrated in Figure 2-7.
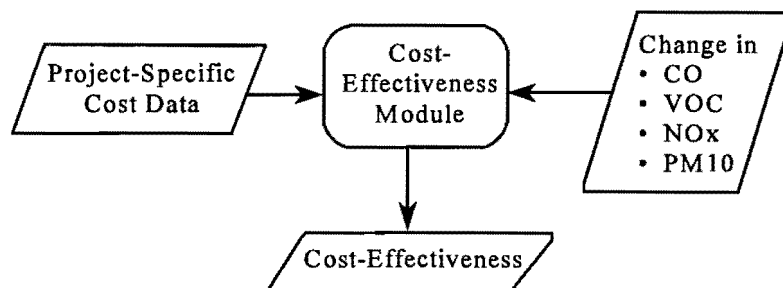
Figure 2-7.   Data Flows for Cost-Effectiveness Module.

Input Data Required

As stated previously, the measure of effectiveness for the cost-effectiveness estimation is kilograms of pollutants reduced per day. The estimated reductions in CO, VOC, NOx, and PM-10 produced by the Emissions Module are input directly into the Cost-Effectiveness Module. As described in the module methodology section, the remaining input data required are the cost data,

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by type of cost, for each of the projects evaluated. These data are input directly by the user. Baseline travel characteristic data and strategy definition data may be used to assist in the process of defining the cost variables. This occurs outside of the TTI CM/AQ Evaluation Model. It is expected that the cost data will be taken from application forms submitted to the local MPO.

Outputs Developed

The Cost-Effectiveness Module produces outputs of the estimated cost-effectiveness by pollutant for each project evaluated. Two estimates of cost-effectiveness are reported based on the following costs:

1.   Total cost to the public sector

2.   Amount of CM/AQ funding requested

The model currently uses only the *Total cost to the public sector* in the Criteria Weighting Module. The second value, *Amount of CM/AQ funding requested*, was included because it was thought to be of some interest.

2.6 CRITERIA WEIGHTING MODULE

Module Purpose

The purpose of the criteria weighting module is to develop a rating of overall effectiveness for each eligible project submitted, which can be used as a basis for ranking all of the projects in comparison to each other. The project rating is based on criteria that have been specified as being of importance in the allocation of CM/AQ funds and weighting factors that have been developed based on the relative importance of these criteria. The criteria and weighting factors that have been selected are:

Criteria	Weighting Factor
Travel Impacts	30
Emission Impacts	30
Cost-Effectiveness	30
Early Project Effectiveness	10

The maximum project rating that can be obtained is 100.

Module Methodology

Each of the weighting factors is considered a maximum "score" for the indicated criteria. The score assigned to a project for each criteria is based on the outputs from each of the modules. With the exception of early project effectiveness, each criterion contains multiple components. To reflect this complexity, an intermediate factor is assigned to each component to weight its relative importance.

These intermediate factors were decided upon based on input from DRCOG staff and the technical advisory committee for the original model. The intermediate factors can be modified to fit an individual metropolitan area's needs. The general equations used to calculate an intermediate score to be applied to the weighting factor and to calculate a final project rating are provided:

$$Intermediate \ Score \ = \ \sum_{all \ components} [(Project \ Impact) * (Intermediate \ Factor)]$$

$$Project \ Rating \ = \ \sum_{all \ criteria} \left[\frac{(Intermediate \ Score)}{100} * (Weighting \ Factor) \right]$$

A summary of the intermediate factors for each component is provided in Table 2-4. The methodology for developing the estimated project impact component for each criterion is described below. It is important to note that any component that has a negative project benefit (e.g., reduces average speed, increases CO emissions) is assigned an Intermediate Score of zero (0) in the model.

Table 2-4
Factors Used in Criteria Weighting Module

Criteria/Components	Intermediate Factors	Weighting Factors
Travel Impacts		30
Percent VMT Reduction	35	
Percent Speed Increase	40	
Percent Idling Reduction	25	
Emissions Impacts		30
Percent CO Reduction	20	
Percent VOC Reduction	20	
Percent NOx Reduction	20	
Percent PM10 Reduction	10	
CO Hot Spot/Hot Grid	20	
PM10 Hot Spot/Hot Grid	10	
Cost-Effectiveness		30
CO cost per kg reduced	30	
VOC cost per kg reduced	20	
NOx cost per kg reduced	30	
PM10 cost per kg reduced	10	
Early Project Effectiveness		10

Note: These factors can be updated, although the same factors should be used for the project ratings in any given analysis year. Each set of intermediate factors and the weighting factors must total 100.

From the Travel Impact Module, changes in VMT, speed, and idling time are used to represent the congestion mitigation potential of each project. Trip reduction is not used in this portion of the analysis because any congestion implications are a result of the associated VMT reduction. For each of the travel impact components, the project impact is defined as the percentage change, in the direction indicated in Table 2-4, multiplied by a factor of 3. The factor of 3 was chosen based on the assumption that a 33 percent change in a travel parameter, such as

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VMT, was a much more reasonable level for assigning full points for the Intermediate Score than a 100 percent change, which would be the implication if no factor were used. To illustrate, without this factor, Percent VMT Reduction could be assigned an Intermediate Score of only 35, the maximum, if all VMT is eliminated. Obviously, this is not a reasonable level of effectiveness for a project. Because of the use of this factor, it is conceivable that a project could be assigned an Intermediate Score greater than the intermediate factor, although a factor of 3 was chosen to minimize this possibility.

From the Emissions Module, percentage changes in each pollutant's emissions will be used as components of this criteria. Similar to the travel impact criteria, the project impact for the reduction in each of the three pollutant emissions is defined as the percentage reduction multiplied by a factor of 3. The reasoning behind using a factor of 3 is the same as the stated above, and there was no obvious reason to use a different factor for each criteria. Half of the emission impact criteria score is assigned to whether or not the project impacts a hot spot or hot grid for CO or PM-10. The project impact value for each of these components is either 1 (affects a hot grid/hot spot) or 0 (does not affect a hot grid/hot spot). The Intermediate Score for each of these components, therefore, will be either the full Intermediate Factor or 0 for each project. Based on this approach, a project that impacts more than one pollutant will achieve a higher score for this criterion.

The methodology used to develop project impacts for each component of the cost-effectiveness criteria is different than those described above because cost-effectiveness is not expressed as a percentage. Instead, a project impact value is assigned based on various ranges of cost-effectiveness; and these are summarized in Table 2-5. The ranges were based on current TCM cost-effectiveness research. As projects are evaluated in a region and more local data on cost-effectiveness are available, these ranges could be updated within the equations in the model. The current ranges apply only to cost-effectiveness calculations using the total public sector cost option.

Table 2-5
Project Impact Values for Cost-Effectiveness Components

Project Impact Value	Cost-Effectiveness Range ($/kg reduced)
1	up to 125
0.75	125 to 250
0.50	250 to 1000
0.25	1000 to 2000
0	2000 and over

The final criterion, Early Project Effectiveness, is based on whether or not the project's emissions impacts are expected to be realized in the short term. "Short term" is defined as being less than three years for this model. Early Project Effectiveness questions should be asked in the application form for the project. The full Intermediate Score of ten will be given to short-term projects, and no score will be given to longer-term projects.

Input Data Required

As indicated in the description of the methodology for this module, the outputs from the Travel Impact Module, the Emissions Module, and the Cost-Effectiveness Module will become inputs to the Criteria Weighting Module. Weighting factors are also required input data for each of 12 criteria. As stated previously, these weighting factors have been initially set for the TTI CM/AQ Evaluation Model; and these will be included as defaults in the Criteria Weighting Module. It is recognized that over time, the priorities of the region may change; therefore, the ability to modify the weighting factors is included as a feature in this module. Changes to the weighting factors can be made only through Paradox. The data flows for this module are illustrated in Figure 2-8.
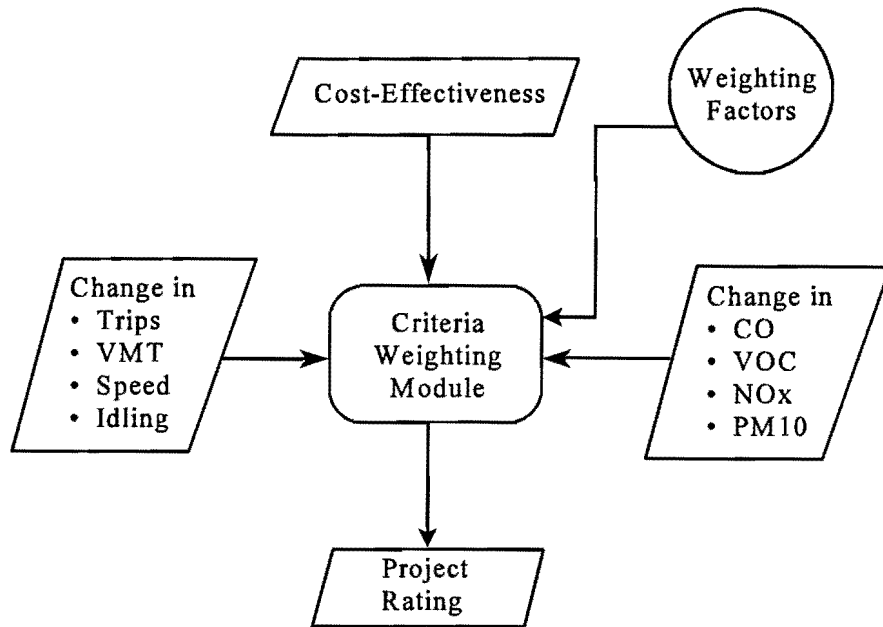
Figure 2-8.   Data Flows for Criteria Weighting Module.

Outputs Developed

The project ratings developed in the Criteria Weighting module are the final outputs for the TTI CM/AQ Evaluation Model. For each project evaluated, a rating will be reported. Because the ratings developed are for each individual project and are not based on a comparison between projects, project ratings from multiple runs of the TTI CM/AQ Evaluation Model can be compared directly.

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SECTION 3
RUNNING THE CM/AQ EVALUATION MODEL

3.1 OVERVIEW OF DATABASE OPERATION

The TTI CM/AQ Evaluation Model is designed so that a user with only a basic knowledge of Paradox can follow the steps outlined in Section 3. The model has been designed with user-friendly menus so that it is easy to move through the database efficiently and to perform key operations. Paradox programs and the TTI CM/AQ Evaluation Model that uses these programs can be accessed with the use of a mouse by pointing to the program name and clicking the button on the left side of the mouse. Alternatively, the arrow keys can be used to highlight the desired program and then striking the "ENTER" key to activate the program.

To use this database model, the user first responds to a series of *yes* or *no* questions to determine the eligibility of the project and then enters baseline travel characteristics (e.g., total number of person trips, percentage of commute trips in the peak period) and assumptions (e.g., elasticities). Based on data collected in the Denver region for the original model, default values for the baseline travel characteristics and the assumptions are included in the database. The user has the choice of using the default values or entering site-specific values for each variable. The purpose of including the default values is so that jurisdictions without extensive data available can still make use of this tool. It is important to keep in mind that the baseline travel characteristics should reflect the geographic area impacted by a particular project and under study. Because many projects will have the same baseline travel characteristics, they can be evaluated together in a model run. Projects with differing baselines (i.e., regions or base years) must be run separately.

For each of the 59 CM/AQ projects included in the database, the user must supply project-specific parameters to identify the particular CM/AQ strategy being evaluated. An example would be subsidizing a transit pass by 50 percent or by 100 percent, where the amount of subsidy is the CM/AQ project-specific parameter. With this input, the resulting impact of the CM/AQ project on number of trips, VMT, and speeds can be calculated.

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The user also supplies information on how the project will affect emissions and on the public sector costs associated with implementing the project. The impact on pollutant emissions and the resulting cost-effectiveness are then calculated. The final output is a project rating based on calculated impacts and criteria weighting factors included in the model.

For each project, the appropriate input values will be obtained from the TIP and CM/AQ applications forms. Local MPO staff should review the data provided carefully to ensure its reasonableness.

Throughout the database, commute and non-commute trips are differentiated. A commute trip is any trip from home to work, or vice versa, including those with intermediate stops (such as for day care or groceries) that occur at any time throughout the day. This is a different definition than those used for trip purposes in network models. For example, a trip from work to the grocery store to home would be a commute trip in this database but would be a work-other trip and an other-home trip in a network model.

The results for each CM/AQ strategy is independent of the values entered in the other CM/AQ strategy categories. In addition, the results for individual CM/AQ projects are not necessarily additive and should not be treated as such. Finally, each model run can contain only one version of each strategy; and all projects in a single run must be consistent with the baseline data entered. If a project is evaluated based on an incorrect baseline, the calculation of the percentage changes in travel and emissions will be incorrect, affecting the project rating.

The following sections present details on operating the TTI CM/AQ Evaluation Model. The highlights of using the model with the Paradox software are summarized in Table 3-1.

Table 3-1
Summary of Commands for Data Entry

Basic Paradox Commands	
Do_It! F2	Saves any changes made for the current analysis, but does not save files, and exits the screen. If no changes are made, can be used to exit. Will not save data if model is exited. To save current files, see "saving files" below.
Alt+F5	Displays and edits numeric value with decimal places that extend beyond the displayed value. When scrolling past variable entries, such numbers will have an asterisk to indicate a hidden value.
Cancel	Escapes current screen and exits to previous screen without saving any data entered. "ESC" key can usually be used in same manner.
Undo	Deletes all changes and restores to values before entering the current screen.
Other Data Entry Notes	
Selecting Options	Mouse used for pointing, highlighting, and selecting choices. In eligibility module, tab key, arrow keys, and space bar can be used to move through choices. ENTER key is used to accept and move to next menu.
Data Entry Records	"Page Down" and "Page Up" keys are used to move from project to project in Travel Impact, Emissions, and Cost-effectiveness modules.
Saving Files	To save entered data before exiting, go to *Inital Set-Up* menu and select *Save Data*. Enter a file name of up to six characters. User will be prompted before overwriting if file already exists.
Percent	Enter all percentages as decimal values; e.g., 51% is entered as "0.51".

3.2 USING THE MENU SYSTEM

To begin using the TTI CM/AQ Evaluation Model, "TTICMAQ" is entered from a DOS prompt; and then the "Enter" key is pressed. This command will open the Paradox software program and automatically transfer the user into the custom-designed application. The menu for the TTI CM/AQ Evaluation Model has the following six choices:

1. *Initial Set-Up*

2. *Input Project Data*

3. *Data I/O*

4. *Run*

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5.   *Reports*

6.   *Exit*

To operate the CM/AQ model, the user will generally move through the menu sequentially. Figure 3-1 presents an overview of the menu system provided in the TTI CM/AQ Evaluation Model. These choices are reviewed in the steps described below:
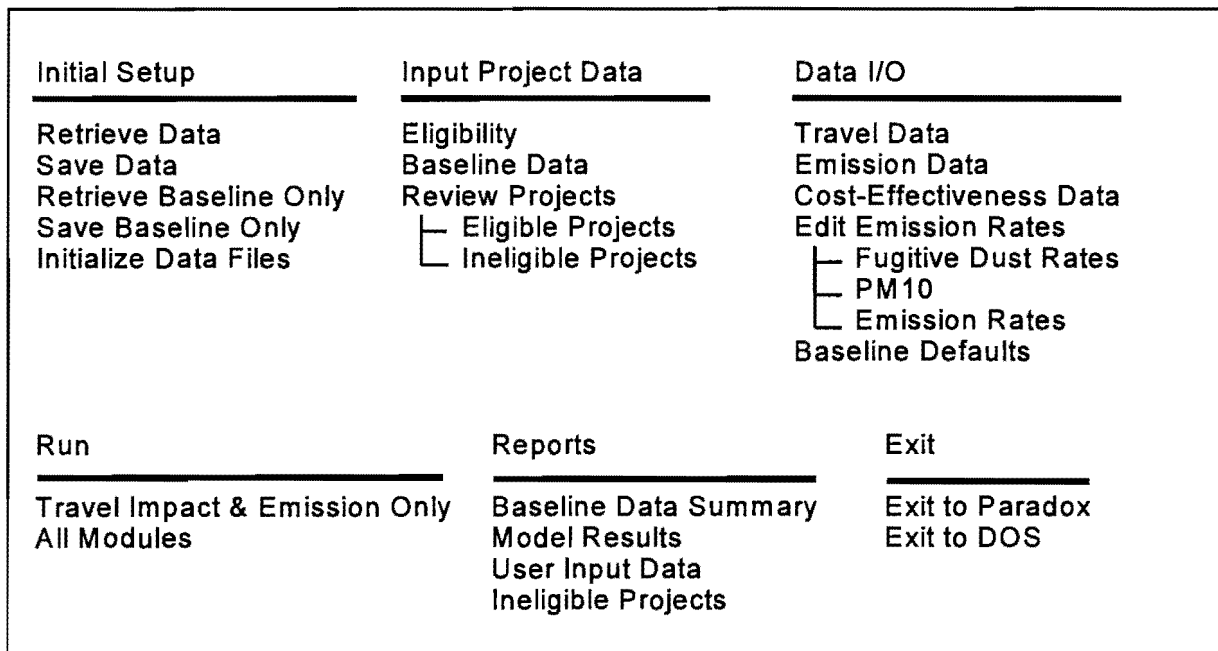
```
┌─────────────────────────────────────────────────────────────────────────────────┐
│                                                                                   │
│  Initial Setup            Input Project Data        Data I/O                      │
│  ────────────             ─────────────────         ───────                       │
│  Retrieve Data            Eligibility               Travel Data                   │
│  Save Data                Baseline Data             Emission Data                 │
│  Retrieve Baseline Only   Review Projects           Cost-Effectiveness Data       │
│  Save Baseline Only        ├─ Eligible Projects     Edit Emission Rates           │
│  Initialize Data Files     └─ Ineligible Projects    ├─ Fugitive Dust Rates       │
│                                                      ├─ PM10                       │
│                                                      └─ Emission Rates            │
│                                                     Baseline Defaults              │
│                                                                                   │
│                                                                                   │
│  Run                          Reports                   Exit                      │
│  ───                          ───────                   ────                      │
│  Travel Impact & Emission Only   Baseline Data Summary    Exit to Paradox         │
│  All Modules                  Model Results             Exit to DOS               │
│                               User Input Data                                     │
│                               Ineligible Projects                                 │
│                                                                                   │
└─────────────────────────────────────────────────────────────────────────────────┘
```

Figure 3-1.   Overview of TTI CM/AQ Evaluation Model Menu System.

Step 1. Retrieving and Saving Files

To retrieve previously saved files or to save newly created or edited files, *Initial Set-Up* in the menu should be selected; and the five choices of *Retrieve Data, Save Data, Retrieve Baseline Data Only, Save Baseline Data Only*, or *Initialize Data Files* will appear on the screen. To retrieve a file, *Retrieve Data* is selected by clicking with the mouse and entering the **six-letter** name of the file. Note that only **six** characters are available for the file name rather than eight, because the last two characters are reserved for use by the model. When using the *Save Data*

command in the program, the user is actually saving three database tables that are specific to the current model run that contain baseline values, data specific to the projects entered, and the results. The *Initialize Data Files* command is used to delete information from the current tables and to start new data files. Current files should be saved before using the initialize command in order to reuse the existing files.

The recommended stage to save files when using the TTI CM/AQ Evaluation Model is after entering data and after running the model. Any work performed after using a Save command in the Files option is not automatically saved. The user who is running the program for the first time can skip Step 1, because no files are available for retrieval and no work has been performed.

Step 2. Beginning a New Session

The *Input Project Data* menu item contains the three options of *Eligibility*, *Baseline Data*, and *Review Projects*. The order of completing these tasks is at the user's discretion, but the Eligibility Module must be used before continuing to other steps. The Eligibility Module enters the names of specific projects into a database table that must be created before using the *Data I/O* menu option.

The Eligibility Module is used to include specific CM/AQ transportation strategies in the model run for evaluation. The *Eligibility* option is chosen under *Input Project Data* and the model asks the user to respond to a series of questions with *yes* or *no* answers. The specific name of the CM/AQ project as it should appear in reports is entered, and then the appropriate TCM category is selected. After clicking on "OK", the user picks the specific measure within the category and again clicks on "OK." The following screen displays a number of questions with the default answer already indicated as *yes*. If these are correct, "OK" is selected and the next screen will appear; if incorrect, the answers should be changed to *no* and then "OK" is selected. Next the user will be asked if other requirements must be met for the project to qualify for CM/AQ funding. The appropriate answer should be selected and the next screen will indicate if the project is eligible for CM/AQ funding and will also ask if the user wishes to process another project. All projects to be included in a single model run should be input. Again, each model run can accommodate only one project for each strategy; and the baseline travel data must be the

same. Each project that qualifies for CM/AQ funding is added by the model to the database table into which the user will enter data for specific variables in the next step. Ineligible projects are placed in a separate table that can be reviewed on screen or printed in the reports menu.

To choose a measure for eligibility screening not listed within the TCM categories, the user goes to *Choose a User Defined TCM*, clicks the left mouse button or tabs to the line and presses the space bar once, this places an X within the brackets next to *Choose a User Defined TCM*. After selecting "OK," another ten categories will be listed, and the user should proceed through the eligibility model as described above. A measure that is eligible from this list will be entered as a user-defined project and only one eligible user-defined project can be entered into the database table in a single model run.

The *Baseline Data* option is used to enter site-specific values for the default values into the Override row that corresponds to the variable. To edit a previously entered value in the Override row, the backspace key is used to delete the values. If an asterisk (*) appears to the right of the number the user must first press the "Alt" and "F5" keys simultaneously before editing the user value . This asterisk indicates that the number contains a value in a decimal place that is not visible on the screen. If the Override value is to be used in the calculations, enter "Y" in the parenthesis next to Override. The letter "N" in parentheses indicates that the default value will be used. When the user is finished entering or editing the values that are specific to the study area, "Do_It!" in the menu bar is selected, which is a SAVE and EXIT command in Paradox.

The *Review Projects* option allows the user to review on the monitor screen either eligible projects or ineligible projects. Information displayed on the screen includes the project name, TCM category, TCM name, and whether the project is eligible for CM/AQ funding. The eligible projects will be included in the table used in the *Data I/O* menu. "Do_It!" is selected to exit this program.

Step 3. Data Entry for Specific CM/AQ Strategies

The *Data I/O* menu option allows the user to enter specific travel impact, emissions, and cost-effectiveness data for eligible CM/AQ projects that were processed in the Eligibility Module in Step 2. Also available from this menu are screens to edit emission factors and baseline

defaults. In general, the data should be entered for the Travel Impact, Emissions, and Cost-Effectiveness Modules in sequential order. Though this order is not required, results from the Emissions or Cost-Effectiveness Module cannot be obtained until the previous module has been run.

After choosing the data entry type, the user will enter the TCM-specific data for each eligible CM/AQ project. The project name entered in the Eligibility Module and the name of the CM/AQ strategy appears in the upper left-hand corner. Beneath these names are the specific data required to run the formulas for that module. If no variable names appear beneath the CM/AQ strategy, then no calculations are required in this module (as is the case for the alternative fuel incentives program and the PM-10 reduction measures in the Travel Impact Module). The values are entered in the right-hand column on the same row as the data variable. Percentages must be entered in decimal format with up to four decimal places: for example 50.5 percent should be entered as a "0.505." Though decimal places will be truncated to less than four places on the screen, the entered value will be maintained when the modules are run. When entering percentage-change in speed for relevant measures in the travel impact module, a positive number indicates a speed increase and a negative number refers to a decrease in average speed. Several measures ask for average idling time per vehicle. Time should be entered in number of seconds.

Emissions Data includes several questions that require *yes/no* or numeric values for answers. A specific project might have a particular benefit to a carbon monoxide hot spot or hot grid or for a PM-10 hot sport or hot grid. To respond to the questions *Impact on CO hot spot/hot grid* and *Impact on PM10 hot spot/hot grid* the following is entered:

"1" Yes

"2" No

The CM/AQ project may be implemented within a particular area type. The user must enter one of the following numeric values to indicate the appropriate area type:

"1" All area types

"2" Central Business District (CBD)

"3" Urban (includes CBD, fringe, urban, and suburban)

"4" Rural

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The *Cost-Effectiveness Data* screen includes two questions to which the user should respond by entering the word rather than a numeric value. *Public* or *CM/AQ* for *Type of Funding Used for TCM* is entered. It is expected that *Public*, which appears as the default value, will be used to be consistent with the current criteria. Enter *Yes* or *No* in response to *Early Project Effectiveness*.

When the user has completed entering the data for each of the three data entry tables, "Do_It!" is selected; and the user can then run the modules.

Changes to the emission rates and baseline values are permanent. If the user is attempting to use multiple scenarios for emission rates and baseline travel characteristics, it is recommended that the user copy the MOBILE5A.DB, PARTEMIS.DB, FUGITIVE.DB, and BASELINE.DB to other file names for each different scenario. Access to editing these databases should be used only when customizing the model for a specific region.

Step 4. Running the TTI CM/AQ Evaluation Model

The user can run the TTI CM/AQ Evaluation Model using one of two options. The menu choice of *Travel Impact & Emissions Only* under the *Run* option will perform only the calculations for these two modules. This option can be used only if the data values for the Travel Impact Module have been entered and the results from this one module need to be viewed. In this case, the results in the emission sections of the results table will be zero. Both travel impact and emissions data must be entered before obtaining emission results. Choosing the *All Modules* will run the Cost-Effectiveness and the Criteria Weighting Modules as well as the Travel Impact and Emission Modules. After running the model, return to Step 1 to save the data entered and the results from the analysis.

Step 5. Viewing the Results

The *Reports* option in the menu is used to view the results from any of the four modules or the data entered into baseline, travel impact, emissions, or cost-effectiveness tables. The four options in the *Reports* menu are as follows:

Baseline Data Summary

Model Results

User Input Data

Ineligible Projects

Choosing *Model Results* will display travel, emission, cost-effectiveness, and project rating results. The results are not sorted by project rating. Development of ordering projects by rating was limited by the Paradox software.

The *User Input Data* choice will report the data entered in all of the modules (Travel Impact, Emissions, and Cost-Effectiveness) in the *Data I/O* menu. The reports can be viewed on the screen, sent to a printer, or sent to an ASCII file. If viewing the reports on screen, the "Page Down", "Page Up", and arrow keys will scroll the text; while clicking on the *Cancel* option in the menu bar will exit the *Reports* option. Choosing of the printer option selects the printer configuration that is set in the Paradox program. If the user chooses the option to create a separate file, an inset screen will appear in which a filename should be entered to save the reports as an ASCII file.

Step 6. Exiting the TTI CM/AQ Evaluation Model

The *Exit* option in the menu provides two choices of exiting to the Paradox program or to DOS. No files or data are automatically saved upon exiting. The CM/AQ Evaluation Model is a custom application designed within Paradox. Several tables within the Emissions Module of this application can be modified only within Paradox but outside the CM/AQ Evaluation Model application. These tables are discussed in the next section.

3.3 MODIFYING TABLES FOR THE EMISSIONS MODULE

Six tables exist within the Paradox program that can be modified, if required, by the user. In most cases, these tables will not need to be modified frequently. Caution should be used when modifying these tables because any changes made to them will remain permanent. One approach to file handling is to create a subdirectory for the original version of these tables as well as for projects that require modifications to the tables. The filenames for the tables used in the TTI

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CM/AQ Evaluation Model must use the names listed. These six tables provide the parameters that determine the values used by the formulas in the Emissions Module. The six tables are:

MOBILE5A.DB	VEHTYPCT.DB
PARTEMIS.DB	COLDPCT.DB
FUGITIVE.DB	DEFEMIS.DB

Each of these files is described and discussed below.

MOBILE5A.DB contains the emission rates from EPA's emission rate model MOBILE5a for the year 1998. The code values used and the file structure of this Paradox table is summarized in Table 3-2. The table contains rates for CO, VOC, and NOx by the seven vehicle types: light duty gasoline vehicle (LDGV), light duty gasoline truck type 1 (LDGT1), light duty gasoline truck type 2 (LDGT2), heavy duty gasoline vehicle (HDGV), light duty diesel vehicle (LDDV), light duty diesel truck (LDDT), and heavy duty diesel vehicle (HDDV). Rates for cold starts, hot starts, idling, and running exhaust emissions are included in the table. The running exhaust emissions vary by speed and are in increments of 2.5 MPH from 2.5 MPH to 65.0 MPH. The rates for VOC include evaporative emissions of running loss, resting loss, and diurnal emissions. This table can be edited using the procedures outlined in Section 2.4.

Table 3-2
File Structure for MOBILE5A.DB Table

Field Name	Code Value for Vehicle and Pollutant Type						
	1	2	3	4	5	6	7
Vehicle Type	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV
Pollutant Type	CO	VOC	NOx				
Emission Rates:							
for Cold Starts	N/A						
for Hot Starts	N/A						
for Idling	N/A						
by Speed:	N/A						
2.5 MPH	N/A						
to							
65.0 MPH	N/A						

Notes:
1. Emission rates to 3 decimal places.
2. Each row is for one vehicle type and one pollutant type.
3. Cold start emission rate = ((100% cold start @ 25.6 MPH) - (100% hot stabilized @ 25.6 MPH)) * 3.59 miles.
4. Hot start emission rate = ((100% hot start @ 25.6 MPH) - (100% hot stabilized @ 25.6 MPH)) * 3.59 miles.

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PARTEMIS.DB contains the vehicle source emission rates for PM-10 generated by EPA's PART5 emission factor model. Table 3-3 contains the code values used to define this Paradox table. This table contains rates for exhaust and wear particulate emissions from vehicles by the seven vehicle types listed above. The exhaust and wear emissions vary by speed and are in increments of 2.5 MPH from 2.5 MPH to 55.0 MPH. This table can be edited using the procedures outlined in Section 2.4. The HDDV vehicle type within PART5 is divided into four additional vehicle types. A weighted average of the emission factors developed for these four vehicle types should be used to represent the HDDV vehicle type in this model.

Table 3-3
File Structure for PARTEMIS.DB Table

Field Name	Code Values						
	1	2	3	4	5	6	7
Vehicle Type PM10 Category	LDGV Exhaust	LDGT1 Exhaust	LDGT2	HDGV	LDDV	LDDT	HDDV
PM10 Emission Rates: by Speed: 2.5 MPH to 55.0 MPH	N/A N/A						

FUGITIVE.DB containing the fugitive dust emission rates for paved and unpaved roads is generated by EPA's PART5 emission factor model. Table 3-4 contains the code values used to define this Paradox table. This table contains fugitive dust rates which vary by speed and are in increments of 2.5 MPH from 2.5 MPH to 55.0 MPH. This table can be edited using the procedures outlined in Section 2.4.

Table 3-4
File Structure for FUGITIVE.DB Table

Field Name	Code Values	
	1	2
Fugitive Category	Unpaved	Paved
Fugitive Emission Rate:		
by Speed		
2.5 MPH	N/A	
to		
55.0 MPH	N/A	

The VEHTYPCT.DB table contains factors to separate the VMT and the vehicle types into the seven vehicle types that are used by the MOBILE5a rates. These factors for the vehicle type percentages are organized according to facility type, area type, and the time periods of peak and off-peak periods, as displayed in Table 3-5. This table also contains different vehicle type groups, because some of the CM/AQ strategies involve only passenger vehicles, commercial vehicles, or diesel vehicles as shown below:

Passenger	Commercial	Diesel
LDGV	LDGT2	LDDV
LDGT1	HDGV	LDDT
LDDV	LDDT	HDDV
	HDDV	

The COLDPCT.DB provides the percentage of vehicle starts that are cold starts according to the facility type, area type, and time period. The table also includes a cold group indicator, because some of the CM/AQ strategies affect only cold starts or only hot starts while others affect both cold and hot starts. Table 3-6 contains the file structure for the COLDPCT.DB table.

The user defines the area type for all but a few of the CM/AQ strategies. The formulas define the time period of peak and off-peak periods. The DEFEMIS.DB contains the values for the other parameters used within the other four tables. These parameters include vehicle group,

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cold group, facility type, and seasonal group, as indicated in Table 3-7. Generally, the only time the user of the CM/AQ Evaluation Model will generally modify the DEFEMIS.DB table is when changing the parameters for the user-defined CM/AQ strategies, which have a default value of "1" for vehicle group, cold group, facility type, and seasonal group.

Table 3-5
File Structure for VEHTYPCT.DB Table

Field Name	Code Value			
	1	2	3	4
Vehicle Type Group	All Types	Passenger	Commercial	Diesel
Time Period	Peak	Off-Peak		
Facility Type	All Types	Freeway	Arterial & Collector	
Area Type	All Types	CBD	Urban	Rural
Vehicle Type Factors:				
Light Duty Gasoline Vehicle	N/A			
Light Duty Gasoline Truck 1	N/A			
Light Duty Gasoline Truck 2	N/A			
Heavy Duty Gasoline Vehicle	N/A			
Light Duty Diesel Vehicle	N/A			
Light Duty Diesel Truck	N/A			
Heavy Duty Diesel Vehicle	N/A			

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Table 3-6
File Structure for COLDPCT.DB Table

Field Name	Code Value			
	1	2	3	4
Cold Start Group	Mixed	100% Cold Starts	100% Hot Starts	
Time Period	Peak	Off-Peak		
Facility Type	All Types	Freeway	Arterial & Collector	
Area Type	All Types	CBD	Urban	Rural
Vehicle Type Factors:				
Light Duty Gasoline Vehicle	N/A			
Light Duty Gasoline Truck 1	N/A			
Light Duty Gasoline Truck 2	N/A			
Heavy Duty Gasoline Vehicle	N/A			
Light Duty Diesel Vehicle	N/A			
Light Duty Diesel Truck	N/A			
Heavy Duty Diesel Vehicle	N/A			

Table 3-7
File Structure for DEFEMIS.DB Table

I. Alpha Numeric Fields - User does not modify		
Field Name	Max. Characters	Description
TCM	9	Reference code for CM/AQ strategy
TCMAT	7	Group heading for CM/AQ Strategy
TCMname	53	Name of CM/AQ Strategy
Emis Formula	12	Type of emission procedure (inactive)

II. Numeric Fields - User may modify, but usually modifies only the user-defined strategies				
Field Name	Code Value			
	1	2	3	4
Vehicle Group	All Types	Passenger	Commercial	Diesel
Cold Group	Mixed	100% Cold Starts	100% Hot Starts	
Facility Type	All Types	Freeway	Arterial & Collector	
Seasonal Group	Winter	Summer		

SECTION 4
SUMMARY

The TTI CM/AQ Evaluation Model represents a significant step forward in the development of analytical methodologies for selecting projects for CM/AQ funding. This model will enable local agency staff to evaluate a wide range of projects on a consistent and comparable basis. The methodology was developed so that staff can defend the process used for recommending projects for CM/AQ funding to the jurisdictions that submit applications. In addition, a documented methodology can now be used to support CM/AQ funding requests to FHWA. Federal, regional, county, and local agencies were involved in the Technical Advising Committee with JHK & Associates for the original model and provided direct input into the development of the criteria and weighting factors.

As mentioned previously, the TTI CM/AQ Evaluation Model has been designed to meet the current needs and priorities of nonattainment regions. These needs and priorities are likely to change over time, so the model has also been designed to be updated and/or further customized in the future. Some updates can be conducted without any reprogramming of the model, such as changing the weighting factors assigned to the criteria or their components. For example, if a region reaches attainment for CO, then the intermediate factors for the emission reduction criteria can be changed so that the project rating is based only on VOC, NOX, and PM-10 reductions. Other updates would require more sophisticated changes to the model, such as adding more strategies and requiring additional programming. In addition, as the TTI CM/AQ Evaluation Model is applied, more data will become available that can be used to update the default values in the model.

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REFERENCES

1.   *CM/AQ Evaluation Model Final Report and User's Guide.* JHK & Associates and Balloffet & Associates for Denver Regional Council of Governments, May 1994.

2.   *CM/AQ Evaluation Model User's Guide.* JHK & Associates for Texas Transportation Institute, March 1995.

APPENDIX A
WORKSHOP SLIDES

CM/AQ Model Workshop

Software and User's Guide

developed by

jhk & associates

for the

Denver Regional Council of Governments

ISTEA and the CM/AQ Program
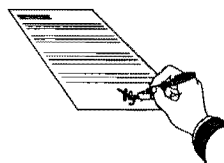
CM/AQ Program Overview

► Eligible/Ineligible Projects

► Funding

► Obligations

► Analysis Tools

CM/AQ Program

► Limited Time: 1992 - 1997

► $6 billion ($1 billion/year)

► Each State Guaranteed 0.5% of Annual Apportionment

CM/AQ Program

▸ 80% Federal Share

▸ Focuses on Projects that Reduce Ozone Precursors

CM/AQ Program

Eligible Projects

▸ TCMs Approved by EPA

▸ Projects which Contribute to Tangible Emission Reductions

CM/AQ Program

Ineligible Projects

▸ Reduce Extreme Cold-Start Emissions

▸ Encourage Removal of Pre-1980 Vehicles

▸ Increase Road Capacity for SOVs

General Classifications of CM/AQ Projects

Transportation Control Measures

▸ Transit Improvements

▸ Shared-Ride Services

▸ Traffic Flow Improvements

General Classifications of CM/AQ Projects

Transportation Control Measures

▸ Demand Management Strategies

▸ Pedestrian and Bicycle Programs

General Classifications of CM/AQ Projects

Non-Transportation Control Measures

▸ Inspection and Maintenance Programs

▸ Other Programs/Projects

Transit Improvements

▸ Expansion

▸ Improvements

▸ Demand/Market Strategies

Shared-Ride Services

▸ Areawide Commute Management Organizations
  ▪ *Carpool Matching Programs*
  ▪ *Vanpool Programs*
  ▪ *Guaranteed Ride Home*

▸ Tax Incentives and Subsidy Programs

Traffic Flow Improvements

- Traffic Signalization/Operations

- Enforcement/Management

- HOV Lanes

Traffic Flow Improvements

Exception

- Cannot Add Additional Lanes
  Except HOV Lanes

Pedestrian and Bicycle Programs

- Pathways

- Amenities

- Education

Inspection and Maintenance Programs

- Technician Training Curriculum

- Enhance/Update Quality Assurance
  Software

- Diagnostic Facility Construction

Other Programs/Projects

▸ Purchase/Conversion of Alternative Fuel Fleet

▸ Feasibility Studies

▸ IVHS (ITS)

CM/AQ Funding

Availability

▸ All States Guaranteed 0.5% Apportionment

▸ Nonattainment States Apportionment Base on:
  ▪ *Severity of Nonattainment*
  ▪ *Nonattainment Area Population*

CM/AQ Funding

Requirements

▸ Funds Must Be Spent in Nonattainment Areas

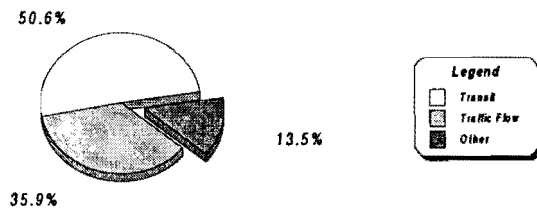▸ Reduce Ozone, Carbon Monoxide, PM10 from Mobile Source Emissions

CMAQ Funding

Process
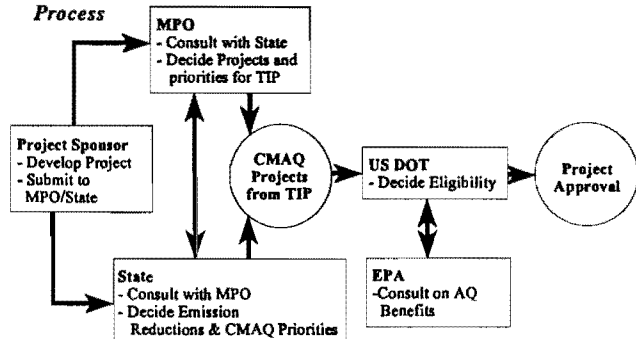
Source: *A Guide to the Congestion Mitigation and Air Quality Improvement Program*, FHWA, 1994.
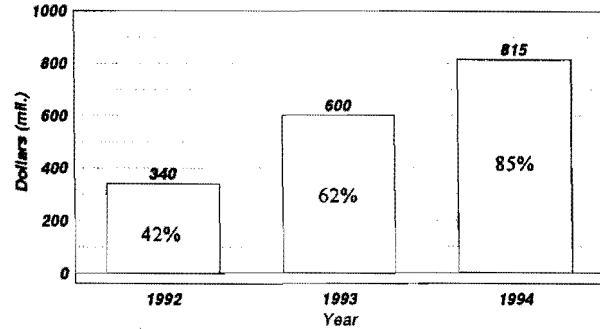
1992 CM/AQ Obligations

National

50.6%

13.5%

35.9%

Legend
☐ Transit
▦ Traffic Flow
■ Other

Source: *A Guide to the Congestion Mitigation and Air Quality Improvement Program,* FHWA, 1994.

Obligations 1992-1994

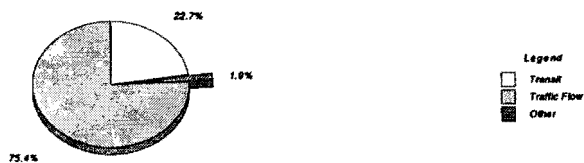*1992-94 Overall Obligation Rate = 64.1%*

Dollars (mil.)

815

600

340

85%

62%

42%

1992   1993   1994
Year

Source: *Clean Air Transportation Report,* 12/94

1992 & 1993 CM/AQ Obligations

Texas

22.7%

1.9%

75.4%

Legend
☐ Transit
▦ Traffic Flow
■ Other

Source: *Investigation of CM/AQ Funding Obligation Improvements,* SWUTC, 1994.

Where Does Texas Stand?

▸ National Obligation Rate = 50%

▸ Texas Obligation Rate = 20%

▸ Texas Apportioned Approx. $90 M / yr.

▸ Texas Apportionment - 3rd Highest

Experiences from Other States

- Washington

- New Jersey

- New York

CM/AQ Analysis Tools

- No EPA methodologies

- Options

CM/AQ Analysis Tools

Options

- Historical Reference Database

- Network-Based Models

- Sketch-Planning Tools

CM/AQ Evaluation Model

Overview

- Introduction
- Model Modules
- General Model Process

CM/AQ Evaluation Model

Introduction

- 60 Strategies
- 4 Pollutants
- 5 Modules

CM/AQ Evaluation Model

Strategies

Improved Public Transit	Rideshare Programs/Services
HOV Facilities	Non-Motorized Facilities
Employer-Based Strategies	Vehicle Idling Controls
Traffic Improvement Projects	Alternative Work Schedules
Park-and-Ride Lots	Alternative Fuels Incentive Programs
Auto/Truck Restrictions	PM10 Reduction Measures
Congestion Pricing	Telecommunications
Parking Management	Other Transportation Projects

CM/AQ Evaluation Model

Modules

- Eligibility

- Travel Impact

- Emissions

CM/AQ Evaluation Model

Modules Continued

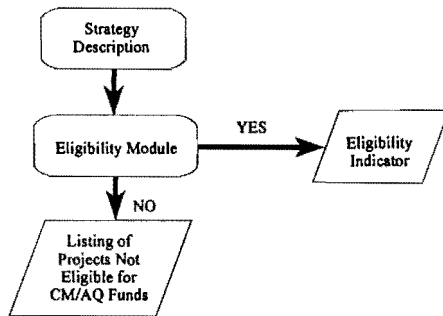- Cost-Effectiveness

- Criteria Weighting

CM/AQ Evaluation Model

Pollutants

- Carbon Monoxide (CO)

- Volatile Organic Compounds (VOC)

- Nitrous Oxides (NOx)

- Particulate Matter (PM10)

Eligibility Module

- Assess a Project's Eligibility

- Uses
  - *Current Federal Law*

  - *U.S. DOT/FHWA Guidelines*
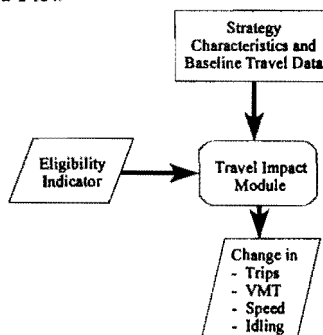
Eligibility Module

Data Flow

Travel Module

▸ **Determines the Project Impacts on**
  - *Vehicle Trips*
  - *Vehicle Miles Traveled (VMT)*
  - *Average Travel Speed*
  - *Vehicle Idling Time*

▸ **Congestion Mitigation Not Directly Assessed**
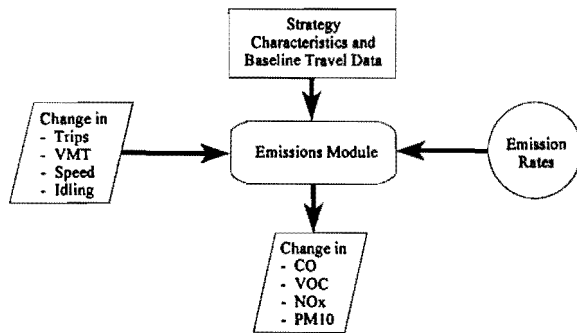
Travel Module

Data Flow

Emissions Module

▸ **Quantifies Emission Impacts of Projects**

▸ **Baseline & Incremental Changes**

▸ **Key Pollutants**

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Emissions Module
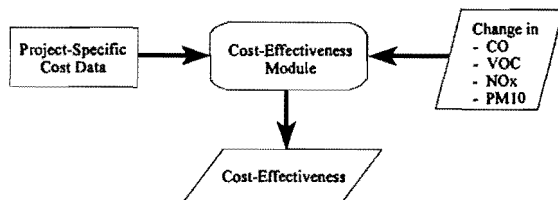
Data Flow

Cost-Effectiveness Module

▸ Total Cost ($)

▸ Dollars Invested per Pollutant Kilogram Reduced ($/kg)

Cost-Effectiveness Module

Data Flow

Criteria Weighting Module

▸ Develop Overall Rating

▸ Only Eligible Projects

▸ Maximum Rating = 100

Criteria Weighting Module

Factor	Value
Travel Impacts	30
Emissions Impacts	30
Cost-Effectiveness	30
Early Project Effectiveness	10
TOTAL	100

Criteria Weighting Module

Weighting Factors

► **Travel Impacts**
- *Percent VMT Reduction*
- *Percent Speed Increase*
- *Percent Idling Reduction*

Criteria Weighting Module

Weighting Factors Continued

► **Emissions Impacts**
- *Percent CO Reduction*
- *Percent VOC Reduction*
- *Percent NOx Reduction*
- *Percent PM10 Reduction*
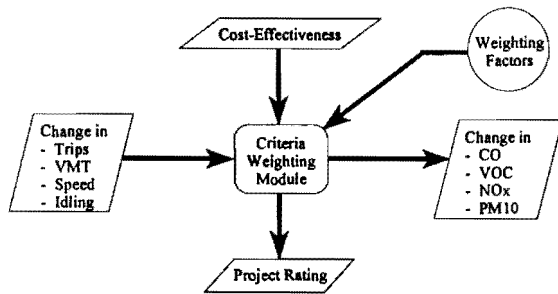- *CO Hot Grid/Hot Spot*
- *PM10 Hot Grid/Hot Spot*

Criteria Weighting Module

Weighting Factors Continued

► **Cost-Effectiveness**
- *CO Cost per kg Reduced*
- *VOC Cost per kg Reduced*
- *NOx Cost per kg Reduced*
- *PM10 Cost per kg Reduced*
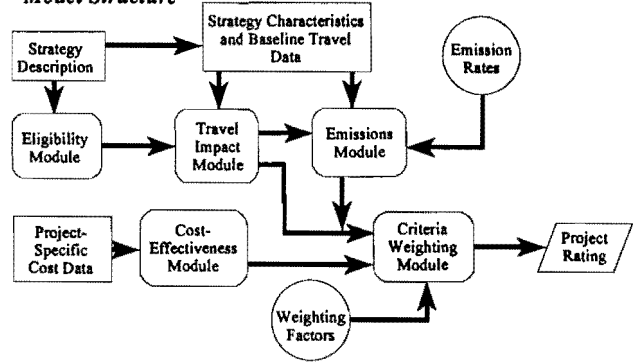
► **Early Project Effectiveness**

Criteria Weighting Module

Data Flow

CM/AQ Evaluation Model

Model Structure

General Model Process
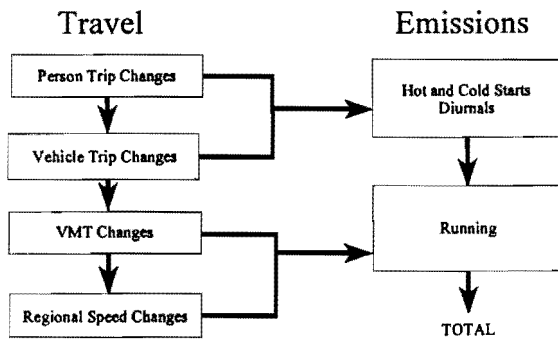
Data Requirements for the CM/AQ Model

Overview

- Travel
- Emissions
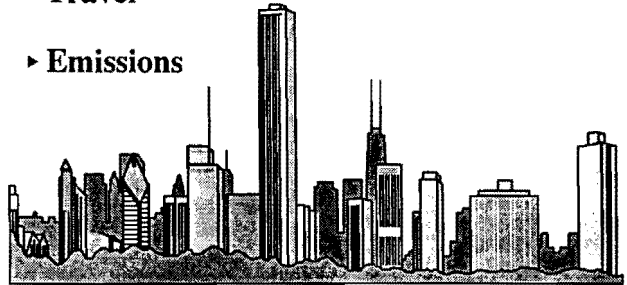
Travel Data

- Baseline
- TCM Specific

Travel Data

Baseline

- Commute/Non-Commute Trips
- Time Periods
- Elasticities
- Other

Commute/Non-Commute Trips

- Commute Trip
  - *Home-Work Including Intermediate Stops*
  - *Different from Network Models*
  - *Trip Chaining*

- Non-Commute Trips

Commute Trip Definition
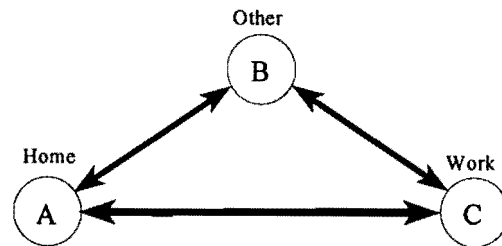
Time Periods

- Average 24-Hour Period

- Peak Period (AM & PM)

- Off-Peak Period

Elasticities

Types Used in CM/AQ Evaluation Model

- Speed to Volume

- Mode Choice to Travel Time

- Mode Choice to Cost

Elasticities

Development

- Point

- Arc

- Shrinkage

Other

- Vehicle/Person Trips

- VMT

- Regional Speed

TCM Specific Travel Data

- Travel
  - *Participants*
  - *Change in Cost*

- Emissions
  - *Hot Spot/Hot Grid*
  - *Area Type*
  - *Speeds*

Emission Data

- Start Fractions

- MOBILE Emission Factors
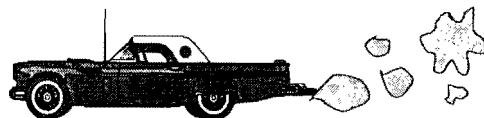
MOBILE Emission Factors

- Seasonal

- 24-Hour Period

- Vehicle Types

Vehicle Type Comparison

CM/AQ Evaluation Model	MOBILE5a
LDGV	LDGV
LDGT1	LDGT1
LDGT2	LDGT2
HDGV	HDGV
LDDV	LDDV
LDDT	LDDT
HDDV	HDDV
No Equiv.	MC
Buses	HDDV

Starting Emission Rates

- Cold Start Rate

  = (100% Cold Start@25.6 MPH - 100% Hot Stabilized@25.6 MPH) * 3.59 miles

- Hot Start Rate

  = (100% Hot Start@25.6 MPH - 100% Hot Stabilized@25.6 MPH) * 3.59 miles

Gathering Data for the Model
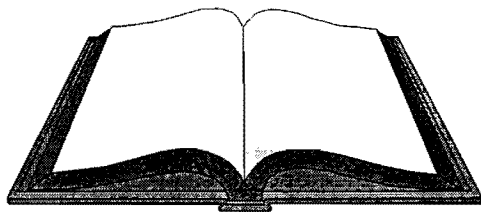
Data Sources

- Census/CTPP
- NPTS
- Traditional Planning Models
- TxDOT District Offices

Data Sources

Continued

- MPO
- Transit Agency
- ITS

Census/CTPP

- Trip Length
- Trips
- Mode
- Employment

NPTS

▸ Total Trips

▸ Trip Purpose

▸ Average Travel Time

▸ VMT

NPTS

▸ Average Vehicle Occupancy

▸ Mode

▸ Household Information

▸ Breakdown by MSA

Traditional Planning Models

▸ Trips
- *Total*
- *Trip Length*
- *Peak/Off-Peak*

▸ Speeds
- *Peak*
- *Off-Peak*

TxDOT District Offices

▸ VMT

▸ Vehicle Registration

MPO

- Depends on Size/Resources

- Various Data

ITS

- Numerous Applications
  - *Video*

  - *AVI*

Transit Agency

- Ridership

- VMT

- Park-and-Ride Lot Utilization

General Recommendations

- Use Census as Foundation

- Be Consistent in Data Gathering

- Use Defaults Only When Necessary

- Use Common Sense

Model Basics I
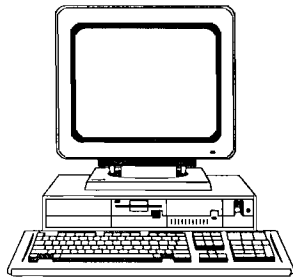
Overview

- Starting the Model

- Data Entry/Movement

- Menu System

Starting the Model

- Type "CMAQ" at DOS Prompt

- Press ENTER

Data Entry/Movement

- Do_It!
  - *Saves Changes for Current Analysis*

  - *DOES NOT Save Files*

  - *Exits Current Screen*

Data Entry/Movement

Continued

▸ **Alt+F5**
- *Display and Edit Numeric Values w/ Decimal Places that Extend Beyond Displayed Value*

- *Asterisk (*) Indicates Hidden Value*

Data Entry/Movement

Continued

▸ **Cancel**
- *Escape Current Screen*

- *DOES NOT Save Data*

- *"ESC" Key Performs Same Function*

Data Entry/Movement

Continued

▸ **Undo**
- *Delete All Changes*

- *Restore to Previously Saved Values*

Data Entry/Movement

Continued

▸ **Selecting Options**
- *Mouse: Point, Highlight, & Select Choices*

- *Tab, Arrow Keys, & Space Bar: Move Through Choices*

- *Enter Key: Accept & Move to Next Menu*

Data Entry/Movement

Continued

▸ **Data Entry Records**
- *"Page Down" & "Page Up":
  Move Between Projects*

Data Entry/Movement

Continued

▸ **Saving Files**
- *Select "Initial Set-Up" Menu*
- *Select "Save Data"*
- *Enter Filename Up to 6 Letters*
- *If Filename Exists, User Prompted Before
  Overwriting*

Data Entry/Movement

Continued

▸ **Percent**
- *Enter as Decimal Values*
- *51% = 0.51*

▸ **Time**
- *Enter as Seconds*
- *Enter as Minutes or Hours When Noted*

Menu System

▸ **Initial Set-Up**

▸ **Input Project Data**

▸ **Data I/O**

Menu System

Continued

► **Run**

► **Reports**

► **Exit**

Menu System

Initial Set-Up

► **Options**
  - *Retrieve Data*
  - *Save Data*
  - *Retrieve Baseline Data Only*
  - *Save Baseline Data Only*
  - *Initialize Data Files*

Initial Set-Up

Retrieving Files

► Click on Retrieve File

► Enter the 6 Letter Name of the File

► The Last 2 Characters are Reserved by the Model

Initial Set-Up

Saving Files

► Click on Save Data

► Model saves 3 tables

► Recommended Practice: After Data Entry and After Running Model

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Initial Set-Up

Initialize Data Files

▸ Deletes Current Tables to Start a New Data File

▸ Save Data Files Before Initializing If You Want to Reuse Existing Files

Menu System

Input Project Data

▸ Options
  ▪ *Eligibility*

  ▪ *Baseline Data*

  ▪ *Review Projects*

Input Project Data

Eligibility

▸ Enter Name of Project

▸ Pick TCM Category

▸ Pick Specific Measure

Input Project Data

Baseline Data

▸ To Modify
  ▪ *Backspace Over "N"*

  ▪ *Hit SPACE*

  ▪ *Click on Do_It!*

Input Project Data

Review Projects

► Displays
  - *Project Name*
  - *TCM Category*
  - *TCM Name*
  - *Eligiblity for CM/AQ Funding*

► Click Do_It! to Exit

Menu System

Data I/O

► Options
  - *Travel*

  - *Emissions*

  - *Cost-Effectiveness*

► SAVE DATA AFTER THIS STEP

Data I/O

Travel

► Strategy Name in Upper Left Corner

► Enter Specific Data

► No Data = No Calculations

Data I/O

Emissions

► Hot Spot/Hot Grid

► Area Type
  - *All Types*
  - *CBD*
  - *Urban*
  - *Rural*

Data I/O

▶ **Funding Type**
  ▪ *Public*

  ▪ *CM/AQ*

▶ **Early Project Effectiveness**

Menu System

▶ **Options**
  ▪ *Travel Impact and Emissions Only*

  ▪ *All Modules*

▶ **SAVE DATA AFTER THIS STEP**

Menu System

▶ **Options**
  ▪ *Baseline Data Summary*

  ▪ *Model Results*

  ▪ *User Input Data*

  ▪ *Ineligible Projects*

Reports

▶ **Output**
  ▪ *Screen*

  ▪ *Printer*

  ▪ *File*

Menu System

▸ **Options**
  ▪ *Exit to Paradox*

  ▪ *Exit to DOS*

▸ **NO FILES SAVED
  AUTOMATICALLY**

Model Basics II

Overview

- Criteria Weighting

- Emission Factors

Criteria Weighting

- CRITERIA.DB

- Group & Intermediate Factors

- Changes Permanent

CRITERIA.DB

File Structure

Criteria	Intermediate Factor	Weighting Factor
Travel Impacts		30
Travel_VMT	35	
Travel_Speed	40	
Travel_Idling	25	
Emission Impacts		30
Emission_CO	20	
Emission_VOC	10	
Emission_NOx	10	
Emission_PM10	20	
Emission_CO Hot Grid...	20	
Emission_PM10 Hot Grid...	20	
Cost-Effectiveness		30
Cost_CO	30	
Cost_VOC	20	
Cost_NOx	20	
Cost_PM10	30	
Early Project Effectiveness		10

Emission Factors

▸ 5 Files
  ▪ *MOBILE5A.DB*
  ▪ *PM10EMIS.DB*
  ▪ *VEHTYPCT.DB*
  ▪ *COLDPCT.DB*
  ▪ *DEFEMIS.DB*

▸ Use Paradox to Edit Files

Emission Factor Data Entry

Continued

▸ Type "PARADOX" at DOS Prompt

▸ Edit "FILENAME"

▸ Save File

MOBILE5A.DB

▸ Winter or Summer

▸ 4 Pollutants

▸ 7 Vehicle Types

MOBILE5A.DB

Continued

▸ Rates: Cold and Hot Starts, Idling, and Running Exhaust

▸ Speeds: 2.5 MPH - 65.0 MPH, increments of 2.5 MPH

MOBILE5A.DB

Continued

▸ **VOC Rates Include Evaporative Emissions**
  - *Running Loss*
  - *Resting Loss*
  - *Diurnal Evaporative*

MOBILE5A.DB

File Structure

Field Name	Code Value for Vehicle and Pollutant Type						
	1	2	3	4	5	6	7
Vehicle Type	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV
Pollutant Type	CO	VOC	NOx				
Emission Rates:							
for Cold Starts	n/a						
for Hot Starts	n/a						
for Idling	n/a						
for Speed:							
2.5 MPH	n/a						
to							
65.0 MPH	n/a						

NOTE:
1. Emission rates to 3 decimal places
2. Each row is for one vehicle type and one pollutant type

PM10EMIS.DB

▸ **Summer and Winter**

▸ **Rates From Colorado State Dept. of Environmental Quality**

▸ **NOT Compatible with PART5**

PM10EMIS.DB

File Structure

Field Name	Code Values			
	1	2	3	4
Seasonal Group	Winter	Summer		
Time Period	Peak	Off-Peak		
Facility Type	All Types	Freeway	Arterial & Collector	
Area Type	All Types	CBD	Urban	Rural
PM10 Emission Rate	n/a			

Analogy

Tree Structure
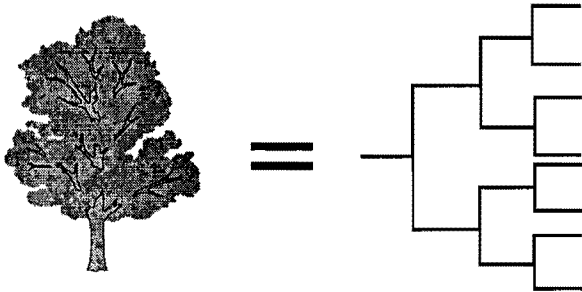
VEHTYPCT.DB

- ▸ Separate VMT and Vehicle Trips
- ▸ 7 Vehicle Types
- ▸ Organization

VEHTYPCT.DB

File Structure

Field Name	Code Value			
	1	2	3	4
Vehicle Type Group	All Types	Passenger	Commercial	Diesel
Time Period	Peak	Off-Peak		
Facility Type	All Types	Freeway	Arterial & Collector	
Area Type	All Types	CBD	Urban	Rural
Vehicle Type Factors:				
LDGV	n/a			
LDGT1	n/a			
LDGT2	n/a			
HDGV	n/a			
LDDV	n/a			
LDDT	n/a			
HDDV	n/a			

COLDPCT.DB

- ▸ Percentage of Vehicle Starts that are Cold

- ▸ Organization
  - ▪ *Facility Type*
  - ▪ *Area Type*
  - ▪ *Time Period*

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COLDPCT.DB

File Structure

Field Name	Code Value			
	1	2	3	4
Cold Start Group	Mixed	100% Cold	100% Hot	
Time Period	Peak	Off-Peak		
Facility Type	All Types	Freeway	Arterial & Collector	
Area Type	All Types	CBD	Urban	Rural
Vehicle Type Factors:				
LDGV	n/a			
LDGT1	n/a			
LDGT2	n/a			
HDGV	n/a			
LDDV	n/a			
LDDT	n/a			
HDDV	n/a			

DEFEMIS.DB

File Structure

I. Alpha Numeric Fields - User Dos Not Modify

Field Name	Maximum Characters	Description
TCM	9	Reference code for CM/AQ strategy
TCMAT	7	Group heading for CM/AQ strategy
TCMname	53	Name of CM/AQ strategy
Emis Formula	12	Type of Emission procedure (inactive)

II. Numeric Fields - User May Modify, But Usually Only the User-Defined Strategies

Field Name	Code Value			
	1	2	3	4
Vehicle Group	All Types	Passenger	Commercial	Diesel
Cold Group	Mixed	100% Cold	100% Hot	
Facility Type	All Types	Freeway	Arterial & Collector	
Seasonal Group	Winter	Summer		

APPENDIX B
TRAVEL IMPACT EQUATIONS

IMPROVED PUBLIC TRANSIT

INCREASED TRANSIT SERVICE

Baseline Travel Characteristics
Peak person trips
Off-peak person trips
Pct of peak trips that are transit
Pct of off-peak trips that are transit
Pct of peak trips that are commute trips
Pct of off-peak trips that are commute trips
Pct of peak trips that are non-commute trips
Pct of off-peak trips that are non-commute trips
Avg transit commute trip length
Avg transit non-commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Total revenue miles during the peak
Total revenue miles during the off-peak
Increase in revenue miles during the peak
Increase in revenue miles during the off-peak
Pct of transit system affected
Pct decrease in wait time during the peak
Pct decrease in wait time during the off-peak˙
Pct of transit ridership increase that equals the trip reduction
Pct decrease in travel time during the peak
Pct decrease in travel time during the off-peak

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed
Number of new buses
Number of new bus miles

Assumptions
Elasticity of transit use with respect to service during peak
Elasticity of transit use with respect to service during off-peak
Elasticity of transit use with respect to travel time during peak
Elasticity of transit use with respect to travel time during off-peak
Elasticity of transit use with respect to wait time in peak
Elasticity of transit use with respect to wait time in off-peak
Peak elasticity of speed with respect to volume
Off-Peak elasticity of speed with respect to volume

Travel Impact Equations

(1)   Increase in Revenue Miles

Peak Trip Reduction = ((Increase in revenue miles during the peak)/(Total revenue miles during the peak))*(Elasticity of transit use with respect to service during the peak)*(Peak person trips)*(Percent of peak trips that are transit)*(Percent of transit ridership increase that equals the trip reduction)

Total Trip Reduction = ((Peak trip reduction)+(Increase in revenue miles during the off-peak)/(Total revenue miles during the off-peak))*(Elasticity of transit use with respect to service during the off-peak)*(Off-peak person trips)*(Percent of off-peak trips that are transit)*(Percent of transit ridership increase that equals the trip reduction)

(2)   Decrease in Travel Time

Peak Trip Reduction = (Percent decrease in travel time during the peak)*(Elasticity of transit use with respect to travel time during the peak)*(Peak person trips)*(Percent of peak trips that are transit)*(Percent of transit system affected)*(Percent of transit ridership increase that equals the trip reduction)

Total Trip Reduction = (Peak trip reduction)+[(Percent decrease in travel time during the off-peak)*-(Elasticity of transit use with respect to travel time during the off-peak)*(Off-peak person trips)*(Percent of off-peak trips that are transit)*(Percent of transit system affected)*(Percent of transit ridership increase that equals the trip reduction)]

(3)   Decrease in Headway

Peak Trip Reduction = (Percent decrease in wait time during the peak)*-(Elasticity of transit use with respect to wait time in the peak)*(Peak person trips)*(Percent of peak trips that are transit)*(Percent of transit system affected)*(Percent of transit ridership increase that equals the trip reduction)

Total Trip Reduction = (Peak trip reduction)+[(Percent decrease in wait time during the off-peak)*-(Elasticity of transit use with respect to wait time in the off-peak)*(Off-peak person trips)*(Percent of off-peak trips that are transit)*(Percent of transit system affected)*(Percent of transit ridership increase that equals the trip reduction)]

Sum of all three measures

Total Trip Reduction = ΣTotals
Peak Trip Reduction = ΣPeaks
Off-Peak Trip Reduction = ΣTotals - ΣPeaks

All other parameters affected the same for all three measures

Peak VMT Reductions = (Peak trip reduction)*[(Percent of peak trips that are commute trips)*(Avg. transit commute trip length)+(Percent of peak trips that are non-commute trips)*(Avg transit non-commute trip length)]

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Off-peak VMT Reduction = (Off-peak trip reduction)*[(Percent of off-peak trips that are commute trips)*(Avg. transit commute trip length)+(Percent of off-peak trips that are non-commute trips)*(Avg. transit non-commute trip length)]

Total VMT Reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

EXPRESS BUS

Baseline Travel Characteristics
Base peak VMT

TCM Specific - Decrease headways
Existing headway
Revised headway
Number of current transit riders on affected express bus routes

TCM Specific - Convert regular bus routes
Existing travel time
Revised travel time
Pct of riders who can use express bus
Number of current transit riders on affected routes

TCM Specific - Both measures
Pct of transit ridership increase that equals the trip reduction
Average express bus trip length

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed
Number of new buses
Number of new bus miles

Assumptions
Elasticity of transit use with respect to headway
Elasticity of transit use with respect to travel time
Peak elasticity of speed with respect to volume

Travel Impact Equations

(1)   Decrease headways on existing routes (in minutes)

Peak Trip Reduction = [(Existing headway)-(Revised headway)]/(Existing headway)*-(Elasticity of transit use with respect to headway)*(Number of current transit riders on affected express bus routes)*(Percent of transit ridership that equals the trip reduction)

(2)   Convert regular bus routes to express routes

Peak Trip Reduction = [(Existing travel time)-(Revised travel time)]/(Existing travel time)*-(Elasticity of transit use with respect to travel time)*(Number of current transit riders on affected routes)*(Percent of riders who can use express bus)*(Percent of transit ridership that equals the trip reduction)

Sum of both measures

Peak Trip Reduction = Σ Peak

All other parameters the same

Total Trip Reduction = Peak Trip Reduction

Off-Peak Trip Reduction = 0
Peak VMT Reduction = (Peak Trip Reduction)*(Average express bus trip length)
Off-Peak VMT Reduction = 0
Total VMT Reduction = (Peak VMT Reduction)

Percent Peak Speed Change = [(Peak VMT Reduction)/(Base Peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = 0

PARATRANSIT

Baseline Travel Characteristics
Peak person trips
Off-peak person trips
Avg transit commute trip length
Pct of peak trips that are non-commute trips
Pct of off-peak trips that are commute trips
Pct of off-peak trips that are non-commute trips
Base peak VMT
Base off-peak VMT

TCM Specific
Pct increase in peak transit use
Pct increase in off-peak transit use
Pct of transit ridership increase that equals the trip reduction

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed
Number of new paratransit vehicles
Number of new paratransit miles

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Peak Trip Reduction = (Peak person trips)*(Pct increase in peak transit use)*(Pct of transit ridership increase that equals the trip reduction)

Off-peak Trip Reduction = (Off-peak person trips)*(Pct of increase in off-peak transit use)*(Pct of transit ridership increase that equals the trip reduction)

Total Trip Reduction = (Peak Trip Reduction)+(Off-peak Trip Reduction)

Peak VMT Reductions=(Peak trip reduction)*(((Pct of peak trips that are commute trips)*(Avg transit commute trip length))+((Pct of peak trips that are non-commute trips)*(Avg transit non-commute trip length)))

Off-peak VMT reduction=(Off-peak trip reduction)*(((Pct of off-peak trips that are commute trips)*(Avg transit commute trip length))+((Pct of peak trips that are non-commute trips)*(Avg transit non-commute trip length)))

Total VMT Reduction = (Peak VMT reduction)+(Off peak VMT reduction)

Pct Peak Speed Change = ((Peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change =((Off-peak VMT reduction)/(Base off-peak VMT))*-(Off-peak elasticity of speed with respect to volume)

LIGHT RAIL

Baseline Travel Characteristics
Peak person trips
Off-peak person trips
Pct of peak trips that are transit
Pct of off-peak trips that are transit
Pct of peak trips that are commute trips
Pct of off-peak trips that are commute trips
Pct of peak trips that are non-commute trips
Pct of off-peak trips that are non-commute trips
Base peak VMT
Base off-peak VMT

TCM Specific
Pct of transit system affected
Pct of transit ridership increase that equals the trip reduction
Pct decrease in travel time during the peak
Pct decrease in travel time during the off-peak
Avg light rail commute trip length
Avg light rail non-commute trip length

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Elasticity of transit use with respect to travel time during peak
Elasticity of transit use with respect to travel time during off-peak
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

> Peak trip reduction=(Pct decrease in travel time during the peak)*-(Elasticity of transit use with respect to travel time during the peak)*(Peak person trips)*(Pct of peak trips that are transit)*(Pct of transit system affected)*(Pct of transit ridership increase that equals the trip reduction)

> Total trip reduction=(ΔTT Peak trip reduction)+((Pct decrease in travel time during the off-peak)*-(Elasticity of transit use with respect to travel time during the off-peak)*(Off-peak person trips)*(Pct of off-peak trips that are transit)*(Pct of transit system affected)*(Pct of transit ridership increase that equals the trip reduction))

> Peak VMT Reduction=(Peak trip reduction)*((Pct of peak trips that are commute trips)*(Avg light rail commute trip length)+(Pct of peak trips that are non-commute trips)*(Avg light rail non-commute trip length))

> Off Peak VMT reduction=(Off-peak trip reduction)*((Pct of off-peak trips that are commute trips)*(Avg light rail commute trip length)+(Pct of off-peak trips that are non-commute trips)*(Avg light rail non-commute trip length))

Total VMT Reduction=(Peak VMT reduction)+(Off-peak VMT reduction)

Pct Peak Speed Change=(Peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change=((Off-peak VMT reduction)/(Base off-peak VMT))*-(Off peak elasticity of speed with respect to volume)

BUS SIGNAL PRE-EMPTION

Baseline Travel Characteristics
Peak person trips
Off-peak person trips
Pct of peak trips that are transit`
Pct of off-peak trips that are transit
Avg transit commute trip length
Avg transit non-commute trip length
Pct of peak trips that are commute trips
Pct of peak trips that are non-commute trips
Pct of off-peak trips that are commute trips
Pct of off-peak trips that are non-commute trips
Base peak VMT
Base off-peak VMT

TCM Specific
Change in peak travel time on affected routes
Change in off-peak travel time on affected routes
Existing peak travel time on affected routes
Existing off-peak travel time of affected routes
Pct of transit system affected during the peak
Pct of transit system affected during the off-peak
Pct of peak speed decrease due to signal timing changes
Pct of off-peak speed decrease due to signal timing changes
Pct of transit ridership increase that equals the trip reduction

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Elasticity of transit use with respect to travel time during the peak
Elasticity of transit use with respect to travel time during the off-peak
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

> Peak Trip Reduction =[(Change in peak travel time on affected routes)/(Existing peak travel time on affected routes)]*-(Elasticity of transit use with respect to travel time during the peak)*(Peak person trips)*(Percent of peak trips that are transit)*(Percent of transit system affected during the peak)*(Percent of transit ridership increase that equals the trip reduction)

> Off-Peak Trip Reduction =[(Change in off-peak travel time on affected routes)/(Existing off-peak travel time on affected routes)]*-(Elasticity of transit use with respect to travel time during the off-peak)*(Off-peak person trips)*(Percent of off-peak trips that are transit)*(Percent of transit system affected during the off-peak)*(Percent of transit ridership increase that equals the trip reduction)

> Total Trip Reduction = (Peak trip reduction)+(Off-peak trip reduction)

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Peak VMT Reduction = (Peak trip reduction)*[[(Percent of peak trips that are commute trips)*(Avg transit commute trip length)] + [(Percent of peak trips that are non-commute trips)*(Avg transit non-commute trip length)]]

Off-Peak VMT Reduction = (Off-peak trip reduction)*[[(Percent of off-peak trips that are commute trips)*(Avg transit commute trip length)] + [(Percent of off-peak trips that are non-commute trips)*(Avg transit non-commute trip length)]]

Total VMT Reduction = (Peak VMT reduction) + (Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)-(Percent peak speed decrease due to signal timing changes)

Percent Off-peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)-(Percent off-peak speed decrease due to signal timing changes)

ACTIVITY CENTER SHUTTLES

Baseline Travel Characteristics
none

TCM Specific
Number of rides provided on shuttle
Pct of trips that were previously walking
Pct of shuttle trips in the peak
Avg shuttle length

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
none

Travel Impact Equations

Total Trip Reduction = (Number of rides provided on shuttle)*(1-(Pct of trips that were previously walking))

Peak Trip Reduction =(Total Trip Reduction)*(Pct of shuttle trips in the peak)

Off-Peak Trip Reduction = (Total trip reduction)-(Peak Trip Reduction)

Peak VMT Reduction =(Peak trip Reduction)*(Avg shuttle trip length)

Off-peak VMT Reduction =(Off-peak Trip Reduction)*(Avg shuttle trip length)

Total VMT Reduction =(Peak VMT Reduction)

TRANSIT ADVANCED TRAVELER INFORMATION SYSTEM

Baseline Travel Characteristics
peak person trips
Off-peak person trips
Avg transit commute trip length
Avg transit non-commute trip length
Pct of peak trips that are commute trips
Pct of peak trips that are non-commute trips
Pct of off-peak trips that are commute trips
Pct of off-peak trips that are non-commute trips
Base peak VMT
Base off-peak VMT

TCM Specific
Pct increase in peak transit use
Pct increase in off-peak transit use
Pct of transit ridership increase that equals the trip reduction

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Peak Trip Reduction = (Peak person trips)*(Pct increase in peak transit use)*(Pct of transit ridership increase that equals the trip reduction)

Off-peak Trip Reduction = (Off-peak person trips)*(Pct of increase in off-peak transit use)*(Pct of transit ridership increase that equals the trip reduction)

Total Trip Reduction =(Peak trip reduction)+(Off-Peak Trip Reduction)

Peak VMT Reductions=(Peak trip reduction)*(((Pct of peak trips that are commute trips)*(Avg transit commute trip length))+((Pct of peak trips that are non-commute trips)*(Avg transit non-commute trip length)))

Off-peak VMT reduction=(Off peak trip reduction)*(((Pct of off-peak trips that are commute trips)*(Avg transit commute trip length))+((Pct of off-peak trips that are non-commute trips)*(Avg transit non-commute trip length)))

Total VMT Reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Pct Peak Speed Change+((Peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

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Pct Off-peak Speed Change=((Off-peak VMT reduction)/(Base off-peak VMT))*-(Off-peak elasticity of speed with respect to volume)

HOV FACILITIES

FREEWAY HOV LANES

Baseline Travel Characteristics
Pct of ridesharing that is commute
Pct of ridesharing that is non-commute
Avg carpool commute trip length
Avg carpool non-commute trip length
Avg carpool size
Base peak VMT
Base off-peak VMT

TCM Specific
Increase in Number of HOVs
Pct of new HOV passengers who still make a trip
Pct of ridesharers who previously rode transit
Induced number of vehicle trips on mixed-flow lanes due to additional capacity
Pct of maximum VMT realized due to circuity of ridesharing

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Peak Trip Reduction =((Increase in Number of HOVs)*2*((1-(1/(Avg carpool size)))*(1-(Pct of new HOV passengers who still make a trip)-(Pct of ridesharers who previously rode transit)))-(Induced number of vehicle trips on mixed-flow lanes due to additional capacity)

Off-peak Trip Reduction = (Induced number of vehicle trips on mixed-flow lanes due to additional capacity)

Total Trip Reduction =(Peak Trip Reduction)+(Off-peak Trip Reduction)

Peak VMT Reduction = (Peak Trip Reduction)*(1+(Pct of new HOV passengers who still make a trip))*(((Pct of ridesharing that is commute)*(Avg carpool commute trip length))+((Pct of ridesharing that is non-commute)*(Avg carpool non-commute trip length)))*(Pct of maximum VMT realized due to circuity of ridesharing)

Off-Peak VMT Reduction=(Off-peak Trip Reduction)*(1+(Pct of new HOV passengers who still make a trip))*(((Pct of ridesharing that is commute)*(Avg carpool commute trip length))+((Pct of ridesharing that is non-commute)*(Avg carpool non-commute trip length)))*(Pct of ridesharing that is non-commute)*(Avg circuity of ridesharing)

Total VMT Reduction=(Peak VMT Reduction)+ Result.y["Off-peak VMT Reduction)

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Pct Peak Speed Change=((Peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change=((Off-peak VMT reduction)/(Base off-peak VMT))-(Off-peak elasticity of speed with respect to volume)

ARTERIAL HOV LANES

Baseline Travel Characteristics
Pct of ridesharing that is commute
Pct of ridesharing that is non-commute
Avg carpool commute trip length
Avg carpool non-commute trip length
Avg carpool size
Base peak VMT
Base off-peak VMT

TCM Specific
Increase in Number of HOV's
Pct of new HOV passengers who still make a trip
Pct of ridesharers who previously rode transit
Induced number of vehicle trips on mixed-flow lanes due to additional capacity
Pct of maximum VMT realized due to circuity of ridesharing

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Peak Trip Reduction=((Increase in Number of HOVs)*2*((1-(1/(Avg carpool size)))*(1-(Pct of new HOV passengers who still make a trip)-(Pct of ridesharers who previously rode transit))-(Induced number of vehicle trips on mixed-flow lanes due to additional capacity)

Off-peak Trip Reduction =- (Induced number of vehicle trips on mixed-flow lanes due to additional capacity)

Total Trip Reduction =(Peak Trip Reduction)+(Off-peak Trip Reduction)

Peak VMT Reduction =(Peak Trip Reduction)* (1+(Pct of new HOV passengers who still make a trip))*(((Pct of ridesharing that is commute)*(Avg carpool commute trip length))+((Pct of ridesharing that is non-commute)*(Avg carpool non-commute trip length)))*(Pct of maximum VMT realized due to circuity of ridesharing)

Off-Peak VMT Reduction =(Off-Peak Trip Reduction)*(1+(Pct of new HOV passengers who still make a trip))*(((Pct of ridesharing that is commute)*(Avg carpool commute trip length))+((Pct of ridesharing that is non-commute)*(Avg carpool non-commute trip length)))*(Pct of maximum VMT realized due to circuity of ridesharing)

Total VMT Reduction =(Peak VMT Reduction)+(Off-Peak VMT Reduction)

Pct Peak Speed Change=((Peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change =((Off-peak VMT reduction)/(Base off-peak VMT))*-(Off-peak elasticity of speed with respect to volume)

RAMP METER BYPASS FOR HOVS

Baseline Travel Characteristics
Pct of ridesharing that is commute
Pct of ridesharing that is non-commute
Avg carpool commute trip length
Avg carpool non-commute trip length
Avg carpool size
Base peak VMT
Base off-peak VMT

TCM Specific
Increase in Number of HOV's
Pct of new HOV passengers who still make a trip
Pct of ridesharers who previously rode transit
Induced number of vehicle trips on mixed-flow lanes due to additional capacity
Pct of maximum VMT realized due to circuity of ridesharing
Avg idling time per vehicle

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected Peak TCM Speed
Off-peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Peak Trip Reduction =((Increase in Number of HOVs)*2*((1-(1/Avg carpool size)))*(1-(Pct of new HOV passengers who still make a trip)-(Pct of ridesharers who previously rode transit)))-(Induced number of vehicle trips on mixed-flow lanes due to additional capacity)

Off-Peak Trip Reduction = - (Induced number of vehicle trips on mixed-flow lanes due to additional capacity)

Total Trip Reduction =(Peak Trip Reduction)+(Off-peak Trip Reduction)

Peak VMT Reduction =(Peak Trip Reduction)*(1+(Pct of new HOV passengers who still make a trip))*(((Pct of ridesharing that is commute)*(Avg carpool commute trip length))+((Pct of ridesharing that is non-commute)*(Avg carpool non-commute trip length)))*(Pct of maximum VMT realized due to circuity of ridesharing)

Off-Peak VMT Reduction =(Off-Peak Trip Reduction)*(1+(Pct of new HOV passengers who still make a trip))*(((Pct of ridesharing that is commute)*(Avg carpool commute trip length))+((Pct of ridesharing that is non-commute)*(Avg carpool non-commute trip length)))*(Pct of maximum VMT realized due to circuity of ridesharing)

Total VMT Reduction=(Peak VMT Reduction)+(Off-Peak VMT Reduction)

Pct Peak Speed Change =((Peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change $=$((Off-peak VMT reduction)/(Base off-peak VMT))*-(Off-peak elasticity of speed with respect to volume)

Change in Idling Time $=$(Increase in Number of HOVs)*(Avg number of drive-through trips per day)

EMPLOYER-BASED STRATEGIES

TRANSIT PASS SUBSIDY

Baseline Travel Characteristics
Total commute person trips
Total non-commute person trips
Pct of commute trips that are transit
Pct of non-commute trips that are transit
Pct of commute trips that are peak trips
Pct of commute trips that are off-peak trips
Pct of non-commute trips that are peak trips
Pct of non-commute trips that are off-peak trips
Pct of peak trips that are commute trips
Pct of peak trips that are non-commute trips
Pct of off-peak trips that are commute trips
Pct of off-peak trips that are non-commute trips
Avg transit commute trip length
Avg transit non-commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Pct subsidy of cost of monthly transit pass
Pct of employees offered transit passes
Pct of transit ridership increase that equals the trip reduction

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Elasticity of transit use with respect to cost for commuters
Elasticity of transit use with respect to cost for non-commuters
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Reduction in Commute Trips = (Percent subsidy of cost of monthly transit pass)*-(Elasticity of transit use with respect to cost for commuters)*(Total commute person trips)*(Percent of employees offered transit passes)*(Percent of commute trips that are transit)*(Percent of transit ridership that equals the trip reduction)

Reduction in Non-Commute Trips = -(Elasticity of transit use with respect to cost for non-commuters)*(Reduction in commute trips)*([(Total commute person trips)/(Total non-commute person trips)]*(Percent of non-commute trips that are transit)*(Percent of transit ridership that equals the trip reduction)

Peak Trip Reduction = [(Reduction in commute trips)*(Percent of commute trips that are peak trips)]+[(Reduction in non-commute trips)*(Percent of non-commute trips that are peak trips)]

Off-Peak Trip Reduction = [Reduction in commute trips)*(Percent of commute trips that are off-peak trips)]+[(Reduction in non-commute trips)*(Percent of non-commute trips that are off-peak trips)]

Total Trip Reduction = (Peak trip reduction)+(Off-peak trip reduction)

Peak VMT Reduction = (Peak trip reduction)*[(Percent of peak trips that are commute trips)*(Avg transit commute trip length)+(Percent of peak trips that are non-commute trips)*(Avg transit non-commute trip length)]

Off-Peak VMT Reduction = (Off-peak trip reduction)*[(Percent of off-peak trips that are commute trips)*(Avg transit commute trip length)+(Percent of off-peak trips that are non-commute trips)*(Avg transit non-commute trip length)

Total VMT Reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]* -(Off-peak elasticity of speed with respect to volume)

EMPLOYEE TRANSPORTATION COORDINATOR

Baseline Travel Characteristics
Pct of commute trips that are peak trips
Avg commute trip length
Avg carpool size
Base peak VMT
Base off-peak VMT

TCM Specific
Number of new ridesharers
Pct of new carpool passengers who still make a trip
Pct of new ridesharers who previously rode transit
Number of new transit riders
Pct of transit ridership increase that equals the trip reduction
Number of new walkers/bicyclists
Pct of maximum VMT realized due to circuity of ridesharing

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction =(Number of new ridesharers)*2*((1-1/(Avg car/vanpool size")*(1-(Pct of new carpool passengers who still make a trip))-(Pct of ridesharers who previously rode transit))+(Number of new transit riders) * 2 * (Pct of transit ridership increase that equals the trip reduction)) ((Number of new walkers/bicyclists) * 2)

Peak Trip Reduction = (Total trip reduction)*(Pct of commute trips that are peak trips)

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak trip reduction)*(Avg commute trip length)*(Pct of maximum VMT reduction realized due to circuity of ridesharing)

Off-Peak VMT Reduction = (Off-peak trip reduction)*(Avg commute trip length)*(Pct of maximum VMT reduction realized due to circuity of ridesharing)

Total VMT Reduction = (Peak VMT reduction) + (Off-Peak VMT reduction)

Pct Peak Speed Change = ((Peak VMT reduction)/(Base peak VMT)*-(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change = ((Off-peak VMT reduction)/(Base off-peak VMT))*-(Off-peak elasticity of speed with respect to volume)

EDUCATION/INFORMATION DISSEMINATION

Baseline Travel Characteristics
Pct of commute trips that are peak trips
Avg commute trip length
Avg carpool size
Base peak VMT
Base off-peak VMT

TCM Specific
Number of new ridesharers
Pct of new carpool passengers who still make a trip
Pct of ridesharers who previously rode transit
Number of new transit riders
Pct of transit ridership increase that equals the trip reduction
Number of new walkers/bicyclists
Pct of maximum VMT realized due to circuity of ridesharing

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

> Total Trip Reduction = (Number of new ridesharers)*2*((1-1/(Avg car/vanpool size")*(1-(Pct of new carpool passengers who still make a trip))-(Pct of ridesharers who previously rode transit))+(Number of new transit riders) * 2 * (Pct of transit ridership increase that equals the trip reduction))+ ((Number of new walkers/bicyclists) * 2)

> Peak Trip Reduction = (Total trip reduction)*(Pct of commute trips that are peak trips)

> Off-Peak Trip reduction = (Total trip reduction)-(Peak trip reduction)

> Peak VMT Reduction = (Peak trip reduction)*(Avg commute trip length)*(Pct of maximum VMT reduction realized due to circuity of ridesharing)

> Off-Peak VMT Reduction = (Off-peak trip reduction)*(Avg commute trip length)*(Pct of maximum VMT reduction realized due to circuity of ridesharing)

> Total VMT Reduction = (Peak VMT reduction) + (Off-Peak VMT reduction)

> Pct Peak Speed Change = ((Peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

> Pct Off-Peak Speed Change = ((Off-peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

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GUARANTEED RIDE HOME

Baseline Travel Characteristics
Total commute person trips
Pct of commute trips that are non-HOV
Avg commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Avg number of guaranteed rides per day
Pct increase in alternative mode use

TCM Specific -Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction = [(Percentage increase in alternative mode use)*(Total commute person trips)*(Percent of commute trips that are non-HOV)]-(Avg number of guaranteed rides per day)

Peak Trip Reduction = (Total trip reduction)*(Percentage of commute trips that are peak trips)

Off-Peak Trip reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak trip reduction)*(Avg commute trip length)

Off-Peak VMT Reduction = (Off-peak reduction)*(Avg commute trip length)

Total VMT Reduction = (Peak VMT reduction)+(Off-Peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

TRIP REDUCTION ORDINANCES

Baseline Travel Characteristics
Total commute person trips Avg commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Avg number of telecommuters per day
Avg number of new telecommuters per day
Pct of employees affected
For employees affected, base pct that arrive in the peak
Base avg vehicle occupancy rate for affected employees
For employees affected, revised pct that arrive in the peak
Revised vehicle occupancy rate for affected employees
Occupancy of vehicles that shift from the peak to the off-peak

TCM Specific -Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Peak Trip Reduction =(Total commute person trips)+(Avg number of telecommuters per day)+(Avg number of new telecommuters per day))*(Pct of employees affected)*(((For employees affected, base pct that arrive in the peak)/(Base avg vehicle occupancy rate for affected employees))-((For employees affected, revised pct that arrive in the peak)/(Revised vehicle occupancy rate for affected employees)))

Off-peak Trip Reduction =((For employees affected, base pct that arrive in the peak)-(For employees affected, revised pct that arrive in the peak))*((Total commute person trips)+(Avg number of telecommuters per day)+(Avg number of new telecommuters per day))*(Pct of employees affected)/(Occupancy of vehicles that shift from the peak to the off-peak)

Total Trip Reduction = (Peak Trip Reduction)+(Off-peak Trip reduction)

Peak VMT Reduction =(Peak Trip Reduction)*(Avg commute trip length)

Off-Peak VMT Reduction =(Off-peak Trip Reduction)*(Avg commute trip length)

Total VMT Reduction =(Peak VMT Reduction)+(Off-Peak VMT Reduction)

Pct change in peak speed=-(Peak VMT Reduction)/(Base Peak VMT)*(Peak elasticity of speed with respect to volume)

Pct change in Off-peak speed= -(Off-Peak VMT Reduction)/(Base Off-Peak VMT)*(Off-Peak elasticity of speed with respect to volume)

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TRAFFIC IMPROVEMENT PROJECTS

TRAFFIC SIGNAL TIMING AND COORDINATION IMPROVEMENTS

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
Pct peak speed change
Pct off-peak speed change

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Peak TCM Speed
Off-Peak TCM Speed
Pct of peak VMT affected
Pct of off-peak VMT affected

Assumptions
none

Travel Impact Equations

TRAFFIC OPERATIONS CENTER

Baseline Travel Characteristics
Base peak VMT
base off-peak VMT

TCM Specific
Pct peak speed change
Pct off-peak speed change

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Peak TCM Speed
Off-Peak TCM Speed
Pct of peak VMT affected
Pct of off-peak VMT affected

Assumptions
none

Travel Impact Equations

COURTESY PATROL

Baseline Travel Characteristics
none

TCM Specific
Pct peak speed change
Pct off-peak speed change

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area type affected
Peak TCM Speed
Off-Peak TCM Speed
Pct of peak VMT affected
Pct of off-peak Vmt affected

Assumptions
none

Travel Impact Equations

OTHER INCIDENT DETECTION & RESPONSE PROGRAMS

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
Pct peak speed change
Pct off-peak speed change

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Peak TCM Speed
Off-Peak TCM Speed
Pct of peak VMT affected
Pct of off-peak VMT affected

Assumptions
none

Travel Impact Equations

MOTORIST INFORMATION

Baseline Travel Characteristics
Pct of peak trips that are commute trips
Pct of peak trips that are non-commute trips
Pct of off-peak trips that are commute trips
Pct of off-peak trips that are non-commute trips
Avg commute trip length
Avg non-commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Peak trip reduction during incidents
Off-peak trip reduction during incidents
Increase in peak VMT due to longer path chosen
Increase in off-peak VMT due to longer path chosen

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Peak Trip Reduction = (Peak trip reduction during incidents)

Off-Peak Trip Reduction = (Off-peak trip reduction during incidents)

Peak VMT Reduction = (Peak trip reduction)*((Pct of peak trips that are commute trips)*(Avg commute trip length))+((Pct of peak trips that are non-commute trips)*(Avg non-commute trip length))

Off-Peak VMT Reduction = (Off-peak trip reduction)*(((Pct of off-peak trips that are commute trips)*(Avg commute trip length))+((Pct of off-peak trips that are non-commute trips)*(Avg non-commute trip length)))

Total VMT Reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Pct Peak Speed Change =((Peak VMT reduction)/(Base peak VMT)*-(Peak elasticity of speed with respect to volume))

Pct Off-Peak Speed Change=((Off-peak VMT reduction)/(Base off-peak VMT))*-(off-peak elasticity of speed with respect to volume)

INTERSECTION IMPROVEMENTS (WIDENING)

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
Pct peak speed change
Pct off-peak speed change

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Peak TCM Speed
Off-Peak TCM Speed
Pct of peak VMT affected
Pct of off-peak VMT affected

Assumptions
none

Travel Impact Equations

RAMP METERING

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
Number of on-ramp vehicles affected
Pct peak speed change on freeway
Increase in idling time per vehicle

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Peak TCM Speed
Off-Peak TCM Speed
Pct of peak VMT affected

Assumptions
none

Travel Impact Equations

Change in Idling Time = (Number of on-ramp vehicles affected)*(Increase in idling time per vehicle)

REVERSIBLE LANES

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
Pct peak speed change
Pct off-peak speed change

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Peak TCM Speed
Off-Peak TCM Speed
Pct of peak VMT affected
Pct of off-peak VMT affected

Assumptions
none

Travel Impact Equations

PARK-N-RIDE LOTS

TRANSIT-ORIENTED

Baseline Travel Characteristics
Pct of commute trips that are peak trips
Pct of non-commute trips that are peak trips
Base peak VMT
Base off-peak VMT

TCM Specific
Number of non-vehicle trips to/from the lot
Pct of lot use that is commute trips
Pct of lot use that is non-commute trips
Number of new park-n-ride lot spaces
Avg utilization rate
Avg length of transit trip from lot

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

(1)   New Transit Service

Total Trip Reduction = (Number of non-vehicle trips to/from the lot)

Peak Trip Reduction = (Total trip reduction)*[(Percent of lot use that is commute trips)*(Percent of commute trips that are peak trips)+(Percent of lot use that is non-commute trips)*(Percent of non-commute trips that are peak trips)]

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Total MT Reduction =[(Total trip reduction)+(Number of new park-and-ride lot spaces)*(Avg utilization rate)*2]*(Avg length of transit from lot)

(2)   Existing Transit Service

Total trip Reduction = 0
Peak Trip Reduction = 0
Off-Peak Trip Reduction = 0

Total VMT reduction = (Number of new park-and-ride lot spaces)*(Avg utilization rate)*(1-(Percent of lot use by existing transit riders)]*2*(Avg length of transit trip from lot)

Total Trip Reduction = Σ Total Trip Reduction

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Peak Trip Reduction = Σ Peak Trip Reduction
Off-Peak Trip Reduction = Σ Off-Peak Trip Reduction
Total VMT Reduction = Σ Total VMT Reduction

Peak VMT Reduction = (Total VMT reduction)*([(Percent of lot use that is commute trips)*(Percent of commute trips that are peak trips)+(Percent of lot use that is non-commute trips)*(Percent of non-commute trips that are peak trips)]

Off-Peak VMT Reduction = (Total VMT reduction)-(Peak VMT reduction)

Percent Peak Speed Change =[(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-peak VMT Reduction)/(Base off-peak VMT)]*-(Off peak elasticity of speed with respect to volume)

CAR/VANPOOL-ORIENTED

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT
Avg carpool size

TCM Specific
Number of new park-n-ride lot spaces
Avg utilization rate
Pct of lot use by previous carpoolers
Number of non-vehicle trips to/from the lot
Number of carpool passengers who previously did not drive
Pct of travel to lot during the peak
Avg length of carpool trip from lot
Number of non-vehicle trips to/from the lot
Number of new carpool trips

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Number of New Carpool Trips = [(Number of new park-and-ride lot spaces)*(Avg utilization rate)*[1-(Percent of lot use by previous car/vanpoolers)]]/(Avg car/vanpool size)*2

Total Trip Reduction = (Number of non-vehicle trips to/from the lot)-(Number of carpool passengers who previously did not drive)-(Number of new carpool trips)

Peak Trip Reduction = (Total trip reduction)*(Percent of travel to lot during the peak)

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Total VMT Reduction = [(Number of new park-and-ride lot spaces)*(Avg utilization rate)*[1-(Percent of use by previous car/vanpoolers)]+(Number of non-vehicle trips to/from the lot)]*2*(Avg length of car/vanpool trip from lot)

Peak VMT Reduction = (Total VMT reduction)*(Percent of travel to lot during the peak)

Off-Peak VMT Reduction = (Total VMT reduction)-(Peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

BIKE TO PARK-N-RIDE PROGRAM

Baseline Travel Characteristics
Pct of commute trips that are peak trips
Pct of non-commute trips that are peak trips
Base peak VMT
Base off-peak VMT

TCM Specific
Pct of park-n-ride lot trips that would bicycle
Total trips to the park-n-ride lot
Pct of lot use that is commute trips
Pct of lot use that is non-commute trips
Avg bicycle trip length to park-n-ride lot
Base pct of park-n-ride trips by bicycle

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction = ((Pct of park-n-ride lot trips that would bicycle)-(Base Pct of park-n-ride trips by bicycle))*(Total trips to the park-n-ride lot)

Peak Trip Reduction =(Percent of lot use that is commute trips)*(Percent of commute trips that are peak trips)+(Percent of lot use that is non-commute trips)*(Percent of non-commute trips that are peak trips)

Off-peak Trip Reduction =(Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction =(Peak trip reduction)*(Avg bicycle trip length to the park-n-ride lot)

Off-Peak VMT Reduction =(Off-peak trip reduction)*[(Avg bicycle trip length to the park-n-ride lot)

Total VMT Reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Pct Peak Speed Change=((Peak VMT reduction)/(Base Peak VMT)*-(Peak elasticity of speed with respect to volume))

Pct Off-Peak Speed Change =((Off-peak VMT reduction)/(Base off-peak VMT))*-(Off-peak elasticity of speed with respect to volume)

AUTO/TRUCK RESTRICTIONS

RESTRICTED TIMES FOR GOODS DELIVERY

Baseline Travel Characteristics
Avg truck trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Number of trucks that shift from peak to off-peak

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Peak trip reduction = (Number of trucks that shift from peak to off-peak)

Off-peak trip reduction = -(Number of trucks that shift from peak to off-peak)

Peak VMT reduction = (Reduction in peak trips)*(Avg truck trip length)

Off-peak VMT reduction = (Reduction in off-peak trips)*(Avg truck trip length)

Total VMT Reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-Peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

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AUTO RESTRICTED ZONES

Baseline Travel Characteristics
Pct of non-commute trips that are peak trips
Base peak VMT
Base off-peak VMT

TCM Specific
Number of trips that shift to transit/walking
Avg length of trip within zone
Increased Peak VMT due to driving around the zone
Increased Off-Peak VMT due to driving around the zone

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction =(Number of trips that shift to transit/walking)

Peak Trip Reduction = (Total Trip Reduction)*(Pct of non-commute trips that occur in the peak period)

Off-Peak Trip Reduction =(Total Trip Reduction)-(Peak Trip Reduction)

Peak VMT Reduction =(Avg length of trip within zone) - (Increased Peak VMT due to driving around the zone)

Off-peak VMT Reduction =((Off-Peak Trip Reduction) * (Avg length of trip within zone))- (Increased Off-Peak VMT due to driving around the zone)

Total VMT Reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change =((Peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = ((Off-peak VMT reduction)/(Base off-peak VMT))*-(Off-peak elasticity of speed with respect to volume)

CONGESTION PRICING

VMT TAX

Baseline Travel Characteristics
Total vehicle trips
Total commute vehicle trips
Total non-commute vehicle trips
Pct of all trips that are commute trips
Pct of all trips that are non-commute trips
Pct of peak trips that are commute trips
Pct of peak trips that are non-commute trips
Pct of off-peak trips that are commute trips
Pct of off-peak trips that are non-commute trips
Pct of all trips in the peak period
Avg commute trip length
Avg non-commute trip length
Avg daily commute out-of-pocket costs
Avg daily non-commute out-of pocket costs
Base peak VMT
Base off-peak VMT

TCM Specific
VMT tax per mile

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume
Elasticity of auto use with respect to auto operating costs

Travel Impact Equations

Percent commute vehicle trips = (Total commute vehicle trips)/(Total vehicle trips)

Percent non-commute vehicle trips = [(Total vehicle trips)-(Total commute vehicle trips)]/(Total vehicle trips)

Percent change in cost = [(VMT tax per mile)*[[(Percent of all trips that are commute trips)*(Avg commute trip length)]+[(Percent of all trips that are non-commute trips)*(Avg non-commute trip length)]]]/[[(Percent commute vehicle trips)*(Avg daily commute out-of-pocket costs)]+[(Percent non-commute vehicle trips)*(Avg daily non-commute out-of-pocket costs)]]

Total trip reduction = -(Percent change in cost)*(Elasticity of auto use with respect to auto operating costs)*(Total vehicle trips)

Peak trip reduction = (Total trip reduction)*(Percent of all trips in the peak period)

Off-peak trip reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT reduction = (Peak trip reduction)*[[(Percent of peak trips that are commute trips)*(Avg commute trip length)]+[(Percent of peak trips that are non-commute trips)*(Avg non-commute trip length)]]

Off-peak VMT reduction = (Off-peak trip reduction)*[[(Percent of off-peak trips that are commute trips)*(Avg commute trip length)]+[(Percent of off-peak trips that are non-commute trips)*(Avg non-commute trip length)]]

Total VMT Reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-Peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

TOLLS

Baseline Travel Characteristics
Avg commute trip length
Avg non-commute trip length
Total vehicle trips
Pct of all trips in the peak period
Pct of peak trips that are commute trips
Pct of peak trips that are non-commute trips
Pct of off-peak trips that are commute trips
Pct of off-peak trips that are non-commute trips
Base peak VMT
Base off-peak VMT

TCM Specific
Amount of toll
Avg number of times too paid per day
Avg daily out-of-pocket costs per vehicle
Pct of travel affected

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Baseline Average Peak Speed
Baseline Average Off-Peak Speed

Assumptions
Elasticity of auto use with respect to auto operating costs
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction = ((Amount of Toll) * (Avg number of time toll paid per day)/(Avg daily out-of-pocket costs per vehicle))*-(Elasticity of auto use with respect to auto operating costs)*(Total vehicle trips)*(Percent of travel affected)

Peak Trip Reduction = (Total Trip Reduction)*(Percent of trips that are peak trips)

Off-Peak Trip Reduction = (Total Trip Reduction)-(Peak Trip Reduction)

Peak VMT Reduction = (Peak Trip Reduction)*((Pct of peak trips that are commute trips)*(Avg commute trip length)+(Pct of peak trips that are non-commute trips) * (Avg non-commute trip length)

Off-Peak VMT Reduction = (Off-peak Trip Reduction) * (Pct of off-peak trips that are commute trips)*(Avg commute trip length) + (Pct of off-peak trips that are non-commute trips) * (Avg non-commute trip length)

Total VMT Reduction = (Peak VMT Reduction) + (O-peak VMT Reduction)

Percent Peak Speed Change = ((Peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = ((Off-peak VMT reduction)/(Base off-peak VMT)) *-(Off-peak elasticity of speed with respect to volume)

RIDESHARE PROGRAMS/SERVICES

REGIONAL OR NEIGHBORHOOD-BASED RIDESHARE PROGRAM

Baseline Travel Characteristics
Pct of person trips that are commute trips
Pct of commute trips that are peak trips
Pct of person trips that are non-commute trips
Pct of non-commute trips that are peak trips
Pct of ridesharing that is commute
Pct of ridesharing that is non-commute
Avg carpool commute trip length
Avg carpool non-commute trip length
Avg carpool size
Base peak VMT
Base off-peak VMT

TCM Specific - Software development operations and maintenance
Number of new ridesharers
Pct of new carpool passengers who still make a trip
Pct of ridesharers who previously rode transit
Pct of maximum VMT realized due to circuity of ridesharing

TCM Specific - Marketing/Advertising
Number of new ridesharers
Pct of new carpool passengers who still make a trip
Pct of ridesharers who previously rode transit
Pct of maximum VMT realized due to circuity of ridesharing

TCM Specific - research/New Product Development
Number of new ridesharers
Pct of new carpool passengers who still make a trip
Pct of ridesharers who previously rode transit
Pct of maximum VMT realized due to circuity of ridesharing

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

> Total Trip Reduction = (Number of new ridesharers)*(2*[[1-1/(Avg car/vanpool size)]*[1-(Percent of new carpool passengers who still make a trip)]-(Percent of ridesharers who previously rode transit)]

> Peak Trip Reduction = (Total trip reduction)*[(Percent of person trips that are commute trips)*(Percent of commute trips that are peak trips)+(Percent of person trips that are non-commute trips)*(Percent of non-commute trips)*(Percent of non-commute trips that are peak trips)]

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak trip reduction)*[(Percent of ridesharing that is commute)*(Avg carpool commute trip length)+(Percent of ridesharing that is non-commute)*(Avg carpool non-commute trip length)]*(Percent if maximum VMT realized due to circuity of ridesharing)

Total VMT Reduction = (Peak VMT reduction) + (Off-Peak VMT reduction)

Percent Peak Speed Change = [Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

TRANSPORTATION MANAGEMENT ASSOCIATIONS

Baseline Travel Characteristics
Pct of commute trips that are peak trips
Avg commute trip length
Avg carpool size
Base peak VMT
Base off-peak VMT

TCM Specific
Number of new ridesharers
Pct of new carpool passengers who still make a trip
Pact of ridesharers who previously rode transit
Number of new transit riders
Pct of transit ridership increase that equals the trip reduction
Number of new walkers/bicyclists
Pct of maximum VMT realized due to circuity of ridesharing

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction = (Number of new ridesharers)*2*((1-1/(Avg car/vanpool size")*(1-(Pct of new carpool passengers who still make a trip))-(Pct of ridesharers who previously rode transit))+(Number of new transit riders) * 2 * (Pct of transit ridership increase that equals the trip reduction)) ((Number of new walkers/bicyclists) * 2)

Peak Trip Reduction = (Total trip reduction)*(Pct of commute trips that are peak trips)

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak trip reduction)*(Avg commute trip length)*(Pct of maximum VMT reduction realized due to circuity of ridesharing)

Off-Peak VMT Reduction = (Off-peak trip reduction)*(Avg commute trip length)*(Pct of maximum VMT reduction realized due to circuity of ridesharing)

Total VMT Reduction = (Peak VMT reduction) + (Off-peak VMT reduction)

Pct Peak Speed Change = ((Peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change = ((Off-peak VMT reduction)/(Base off-peak VMT))*-(Off-peak elasticity of speed with respect to volume)

VANPOOL PROGRAMS

Baseline Travel Characteristics
Pct of commute trips that are peak trips
Base peak VMT
Base off-peak VMT

TCM Specific
Number of new vanpool passengers
Avg vanpool size
Pct of new passengers who still make a trip
Pct of vanpoolers who previously rode transit or carpooled
Avg vanpool commute trip length

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction = (Number of new vanpool passengers)*2*((1-1/(Avg vanpool size)) *(1-(Pct of new passengers who still make a trip))-(Pct of vanpoolers who previously rode transit or carpooled))

Peak Trip Reduction = (Total trip reduction)*(Pct of commute trips that are peak trips)

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak trip reduction)*(Avg vanpool commute trip length)

Off-Peak VMT Reduction = (Off-peak trip reduction) *(Avg vanpool commute trip length)

Total VMT Reduction = (Peak VMT reduction) + (Off-Peak VMT reduction)

Pct Peak Speed Change = ((Peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change = ((Off-peak VMT reduction)/(Base off-peak VMT)) *-(Off-peak elasticity of speed with respect to volume)

NON-MOTORIZED FACILITIES

PEDESTRIAN IMPROVEMENTS

Baseline Travel Characteristics
Pct of person trips that are commute trips
Pct of commute trips that are peak trips
Pct of person trips that are non-commute trips
Pct of non-commute trips that are peak trips
Pct of walking that is commute
Pct of walking that is non-commute
Avg walking commute trip length
Avg walking non-commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Number of new walkers

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction = (Number of new walkers/bicyclists) * 2

Peak Trip Reduction = (Total trip reduction)*([(Pct of person trips that are commute trips)*(Pct of commute trips that are peak trips)+(Pct of person trips that are non-commute trips)*(Pct of non-commute trips that are peak trips))

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak trip reduction)*((Pct of walking that is commute)*(Avg walking commute trip length)+(Pct of walking that is non-commute)*(Avg walking non-commute trip length))

Off-Peak VMT Reduction = (Off-peak trip reduction) *((Pct of walking that is commute) *(Avg walking commute trip length)+(Pct of walking that is non-commute)*(Avg walking non-commute trip length))

Total VMT Reduction =(Peak VMT reduction) + (Off-Peak VMT reduction)

Pct Peak Speed Change =((Peak VMT reduction)/(Base peak VMT)) *-(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change = ((Off-peak VMT reduction)/(Base off-peak VMT)) *-(Off-peak elasticity of speed with respect to volume)

BICYCLE LANES, PATHS

Baseline Travel Characteristics
Total commute person trips
Total non-commute person trips
Pct of commute trips less than 6 miles
Pct of non-commute trips less than 5 miles
Pct of commute trips that are peak trips
Pct non-commute trips that are peak trips
Pct of peak trips that are commute trips
Pct peak trips that are non-commute trips
Pct of off-peak trips that are commute trips
Pct of off-peak trips that are non-commute trips
Base percent of commute trips by bicycle
Base percent of non-commute trips by bicycle
Base peak VMT
Base off-peak VMT

TCM Specific
Pct of commute trips that would bicycle
Pct of non-commute trips that would bicycle
Avg bicycle commute trip length
Avg bicycle non-commute trip length

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction = [[(Percent of commute trips that would bicycle)-(Base percent of commute trips by bicycle)]*(Total commute person trips)*(Percent of commute trips less than 6 miles)]+[[(Percent of non-commute trips that would bicycle)-(Base percent of non-commute trips by bicycle)]*(Total non-commute person trips)*(Percent of non-commute trips less than 5 miles)]

Peak Trip Reduction = [[(Percent of commute trips that would bicycle) - (Base percent of commute trips by bicycle)]*(Total commute person trips)*(Percent of commute trips less that 6 miles)*(Percent of commute trips that are peak trips)]+[[Percent of non-commute trips that would bicycle)-(Base percent of non-commute trips by bicycle)]*(Total non-commute person trips)*(Percent of non-commute trips less than 5 miles)*(Percent of non-commute trips that are peak trips)]

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak trip reduction)*[(Avg bicycle commute trip length)*(Percent of peak trips that are commute trips)+(Avg bicycle non-commute trip length)*(Percent of peak trips that are non-commute trips)]

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Off-Peak VMT Reduction = (Off-peak VMT reduction)*[(Avg bicycle commute trip length)*(Percent of off-peak trips that are commute trips)+(Avg bicycle non-commute trip length)*(Percent of off-peak trips that are non-commute trips)]

Total VMT Reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction))/(Base Peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

BICYCLE AMENITIES (LOCKERS, SHOWERS, SECURE STORAGE)

Baseline Travel Characteristics
Pct of person trips that are commute trips
Pct of commute trips that are peak trips
Pct of person trips that are non-commute trips
Pct of non-commute trips that are peak trips
Pct of bicycling that is commute
Pct of bicycling that is non-commute
Avg bicycling commute trip length
Avg bicycling non-commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Number of new bicyclists

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction = (Number of new bicyclists) * 2

Peak Trip Reduction = (Total trip reduction)*([(Pct of person trips that are commute trips)*(Pct of commute trips that are peak trips) +(Pct of person trips that are non-commute trips)*(Pct of non-commute trips that are peak trips))

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak trip reduction)*((Pct of bicycling that is commute)*(Avg bicycling commute trip length)+(Pct of bicycling that is non-commute)*(Avg bicycling non-commute trip length))

Off-Peak VMT Reduction =(Off-peak trip reduction)*((Pct of bicycling that is commute)*(Avg bicycling commute trip length)+(Pct of bicycling that is non-commute)*(Avg bicycling non-commute trip length))

Total VMT Reduction = ((Peak VMT reduction + (Off-Peak VMT reduction)

Pct Peak Speed Change = ((Peak VMT reduction)/(Base peak Vmt))*-(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change = ((Off-peak VMT reduction)/(Base off-peak VMT)) *-(Off-peak elasticity of speed with respect to volume)

PUBLIC EDUCATION CAMPAIGN

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
Peak trip reduction
Off-peak trip reduction
Peak VMT reduction
Off-peak VMT reduction

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM speed
Cold Start Group
Vehicle Type Group
Facility Type Affected Seasonal Group

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total trip reduction = (Peak trip reduction)+(Off-peak trip reduction)

Total VMT reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-Peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

BICYCLE/PEDESTRIAN COORDINATOR POSITIONS

Baseline Travel Characteristics
Pct of person trips that are commute trips
Pct of commute trips that are peak trips
Pct of person trips that are non-commute trips
Pct of non-commute trips that are peak trips
Pct of walking/bicycling that is commute
Pct of walking/bicycling that is non-commute
Avg walking/bicycling commute trip length
Avg walking/bicycling non-commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Number of new walkers/bicyclists

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction = (Number of new walkers/bicyclists) * 2

Peak Trip Reduction = (Total trip reduction) *([(Pct of person trips that are commute trips)*(Pct of commute trips that are peak trips)+(Pct of person trips that are non-commute trips)*(Pct of non-commute trips that are peak trips))

Off-peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak trip reduction) *((Pct of walking/bicycling that is commute)*(Avg walking/bicycling commute trip length)+(Pct of walking/bicycling that is non-commute)*(Avg walking/bicycling non-commute trip length))

Off-Peak VMT Reduction = (Off-peak trip reduction) * ((Pct of walking/bicycling that is commute) * (Avg walking/bicycling commute trip length) + (Pct of walking/bicycling that is non-commute) * (Avg walking/bicycling non-commute trip length))

Total VMT Reduction = (Peak VMT reduction) + (Off-Peak VMT reduction)

Pct Peak Speed Change = ((Peak VMT reduction)/(Base peak VMT)) * -(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change = ((Off-peak VMT reduction)/(Base off-peak VMT)) *-(Off-peak elasticity of speed with respect to volume)

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VEHICLE IDLING CONTROLS

DRIVE-THROUGH RESTRICTIONS

Baseline Travel Characteristics
none

TCM Specific
Number of sites impacted
Avg number of drive-through trips per day
Avg idling time per vehicle
Pct of trips affected

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Are Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Travel Impact Equations

Change in Idling Time = (Number of sites impacted)*(Avg number of drive-through trips per day)*(Avg idling time per vehicle)*(Percent of trips affected)

Increase in Hot Starts = (Number of sites impacted)*(Avg number of drive-through trips per day)*(Pct of trips affected)

CURB-SIDE IDLING RESTRICTIONS

Baseline Travel Characteristics
none

TCM Specific
Number os sites impacted
Avg number of vehicles affected per site
Avg idling time per vehicle
Pct reduction in idling time for those vehicles that continue to idle
Pct of vehicles that no longer idle

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Travel Impact Equations

Change in Idling Time = (Number of sites impacted)*(Avg number of vehicles affected per site)*(Avg idling time per vehicle)*[(Percent reduction idling time for those vehicles that continue to idle)+(Percent of vehicles that no longer idle)]

Increase in Hot Starts = (Number of sites impacted)*(Avg number of vehicles affected per site) *(Pct of vehicle that no longer idle)

VEHICLE IDLING RESTRICTIONS BY BUSES AND TRUCKS

Baseline Travel Characteristics
none

TCM Specific
Number of loading/delivery sites affected
Number of idling truck trips per day
Avg idling time per truck
Pct of truck trips affected
Number of bus stops affected
Number of buses arriving per but stop per day
Reduction in bus idling time per stop

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
none

Travel Impact Equations

Change in Idling Time = [(Number of loading/delivery sites affected)*(Number of idling truck trips per day)*(Avg idling time per truck)*(Percent of trips affected)]*[(Number of bus stops affected)*(Number of buses arriving per but stop per day)*(Reduction in but idling time per stop)]

Increase in Hot Starts = (Number of loading/delivery sites affected)*(Number of idling trucks per day)*(Percent of trips affected))+((Number of bus stops affected)
*(Number of buses arriving per bus stop per day))

ALTERNATIVE WORK SCHEDULES

COMPRESSED WORK WEEK

Baseline Travel Characteristics
Total commute vehicle trips
Total commute person trips
Pct o commute trips that are peak trips
Pct of non-commute trips that are peak trips
Avg commute trip length
Avg non-commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Pct of employees participating
Increase in number of days off per week
Avg number of induced non-commute trips on employee's day off
Pct of participating trips that shift out of the peak period

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Commute Trip Reduction = (Total commute vehicle trips)*(Percent of employees participating)*[(Increase in number of days off per week)/5)

Non-Commute Trip Increase = [(Total commute person trips)/2]*(Percent of employees participating)*[(Avg number of induced non-commute trips on employee's day off)*(Increase in number of days off per week)/5]

Total Trip Reduction = (Commute trip reduction)-(Non-commute trip increase)

Peak Commute Trip Reduction = [(Commute trip reduction)*(Percent of commute trips that are peak trips)]+[[(Total commute vehicle trips)*(Percent of employees participating)_(Commute trip reduction)]*(Percent of participating trips that shift out of the peak period)]

Peak Non-Commute Trip Increase = (Non-commute trip increase)*(Percent of non-commute trips that are peak trips)

Peak Trip Reduction = (Peak commute trips reduction)-(Peak non-commute trip increase)

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak commute trip reduction)*(Avg commute trip length)-(Peak non-commute trip increase)*(Avg non-commute trip length)

Total VMT Reduction = (Commute trip reduction)*(Avg commute trip length)-(Non-commute trip increase)*(Avg non-commute trip length)

Off-Peak VMT Reduction = (Total VMT reduction)-(Peak VMT reduction)

Percent Peak Speed change = [Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

FLEXIBLE WORK HOURS

Baseline Travel Characteristics
Total commute vehicle trips
Avg commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Pct of employees affected
Pct of employees' trips that shift out of the peak period

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Peak TCM Speed
Off-Peak TCM Speed
Pct of peak VMT affected (Please enter "1.00" for this TCM)
Pct of off-peak VMT affected (Please enter "1.00" for this VMT)

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Peak Trip Reduction = (Total commute vehicle trips)*(Percent of employees affected)*(Percent of employee's trips that shift out of the peak period)

Off-Peak Trip Reduction = -(Peak Trip Reduction)

Total Trip Reduction = 0

Peak VMT Reduction = (Peak trip reduction)*(Avg commute trip length)

Off-Peak VMT Reduction = -(Peak VMT reduction)

Total VMT Reduction = 0

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

STAGGERED WORK HOURS

Baseline Travel Characteristics
Total commute vehicle trips
Avg commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Pct of employees affected
Pct of employees' trips that shift out of the peak period

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Peak TCM Speed
Off-Peak TCM Speed
Pct of peak VMT affected (Please enter "1.00" for this TCM)
Pct of off-peak VMT affected (Please enter "1.00" for this TCM)

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Peak Trip Reduction = (Total commute vehicle trips)*(Pct of employees affected)*(Pct of employee's trips that shift out of the peak period)

Off-Peak Trip Reduction = -(Peak Trip Reduction)

Total Trip Reduction = 0

Peak VMT Reduction = (Peak trip reduction)*(Avg commute trip length (miles))

Off-Peak VMT Reduction = -(Peak VMT reduction)

Total VMT Reduction = 0

Pct Peak Speed Change = ((Peak VMT reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change = ((Off-peak VMT reduction)/(Base off-peak VMT))*-(Off-peak elasticity of speed with respect to volume)

ALTERNATIVE FUELS INCENTIVE PROGRAMS

PUBLIC FLEET COMPRESSED NATURAL GAS

Baseline Travel Characteristics
Pct of all trips that are commute trips
Pct of all trips that are non-commute trips
Avg commute trip length
Avg non-commute trip length

TCM Specific
none

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Area Type Affected
TCM Speed
Pct reduction in CO emission rates
Pct reduction in VOC emission rates

Assumptions
none

Travel Impact Equations

REFORMULATED GASOLINE/DIESEL

Baseline Travel Characteristics
Pct of all trips that are commute trips
Pct of all trips that are non-commute trips
Avg commute trip length
Avg non-commute trip length

TCM Specific
none

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Area Type Affected
TCM speed
Pct reduction in CO emission rates
Pct reduction in VOC emission rates

Assumptions
none

Travel Impact Equations

PM10 REDUCTION MEASURES

ENHANCED STREET SWEEPING

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
none

TCM Specific - Emissions
Impact on PM10 hot spot/hot grid
Area Type Affected
Pct of peak VMT affected
Pct of off-peak VMT affected
Pct reduction in PM10 emission rates

Assumptions
none

Travel Impact Equations

ROAD SANDING/SALTING ALTERNATIVES

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
none

TCM Specific - Emissions
Impact on PM10 hot spot/hot grid
Area Type Affected
Pct of peak VMT affected
Pct of off-peak VMT affected
Pct reduction in PM10 emission rates

Assumptions
none

Travel Impact Equations

DIESEL CONTROL PROGRAMS

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
none

TCM Specific - Emissions
Impact on PM10 hot spot/hot grid
Area Type Affected
Pct of peak VMT affected
Pct of off-peak VMT affected
Pct reduction in PM10 emission rates

Assumptions
none

Travel Impact Equations

TELECOMMUNICATIONS

HOME-BASED TELECOMMUTING

Baseline Travel Characteristics
Total commute vehicle trips
Pct of commute trips that are peak trips
Avg commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Pct of employees participating
Pct of work days employees telecommute

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction = (Total commute vehicle trips)*(Percent of employees participating)*(Percent of work days employees telecommute)

Peak Trip Reduction = (Total trip reduction)*(Percent of commute trips that are peak trips)

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak trip reduction)*(Avg commute trip length)

Off-Peak VMT Reduction = (Off-peak trip reduction)*(Avg commute trip length)

Total VMT Reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

SATELLITE WORK CENTER

Baseline Travel Characteristics
Total commute person trips
Pct of commute trips by carpool
Avg carpool size
Pct of commute trips by transit
Pct of commute trips that are peak trips
Avg commute trip length
Base peak VMT
Base off-peak VMT

TCM Specific
Pct of employees participating
Pct of workdays employees telecommute
Pct of telecommuters who bicycle/walk/transit to the work center
Avg distance to work center
Pct of commute trips by carpool
Pct of commute trips by transit

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Number of Telecommuter Per Day = (Total commute person trips)*(Percent of employees participating)*(Percent of workdays employees telecommute)

Total Trip Reduction = (Number of telecommuters per day)*[(Percent of telecommuters who bicycle/walk/transit to the work center)-[(Percent of commute trips by carpool)*(1/1-(Avg carpool size)]-(Percent of commute trips by transit)]

Peak Trip Reduction = (Total trip reduction)*(Percent of commute trips that are peak trips)

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Total VMT Reduction = [(Total trip reduction)*(Avg commute trip length)]+[[(Number of telecommuters per day)-(Total trip reduction)]*[(Avg commute trip length)-(Avg distance to work center)]]

Peak VMT Reduction = (Total VMT reduction)*(Percent of commute trips that are peak trips)

Off-Peak VMT Reduction = (Total VMT reduction)-(Peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

TELECONFERENCING

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
Number of work sites with teleconferencing facilities
Number of meetings per day using facilities
Avg number of employees per site per meeting
Pct of meetings during the peak
Avg length of business-related trip

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction = (Number of worksites with teleconferencing facilities)*(Number of meetings per day using facilities)*(Avg number of employees per site per meeting)

Peak Trip Reduction = (Total trip reduction)*(Percent of meetings during the peak)

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Total trip reduction)*(Avg length of business-related trip)

Off-Peak VMT Reduction = (Off-peak trip reduction)*(Avg length of business-related trip)

Total VMT Reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

PARKING MANAGEMENT

RESTRICTED PARKING SUPPLY

Baseline Travel Characteristics
Avg vehicle occupancy
Avg commute trip length
Avg non-commute trip length
Pct of short-term parking that occurs during the peak
Pct of short-term parking that occurs during the off-peak
Base peak VMT
Base off-peak VMT

TCM Specific
Number of vehicle trips no longer made to site
Number of vehicle trips displaced to other destinations
Pct of reduced parking spaces that were long-term spaces
Pct of reduced parking spaces that were short-term spaces

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-Peak TCM Speed

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip Reduction = ((Number of vehicle trips no longer made to site)-(Number of vehicle trips displaced to other destinations))/(Avg vehicle occupancy)

Peak Trip Reduction = (Total Trip Reduction)*((Pct of reduced parking spaces that were long-term spaces)+(Pct of reduced parking spaces that were short-term spaces)*(Pct of short-term parking that occurs during the peak))

Off-Peak Trip Reduction = (Total Trip Reduction)-(Peak Trip Reduction)

Total VMT Reduction = (Total Trip Reduction)*((Pct of reduced parking spaces that were long-term spaces)*(Avg commute trip length)+(Pct of reduced parking spaces that were short-term spaces)*(Avg non-commute trip length)

Off-Peak VMT Reduction = (Total Trip Reduction)*(Pct of reduced parking spaces that were short-term spaces)*(Pct of short-term parking that occurs during the off-peak)*(Avg non-commute trip length)

Pct Peak Speed Change = ((Peak VMT Reduction)/(Base peak VMT))*-(Peak elasticity of speed with respect to volume)

Pct Off-Peak Speed Change = ((Off-peak VMT reduction)/(Base off-peak VMT))*-(Off-peak elasticity of speed with respect to volume)

PARKING CHARGES

Baseline Travel Characteristics
Avg daily commuter out-of-pocket costs
Avg daily non-commute out-of-pocket costs
Avg commute trip length
Avg non-commute trip length
Total commute vehicle trips
Total non-commute vehicle trips
Pct of commute trips that are peak trips
Pct of non-commute trips that are peak trips
Base peak VMT
Base off-peak VMT

TCM Specific
Increase in daily parking charge
Increase in hourly parking charge
Avg length of time parked
Pct of employees affected
Percent of non-commute travel affected

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-peak TCM Speed

Assumptions
Elasticity of parking demand with respect to cost for commute trips
Elasticity of parking demand with respect to cost for non-commute trips
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

(1)   Commute Parking Charges

Total Trip Reduction = [(Increase in daily parking charge)/(Avg. daily commute our-f pocket costs)]*-(Elasticity of parking demand with respect to cost for commute trips)*(Total commute vehicle trips)*(Percent of employees affected)

Peak-Trip Reduction = (Total trip reduction)*(Percent of commute trips that are peak trips)

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak trip reduction)*(Avg commute trip length)

Off-Peak VMT Reduction = (Off-peak trip reduction)*(Avg commute trip length)

(2)   Non-commute Parking Charges

Total Trip Reduction =[(Increase in hourly parking charge)*(Avg length of time parked)/(Avg daily non-commute out-of-pocket costs)]*-(Elasticity of parking demand with respect to cost for non-commute trips)*(Total non-commute vehicle trips)*(Percent of non-commute travel affected)

Peak Trip Reduction = (Total trip reduction)*(Percent of non-commute trips that are peak trips)

Off-Peak Trip Reduction = (Total trip reduction)-(Peak trip reduction)

Peak VMT Reduction = (Peak trip reduction)*(Avg non-commute trip length)

Off-Peak VMT Reduction = (Off-peak trip reduction)*(Avg non-commute trip length)

Combination of Commute and Non-Commute Parking Charges

> Total Trip Reduction = Σ Total trip reduction
> Peak Trip Reduction = Σ Peak trip reduction
> Off-Peak Trip Reduction = Σ Off-peak trip reduction
> Peak VMT Reduction = Σ Peak VMT reduction
> Off-peak VMT Reduction = Σ Off-peak VMT reduction
> Total VMT Reduction = Σ (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

PREFERENTIAL PARKING FOR CARPOOLS AND VANPOOLS

Baseline Travel Characteristics
Avg daily commute out-of-pocket costs
Avg daily non-commute out-of-pocket costs
Avg commute trip length
Avg non-commute trip length
Total commute vehicle trips
Total non-commute vehicle trips
Avg carpool size
Pct of commute travel that is ridesharing
Pct of commute trips that are peak trips
Pct of non-commute trips that are peak trips
Base peak VMT
Base off-peak VMT

TCM Specific
Decrease in daily parking charge
Decrease in hourly parking charge
Avg length of time parked
Pct of employees affected
Pct of non-commute travel affected

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-peak TCM Speed

Assumptions
Elasticity of parking demand with respect to cost for commute trips
Elasticity of parking demand with respect to cost for non-commute trips
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Commute Preferential Parking Total Trip Reduction = ((Decrease in daily parking charge)*(1-(Avg car/vanpool size))/(Avg daily commute out-of-pocket costs))*-(Elasticity of parking demand with respect to cost for commute trips)*(Total commute vehicle trips)*(Percent of employees affected)*(Pct of commute travel that is ridesharing)

Commute Preferential Parking Peak Trip Reduction = Commute Preferential Parking Total Trip Reduction *(Percent of commute trips that are peak trips)

Commute Preferential Parking Off-Peak Trip Reduction = Commute Preferential Parking Total Trip Reduction-Commute Preferential Peak Trip Reduction

Commute Preferential Parking Peak VMT Reduction = Commute Preferential Parking Peak Trip Reduction*(Avg commute trip length)

Commute Preferential Parking Off-Peak VMT Reduction = Commute Preferential Parking Off-Peak Trip Reduction *(Avg commute trip length)

Non-Commute Preferential parking Total Trip Reduction = ((Decrease in hourly parking charge)*(1-1/(Avg car/vanpool size))*(Avg length of time parked)/(Avg daily non-commute out-or-pocket costs))*(Elasticity of parking demand with respect to cost for non-commute trips)*(Total non-commute vehicle trips)*(Percent of non-commute travel affected)*(Pct of commute travel that is ridesharing)

Non-commute Preferential Parking Peak Trip Reduction = Non-Commute Preferential Parking Total Trip Reduction *(Percent of non-commute trips that are peak trips)

Non-commute Preferential Parking Off-Peak Trip Reduction = Non-Commute Preferential Parking Total Trip Reduction-Non-Commute Preferential Parking Peak trip Reduction

Non-Commute Preferential Parking Peak VMT Reduction = Non-Commute Preferential Parking Peak Trip Reduction *(Avg non-commute trip length)

Non-Commute Preferential Parking Off-Peak VMT Reduction = Non-commute Preferential Parking Off-peak Trip Reduction *(Avg non-commute trip length)

Total Trip Reduction = Commute Preferential Paring Total Trip Reduction + Non-commute Preferential Parking Total Trip Reduction

Peak Trip Reduction = Commute Preferential Parking Peak Trip Reduction + Non-Commute Preferential Parking Peak Trip Reduction

Off-Peak Trip Reduction = Commute Preferential Parking Off-Peak Trip Reduction + NCP Off-Peak Trip Reduction

Peak VMT Reduction = Commute Preferential Parking Peak VMT Reduction + Non-commute Preferential Parking Peak VMT Reduction

Off-Peak VMT Reduction = Commute Preferential Parking Off-Peak VMT Reduction + Non-commute Preferential Parking Off-Peak VMT Reduction

Total VMT Reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = ((Peak VMT reduction)/(Base Peak VMT))*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed cHange = ((Off-Peak VMT reduction)/(Base off-peak VMT))*-(Off-Peak elasticity of speed with respect to volume)

OTHER TRANSPORTATION PROJECTS

PROMISING TECHNOLOGIES

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
Peak trip reduction
Off-peak trip reduction
Peak VMT reduction
Off-Peak VMT reduction

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-peak TCM Speed
Cold Start Group
Vehicle Type Group
Facility Type Group
Seasonal Group

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip reduction = (Peak trip reduction)+(Off-peak trip reduction)

Total VMT reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-Peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

FEASIBLE APPROACHES

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
Peak trip reduction
Off-peak trip reduction
Peak VMT reduction
Off-peak VMT reduction

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-peak TCM Speed
Cold Start Group
Vehicle Type Group
Facility Type Group
Seasonal Group

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip reduction = (Peak trip reduction)+(Off-peak trip reduction)

Total VMT reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-Peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

USER DEFINED APPROACHES

Baseline Travel Characteristics
Base peak VMT
Base off-peak VMT

TCM Specific
Peak trip reduction
Off-peak trip reduction
Peak VMT reduction
Off-Peak VMT reduction

TCM Specific - Emissions
Impact on CO hot spot/hot grid
Impact on PM10 hot spot/hot grid
Area Type Affected
Peak TCM Speed
Off-peak TCM Speed
Cold Start Group
Vehicle Type Group
Facility Type Group
Seasonal Group

Assumptions
Peak elasticity of speed with respect to volume
Off-peak elasticity of speed with respect to volume

Travel Impact Equations

Total Trip reduction = (Peak trip reduction)+(Off-peak trip reduction)

Total VMT reduction = (Peak VMT reduction)+(Off-peak VMT reduction)

Percent Peak Speed Change = [(Peak VMT reduction)/(Base peak VMT)]*-(Peak elasticity of speed with respect to volume)

Percent Off-Peak Speed Change = [(Off-Peak VMT reduction)/(Base off-peak VMT)]*-(Off-peak elasticity of speed with respect to volume)

APPENDIX C
EMISSIONS EQUATIONS

EMISSIONS EQUATIONS

The basic elements of the emissions equations used in the TTI CM/AQ Evaluation Model are presented in this appendix. These equations do not exactly duplicate the code in the model. Estimation of CO, VOC, NOx, and PM10 emissions are based on separately estimating emissions by vehicle and then summing the results for reporting purposes. The process of calculating emissions for each vehicle type is not presented below.

I. Formulas for estimating baseline emissions

A. CO, VOC and NOx emissions

Peak Trip Emissions = (Peak Trips for Cold Starts * Cold Start Emission Rate) + (Peak Trips for Hot Starts * Hot Start Emission Rate)

Off-Peak Trip Emissions = (Off-Peak Trips for Cold Starts * Cold Start Emission Rate) + (Off-Peak Trips for Hot Starts * Hot Start Emission Rate)

Peak VMT Emissions = (Peak VMT by Vehicle Type * Emission Rate)

Off-Peak VMT Emissions = (Off-Peak VMT by Vehicle Type * Emission Rate)

Base CO = Peak VMT Emissions + Off-Peak VMT Emissions + Peak Trip Emissions + Off-Peak Trip Emissions

Base VOC = Peak VMT Emissions + Off-Peak VMT Emissions + Peak Trip Emissions + Off-Peak Trip Emissions

Base NOx = Peak VMT Emissions + Off-Peak VMT Emissions + Peak Trip Emissions + Off-Peak Trip Emissions

B. PM10 emissions

Peak PM10 Emissions = (Peak VMT by Vehicle Type * Peak PM10 Emission Rate) + (Peak VMT by Vehicle Type * Pct of VMT on Unpaved Roads * Unpaved Fugitive Dust Rate) + (Peak VMT by Vehicle Type * (1 - Pct of VMT on Unpaved Roads) * Unpaved Fugitive Dust Rate)

Off-Peak PM10 Emissions = (Off-Peak VMT by Vehicle Type * Off-Peak PM10 Emission Rate) + (Off-Peak VMT by Vehicle Type * Pct of VMT on Unpaved Roads * Unpaved Fugitive Dust Rate) + (Off-Peak VMT by Vehicle Type * (1 - Pct of VMT on Unpaved Roads) * Unpaved Fugitive Dust Rate)

Base PM10 = Peak PM10 Emissions + Off-Peak PM10 Emissions

II. Formulas for estimating emissions reductions from change in trips and VMT

A. CO, VOC, and NOx emissions

New Peak Speed = (1 + Pct peak speed change) * Peak TCM speed

New Off-Peak Speed = (1 + Pct off-peak speed change) * Off peak TCM speed

Peak Trip Emission Reduction = (Peak Trip Reduction for Cold Starts * Cold Start Emission Rate) + (Peak Trip Reduction for Hot Starts * Hot Start Emission Rate) - (New Buses * Cold Start Emission Rate for HDDT)

Off-Peak Trip Emission Reduction = (Off-Peak Trip Reduction For Cold Starts * Cold Start Emission Rate) + (Off-Peak trip Reduction for Hot Starts * Hot Start Emission Rate) - (New Buses* Hot Start Emission Rate for HDDT)

Peak VMT Emission Reduction = (Peak VMT Reduction By Vehicle Type * Emission Rate) - (New Bus Miles * Pct of all trips in peak period * Peak Emission Rate for HDDT)

Off-Peak VMT Emission Reduction = (Peak VMT Reduction by Vehicle Type * Emission Rate) - (New Bus Miles * Pct of all trips in peak period * Peak Emission Rate for HDDT)

CO Reduction = Peak VMT Emission Reduction + Off-Peak VMT Emission Reduction + Peak Trip Emission Reduction + Off-Peak Trip Emission Reduction

VOC Reduction = Peak VMT Emission Reduction + Off-Peak VMT Emission Reduction + Peak Trip Emission Reduction + Off-Peak Trip Emission Reduction

NOx Reduction = Peak VMT Emission Reduction + Off-Peak VMT Emission Reduction + Peak Trip Emission Reduction + Off-Peak Trip Emission Reduction

B. PM10 emissions

Peak VMT Reduction = (Peak VMT Reduction by Vehicle Type * Peak PM10 Emission Rate) - (New Bus Miles * Pct of all trips in peak period * Peak Emission Rate for HDDT) + (Peak VMT by Vehicle Type * Pct of VMT on Unpaved Roads * Unpaved Fugitive Dust Rate) + (Peak VMT by Vehicle Type * (1 - Pct of VMT on Unpaved Roads) * Unpaved Fugitive Dust Rate)

Off-Peak VMT Reduction = (Off-Peak VMT Reduction by Vehicle Type * Off-Peak PM10 Emission Rate) - (New Bus Miles * Pct of all trips in peak period * Off-Peak Emission Rate for HDDT) + (Off-Peak VMT by Vehicle Type * Pct of VMT on Unpaved Roads * Unpaved Fugitive Dust Rate) + (Off-Peak VMT by Vehicle Type * (1 - Pct of VMT on Unpaved Roads) * Unpaved Fugitive Dust Rate)

PM10 Reduction = Peak VMT Reduction + Off-Peak VMT Reduction

III. Formulas for estimating emissions reductions from change in speed only, no changes in trips or VMT, for CO, VOC and NOx, no PM10 reductions

New Peak Speed = (1 + Pct peak speed change) * Peak TCM speed

New Off-Peak Speed = (1 + Pct off-peak speed change) * Off-peak TCM speed

Peak VMT Emission Reduction = ((Peak VMT by Vehicle Type * Pct of peak VMT affected * Emission Rate at Peak TCM Speed) - (Peak VMT by Vehicle Type * Pct of peak VMT affected * Emission Rate))

Off-Peak VMT Emission Reduction = Off-Peak VMT Emission Reduction + ((Off-Peak VMT by Vehicle Type * Pct of off-peak VMT affected * Emission Rate At Off-Peak TCM Speed) - (Off-Peak VMT by Vehicle Type * Pct of off-peak VMT affected * Emission Rate))

CO Reduction = CO Reduction + Peak VMT Emission Reduction + Off-Peak VMT Emission Reduction

VOC Reduction = Peak VMT Emission Reduction + Off-Peak VMT Emission Reduction

NOx Reduction = Peak VMT Emission Reduction + Off-Peak VMT Emission Reduction

IV. Formulas for estimating emissions reductions from change in idling, for CO, VOC, and NOx, no PM10 reductions

Idle Emission Reduction = ((Change in Idling Time by Vehicle Type * Idle Emission Rate) - (Hot Starts by Vehicle Type * Hot Start Emission Rate))

CO Reduction = Idle Emission Reduction

VOC Reduction = Idle Emission Reduction

NOx Reduction = Idle Emission Reduction

V. Formulas for estimating emissions reductions from change in emission rates

A. CO, VOC, and NOx emissions

Note: Off-peak vehicle type factors used in calculations but total daily trips and trip distance are used to estimate reductions.

Avg Trip Distance = (Pct of all trips that are commute trips * Avg commute trip length (miles)) + (Pct of all trips that are non-commute trips * Avg non-commute trip length (miles))

Trips by Vehicle Type = Number of vehicles involved in the program * Avg number of daily trips per vehicle * Vehicle Type Factor

VMT by Vehicle Type = Number of vehicles involved in the program * Avg number of daily trips per vehicle * Avg Trip Distance * Vehicle Type Factor

Daily VMT Emissions = (Off-Peak VMT by Vehicle Type * Emission)

Daily Trip Emissions = (Off-Peak Trip Emissions * Cold Start Emission Rate) + (Off-Peak Trips for Hot Starts * Hot Start Emission Rate)

CO Reduction = (Daily VMT Emission + Daily Trip Emissions) * Pct reduction in CO emission rates

VOC Reduction = (Daily VMT Emissions + Daily Trip Emissions) * Pct reduction in VOC emission rates

NOx Reduction = (Daily VMT Emissions + Daily Trip Emissions) * Pct reduction in NOx emission rates

B. PM10 Emissions

Peak VMT Emission Reduction = Base Peak VMT * Pct of peak VMT affected * Peak PM10 Emission Rate

Off-Peak VMT Emission Reduction = Base Peak VMT * Pct of peak VMT affected * Peak PM10 Emission Rate

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PM10 Reduction = (Peak VMT Emission Reduction + Off-Peak VMT Emission Reduction) * Pct Reduction in PM10 Emission Rate

DRCOG MOBILE SOURCE AIR POLLUTANT EMISSIONS FACTORS

This section of the appendix documents the approaches used for defining mobile source air pollutant emissions for the CM/AQ project. Emission factors were either calculated through modeling or derived from literature sources, depending upon the parameter involved. The emission factors were developed to support the TTI CM/AQ Evaluation Model. This model uses transportation strategies, travel characteristics, traffic volumes, emission factors, and other information to evaluate proposed projects against a set of criteria. Air quality impacts of projects are determined by the model through coupling traffic volumes with emission factors. This results in a form of total burden analysis. It should be noted that estimation of carbon monoxide "hot spot" are not a part of this model.

In general, emission factors for a range of vehicle types, speeds, and operating conditions (or roadway areas and types, as appropriate) were developed. Emission factors are used directly in database format by the model and do not require any further calculation.

Pollutants Included: Of the six criteria pollutants under the 1990 Clean Air Act Amendments, the Denver Metropolitan Area is a nonattainment area for CO and PM10; it is transitional for ozone. Through discussions between JHK and the APCD, it was established that this model would consider CO, HC, NOx, and PM10 (re-entrained road dust and emissions from road sanding.) Of total HC emissions, the VOC component is of interest, due to its role as an ozone precursor. NOx emission factors were not used directly, but were evaluated for their contribution to nitrates, which constitute a secondary particulate. As part of a contract with the Texas Transportation Institute, NOx was added to the model by JHK & Associates.

Emission Factor Sources: Emission factors for CO, HC, and NOx were developed using the EPA's MOBILE5a and MOBILE 4.1 models. MOBILE5a was used for non-idle emissions and MOBILE 4.1 was used for idle emissions (MOBILE5a is not capable of directly modeling idle emissions.) PM10 emission factors were taken from the Denver Metropolitan Nonattainment Area

SIP for Particulate Matter Evaluation of the contributions of NOx to PM10 was based upon information developed by the RAQC and APCD.

Study Parameters: Parameters for the development of emission factors for the original model were as follows:

a. Base Year: 1998, with contemporary Inspection and Maintenance Program and other input data furnished by the APCD.

b. Operating Conditions: "Worst-case" conditions were used in MOBILE modeling for determining pollutant emissions. One set of runs was done with wintertime temperatures to provide these conditions for CO, and another set was done with summertime temperatures for VOC and NOx. Daily average pollutant emission rates were calculated.

c. Speeds modeled: Speeds were set at 2.5 MPH increments (from 2.5 MPH through 65.0 MPH) for MOBILE5a; MOBILE 4.1 was used at idle.

d. Operating modes: Cold start, hot start, and hot stabilized (catalyst and non-catalyst) operating modes were used.

e. Roadway categories: The VMT mix and trip data are applied in the Evaluation Model; therefore, roadway categories were not modeled individually as a part of emission factor development for CO, VOC, and NOx. PM10 data were by area and road type.

f. Vehicle types: Emission factors were calculated for each vehicle type (LDGV, LDGT1, LDGT2, HDGV, LDDV, LDDT, and HDDV) except motorcycles. Transit buses are considered to be in the HDDV category, and emission factors for them were developed through application of the MOBILE models. These were checked against the transit bus emission factors contained in Appendix N, Volume II, AAP-42.

MOBILE5a and MOBILE 4.1 Modeling: Input to the MOBILE models included the following flag settings for the original DRCOG model:

Flag Setting	Flag	Notes
1	PROMPT	No prompting
1	TAMFLAG	Use default rates

1	SPDFLG	One speed for all vehicle types
1	VMFLAG	Use default values
3	MYMRFG	User-specified vehicle distribution by age
1	NEWFLG	Default emission rates
3	IMFLAG	Local I/M program used
1	ALHFLG	No additional correction factors used
8	ATPFLG	User-specified ATP, et al. (Setting 2 for MOBILE 4.1)
1	RLFLAG	Uncontrolled refueling emission rates
2	LOCFLG	One LAP record for all scenarios
1	TEMFLG	Use ambient temperature range
4	OUTFMT	80-column output format
4	PRTFLG	Calculate and output CO, HC, and NOx (Setting 2 for winter-time - CO only)
1	IDLFLG	Do not calculate idle emissions (Setting 2 in MOBILE 4.1)
3	NMHFLG	VOC component of THC
1	HCFLAG	No component HC emission factors

The one-time data section was not modified from that supplied by the APCD, as it contains a locally derived vehicle registration mix. The Local Area Parameter record was modified to represent summertime or wintertime ambient temperature ranges and RVP values, as appropriate to the parameter being modeled. It also used OXYFLG 2 in order to model the wintertime use of oxygenated fuels.

As indicated, roadway categories were not modeled individually; a single scenario record was repeated with appropriate entries. The default values of VMT mix did not apply, as emission factors for individual vehicle types were extracted from each scenario record calculation. MOBILE5a was run successively with the following inputs: speed; temperature; and

PCCN/PCHC/PCCC operating mode "bags", appropriate to cold start (100/0/100), hot start (0/100/0), or hot stabilized (0/0/0) operating modes.

Particulates: The approach to PM10 is somewhat different from that used for the gaseous emission factors (CO, VOC, and NOx) determined through MOBILE5a and 4.1. Access to the PM10 data by the Evaluation Model is accordingly somewhat different.

As a precursor to the development of emissions inventories for the PM10 SIP, the APCD and other agencies in Colorado conducted a series of studies to determine PM10 concentrations (and emission factors) in the vicinity of various types of roadways. These studies included particulates from mobile sources, re-entrained dust, and sanding. Of these, re-entrained dust is the largest single component.

The PM10 vehicular emissions in the SIP are based upon MOPAR modeling done as a part of SIP development. Particulates from mobile sources are largely HC, so it is necessary to subtract these emissions from overall roadway-related particulate emissions in order to avoid double counting. Particulate emissions constitute about fifteen to twenty percent of total HC emissions from mobile sources and are equivalent to between ten and fifteen percent of re-entrained dust emissions. In preparing PM10 emissions inventories, the APCD adjusted MOPAR-derived values in order to account for a series of emissions control strategies. Adjusted mobile source PM10 emission factors are thus available on a weighted-average basis for each of the eight vehicle types.

Emission factors for re-entrained road dust do not include mobile source particulates or road sand; they do not vary with the season. The emission factor for sanding is 0.0896 gm/VMT, applicable to freeways, major regional highways, principal and minor arterials, and collectors. It is only used in winter (December-February) and is added to the re-entrained road dust emission factor.

NOx Contribution to PM10: Through air quality monitoring in the Denver area, it has been determined that nitrate and sulfate secondary particulates are a significant component of ambient PM10 concentrations. Nitrate concentrations are about twice those of sulfates. Nitrates are of

potential significance to the CM/AQ project since they are derived from NOx (NO and NO$_2$) through a reaction with ammonia, for which sewage treatment plants and feedlots are primary sources.

About one-quarter of the NOx emissions in the Denver Metropolitan Area are from mobile sources. In 1995, the APCD projects that there will be about 300 T/yr of mobile source NOx emissions (Reference 10.c.) with a traffic volume of 37x10^6 VMT/yr (Reference 10.b.) Both the NOx emissions and the VMT are relatively evenly distributed throughout the year. Ambient nitrate concentrations are higher in the winter and spring (by a factor of about five) than in the summer and fall; the contribution from mobile sources to ambient concentrations of nitrates is about 5μg/m$_3$ in summer and fall. The significance of NOx/nitrates to the project may be evaluated in terms of the VMT necessary to make a 1 μg/m^3 difference in ambient nitrate concentrations. By this measure, VMT differentials in excess of 3x10^6 in the winter and spring and 16x10^6 in the summer and fall would be required. In comparison, total VMT in the area for each of these two periods are expected to be about 18x10^6. It is not likely that the strategies or projects evaluated under CM/AQ will develop VMT differentials of this magnitude. Another measure of the significance of NOx/nitrates to the project is that the level of contribution of mobile sources to atmospheric nitrates at VMT levels of less than one million per year is so low as to not be significant.

It is not possible to precisely determine a relationship between the rate of mobile source NOx emissions and ambient nitrate concentrations without performing an extensive chemical mass balance analysis, which is beyond the scope of this project. However, by using simplifying assumptions, it is possible to establish some useful relationships between the two. For example, in winter and spring, about 9 percent of NOx emissions contribute to nitrate concentrations; in summer and fall this drops to about 2 percent.

As determined by MOBILE5a modeling, the VMT-averaged NOx emission factor (25 mi/hr, summer temperatures, and hot stabilized operation) is 1.94 gm/mi. On this basis, the contribution of nitrates from mobile sources is 0.179 gm/mi in winter and spring and 0.0363 gm/mi in summer and fall. To place these in perspective, daily average re-entrained dust emission factors for urban areas range from 0.4944 gm/mi for freeways to 1.6964 gm/mi for collectors.

Another comparison may be made with mobile source particulate emissions, discussed earlier, which have a weighted average, adjusted emission factor of 0.14425 gm/mi.

It should be kept in mind that the work done to date by the APCD and the RAQC on secondary particulates relates to emissions inventories and control strategies and not to the development of emission factor relationships. Further, the previously discussed monitoring and analysis work done to determine re-entrained dust emission factors implicitly included secondary particulates. From this, it may be concluded that the published re-entrained dust emission factors include a secondary particulate component and that this does not have to be added for the CM/AQ project.

Reference Database of Emission Factors: Emission factors are included in a Paradox database for reference use as a part of the Evaluation Model. The database and interrogation hierarchy contain several variables specific to VOC and HC emission factors These include:

        a.   Seven vehicle types

        b.   Three operation modes (cold start/hot start/hot stabilized.)

        c.   Twenty-six operating speeds, plus idle

Aggregate PM10 was accessed through area and facility type.

Glossary:

APCD	Air Pollution Control Division, Colorado Department of Health
CM/AQ	Congestion Management/Air Quality
CO	Carbon Monoxide
EPA	U.S. Environmental Protection Agency
HC	Hydrocarbons
HDDV	Heavy Duty Diesel Vehicle
HDGV	Heavy Duty Gas Vehicle
LDDT	Light Duty Diesel Truck
LDDV	Light Duty Diesel Vehicle

LDGT 1   Light Duty Gas Truck 1 (up to 6,000 lbs. Gross Vehicle Weight)

LDGT 2   Light Duty Gas Truck 2 (Gross Vehicle Weight between 6,001 and 8,500 lbs)

LDGV   Light Duty Gas Vehicle

MOPAR   Mobile Particulate Model (EPA)

NOx   Oxides of Nitrogen

PCCC   Catalyst-equipped vehicle, cold start

PCCN   Non-catalyst vehicle, cold start

PCHC   Catalyst-equipped vehicle, hot start

PM10   Particulate Matter, less than 10 microns in diameter

RAQC   Regional Air Quality Council

RVP   Reid Vapor Pressure

SIP   State Implementation Plan

VMT   Vehicle Miles Traveled

VOC   Volatile Organic Compunds

References: Documents used as references for this section include:

User's Guide to MOBILE 4.1 Office of Air and Radiation, Office of Mobile Sources, EPA, July 1991, with revised Chapter 2 describing MOBILE5a revisions, March 1993.

Colorado State Implementation Plan (SIP) for Particulate Matter (PM10), Denver Metropolitan Nonattainment Area Element (draft), RAQC and APCD, February 1993.

Memo, Kevin Briggs to Bob Graves, Subject: "Draft Denver PM10 - Secondary Particulate Concentrations for 1995 Attainment Scenario Five (uncontrolled)", APCD, December 23, 1992.

Compilation of Air Pollutant Emission Factors, AP-42, V. II: Mobile sources, Fourth Ed., EPA, September 1985.

APPENDIX D
VARIABLE DEFINITIONS

VARIABLE DEFINITIONS

GENERAL DEFINITIONS

<u>Commute Trip</u> - Any trip from home to work, or vice versa, including those with intermediate stops (such as for daycare, groceries). Includes all trips that fall into this category throughout a 24-hour average day, not only those within the peak period.

<u>Peak Period</u> - Includes both the A.M. and P.M. peak periods when the heaviest amount of commute traffic is present on the roadways. The length of this total period is not preset for the area being analyzed, but must be the same for the entire area.

BASELINE TRAVEL CHARACTERISTICS

<u>Average bicycling commute trip length</u> - The average distance traveled for a commute trip by bicycling, one-way. Measured in miles.

<u>Average bicycling non-commute trip length</u> - The average distance traveled for a non-commute trip by bicycling, one-way. Measured in miles.

<u>Average commute trip length</u> - The average distance traveled for a commute trip, one-way. Measured in miles.

<u>Average non-commute trip length</u> - The average distance traveled for a non-commute trip, one-way. Measured in miles.

<u>Average transit commute trip length</u> - The average distance traveled for a commute trip using transit, one-way. Measured in miles.

<u>Average transit non-commute trip length</u> - The average distance traveled for a non-commute trip using transit, one-way. Measured in miles.

<u>Average carpool commute trip length</u> - The average distance traveled for a commute trip in a carpool, one-way. Measured in miles.

<u>Average carpool non-commute trip length</u> - The average distance traveled for a non-commute trip in a carpool, one-way. Measured in miles.

<u>Average trip length for trucks</u> - The average distance traveled by a medium-duty or heavy-duty truck, one-way. Measured in miles.

<u>Average walking commute trip length</u> - The average distance traveled for a commute trip by

walking, one-way. Measured in miles.

Average walking non-commute trip length - The average distance traveled for a non-commute trip by walking, one-way. Measured in miles.

Average walking/bicycling commute trip length - The combined average distance traveled for a commute trip by a combination of bicycling and walking one-way. Measured in miles.

Average walking/bicycling non-commute trip length - The combined average distance traveled for a non-commute trip by a combination of bicycling and walking one-way. Measured in miles.

Average daily commute out-of-pocket cost per vehicle - For each vehicle, the average out-of-pocket commuting costs paid per day. Would include items such as parking, gasoline, and bridge tolls, but no cot of the vehicle or maintenance of the vehicle.

Average daily non-commute out-of-pocket cost per vehicle - For each vehicle, the average out-of-pocket costs paid per day for non-commute trips. Would include items such as parking, gasoline, and bridge tolls, but no cot of the vehicle or maintenance of the vehicle.

Average carpool size - The average number of occupants per carpool vehicle including vanpools.

Average vehicle occupancy - The average number of daily person trips excluding bicycling and walking trips divided by the average number of daily vehicle trips.

Base percent of commute trips that are bicycling - Of all commute person trips made in an average day, the percent that use bicycling as a mode of transportation.

Base percent of non-commute trips that are bicycling - Of all non-commute person trips made in an average day, the percent that use bicycling as a mode of transportation.

Commute trips as a share of total transit trips - Of all trips made on transit, the percent that are commute trips.

Base peak VMT - Total vehicle miles traveled on all roadways during the peak periods.

Base off-peak VMT - Total vehicle traveled on all roadways during the off-peak periods.

Off-peak person trips - The number of trips taken by individuals during times other than the A.M. and P.M. peak periods on an average day. The sum of Peak Person Trips and Off-Peak Person Trips should equal the total person trips for an average day.

Peak person trips - The number of trips taken by individuals during the A.M. peak period and the P.M. peak period on an average day.

<u>Percent of all trips in peak period</u> - Of all the trips in an average, 24-hour day, the percent that occur during the A.M. and P.M. peak periods. It is assumed that this percentage will be the same for vehicle trips as for person trips.

<u>Percent of all trips that are commute trips</u> - Of all the vehicle trips in an average, 24-hour day, the percent that are commute trips.

<u>Percent of all trips that are non-commute trips</u> - Of all the vehicle trips in an average, 24-hour day, the percent that are non-commute trips. The sum of Percent of All Trips That Are Commute Trips and Percent of All Trips That Are Non-Commute Trips must equal one (1).

<u>Percent of all trips that are transit</u> - Of all person trips made in an average day, the percent that use transit as a mode of transportation.

<u>Percent of commute trips less than 6 miles</u> - Of all commute vehicle trips, the percent that are less than six miles in length.

<u>Percent of commute trips that are non-SOV</u> - The percentage of commute person trips for which there is more than one occupant in the vehicle or for which a vehicle is not used.

<u>Percent of commute trips that are off-peak trips</u> - The percent of the commute trips that occur during times other than the A.M. and P.M. peak periods. It is assumed that this percentage will be the same for vehicle trips as for person trips.

<u>Percent of commute trips that are peak trips</u> - The percent of the commute trips that occur in the A.M. and P.M. peak periods. It is assumed that this percentage will be the same for vehicle trips as for person trips.

<u>Percent of commute trips that are ridesharing</u> - Of all commute person trips made in an average day, the percent that are ridesharing as a mode of transportation.

<u>Percent of commute trips that are transit</u> - Of all commute person trips made in an average day, the percent that use transit as a mode of transportation.

<u>Percent of non-commute trips less than 5 miles</u> - Of all non-commute vehicle trips, the percent that are less than five miles in length.

<u>Percent of non-commute trips that are off-peak trips</u> - The percent of the non-commute trips that occur during times other than the A.M. and P.M. peak periods. It is assumed that this percentage will be the same for vehicle trips as for person trips.

<u>Percent of non-commute trips that are peak trips</u> - The percent of the non-commute trips that occur in the A.M. and P.M. peak periods. It is assumed that this percentage will be the same for

vehicle trips as for person trips.

Percent of non-commute trips that are transit - Of all non-commute person trips made in an average day, the percent that use transit as a mode of transportation.

Percent of off-peak trips that are commute trips - The percent of trips that occur in the off-peak that are commute trips. It is assumed that this percentage will be the same for vehicle trips as for person trips.

Percent of off-peak trips that are non-commute trips - The percent of trips that occur in the off-peak that are non-commute trips. It is assumed that this percentage will be the same for vehicle trips as for person trips.

Percent of peak trips that are commute trips - The percent of trips that occur in the A.M. and P.M. peak periods that are commute trips. It is assumed that this percentage will be the same for vehicle trips as for person trips. This is not an inverse of Percent of Commute Trips in Peak Period.

Percent of peak trips that are non-commute trips - The percent of trips that occur in the peak that are non-commute trips. It is assumed that this percentage will be the same for vehicle trips as for person trips.

Percent of off-peak trips that are transit - Of all person trips made during the off-peak period in an average day, the percent that use transit as a mode of transportation.

Percent of peak trips that are transit - Of person trips made during the A.M. and P.M. peak periods in an average day, the percent that use transit as a mode of transportation.

Percent of ridesharing that is commute - The percent of ridesharing trips that are commute trips.

Percent of ridesharing that is non-commute - The percent of ridesharing trips that are non-commute trips. The sum of Percent of Bicycling that is Commute and Percent of Bicycling that is Non-Commute must equal one (1).

Percent of bicycling that is commute - The percent of bicycling trips that are commute trips.

Percent of bicycling that is non-commute - The percent of bicycling trips that are non-commute trips. The sum of Percent of Bicycling that is Commute and Percent of Bicycling that is Non-Commute must equal one (1).

Percent of person trips that are commute trips - Of all the person trips in an average, 24-hour day, the percent that are commute trips.

Percent of person trips that are non-commute trips - Of all the person trips in an average, 24-hour day, the percent that are non-commute trips.

Percent of ridesharing that is commute - The percent of ridesharing trips that are commute trips.

Percent of ridesharing that is non-commute - The percent of ridesharing trips that are non-commute trips. The sum of Percent of Bicycling that is Commute and Percent of Bicycling that is Non-Commute must equal one (1).

Percent of walking that is commute - The percent of walking trips that are commute trips.

Percent of walking that is non-commute - The percent of walking trips that are non-commute trips. The sum of Percent of Walking that is Commute and Percent of Walking that is Non-Commute must equal one (1).

Percent of walking/bicycling that is commute - The percent of walking and bicycling trips that are commute trips.

Percent of walking/bicycling that is non-commute - The percent of walking and bicycling trips that are non-commute trips. The sum of Percent of Walking/Bicycling that is Commute and Percent of Walking/Bicycling that is Non-Commute must equal one (1).

Total commute person trips - Total number of commute trips taken by individuals on an average day. A person traveling to and from work would have a total of two commute person trips.

Total commute vehicle trips - Total number of commute trips taken by a vehicle on an average day. There may be more than one person in the vehicle, therefore, a vehicle trip may consist of more than one person trip.

Total non-commute person trips - Total number of non-commute trips taken by individuals on an average day. The sum of Total Commute Person Trips and Total Non-Commute Person Trips should equal the total person trips for an average day.

Total non-commute vehicle trips - Total number of non-commute trips taken by a vehicle on an average day. The sum of Total Commute Vehicle Trips and Total Non-Commute Vehicle Trips should equal the total vehicle trips for an average day.

Total vehicle trips - Total number of trips involving a vehicle on an average day.

ASSUMPTIONS

<u>Elasticity of auto use with respect to auto operating costs</u> - The percent change in auto use that will be experienced for a unit change in auto operating cost.

<u>Elasticity of parking demand with respect to cost for commute trips</u> - The percent change in parking demand for commute trips that will be experienced for a unit change in cost. The default value assumes no alternative parking available free from the parking increase. The user could insert an elasticity that takes other available parking into account.

<u>Elasticity of parking demand with respect to cost for non-commute trips</u> - The percent change in parking demand for non-commute trips that will be experienced for a unit change in cost. The default value assumes no alternative parking available free from the parking increase. The user could insert an elasticity that takes other available parking into account.

<u>Elasticity of speed with respect to volume (peak and off-peak)</u> - The percent that speed will change with a unit change in volume, defined here as vehicle miles traveled. The elasticity will be different for the peak period than for the off-peak period.

<u>Elasticity of transit use with respect to cost</u> - The percent change in transit ridership that will be experienced for a unit change in cost.

<u>Elasticity of transit use with respect to cost for commuters</u> -The percent change in transit ridership that will be experienced for a unit change in cost for commuters.

<u>Elasticity of transit use with respect to headway</u> - The percent change in transit ridership that will be experienced for a unit change in headway time expressed in minutes.

<u>Elasticity of transit use with respect to service (peak and off-peak)</u> - The percent change in transit ridership that will be experienced for a unit change in service expressed in route miles. The elasticity will be different for the peak period than for the off-peak period.

<u>Elasticity of transit use with respect to travel time (peak and off-peak)</u> - The percent change in transit ridership that will be experienced for a unit change in travel time expressed in minutes. The elasticity will be different for the peak period than for the off-peak period.

<u>Elasticity of transit use with respect to wait time (peak and off-peak)</u> - The percent change in transit ridership that will be experienced for a unit change in wait time expressed in minutes. The elasticity will be different for the peak period than for the off-peak period.

TCM SPECIFIC TRANSPORTATION VARIABLES

Improved Public Transit

Increased Transit Service

Increase in revenue miles during the peak - The additional number of vehicle revenue miles driven during the two peak periods by transit vehicles while in service on an average day.

Increase in revenue miles during the off-peak - The additional number of vehicle revenue miles driven during the off-peak period by transit vehicles while in service on an average day.

Percent decrease in travel time during the off-peak - The percentage decrease in average travel time for a transit passenger during the off-peak period.

Percent decrease in travel time during the peak - The percentage decrease in average travel time for a transit passenger during the A.M. and P.M. peak periods.

Percent decrease in wait time during the off-peak - The percentage decrease in average wait time for a transit vehicle during the off-peak period.

Percent decrease in wait time during the peak - The percentage decrease in average wait time for a transit vehicle during the A.M. and P.M. peak periods.

Percent of transit ridership increase that equals the trip reduction - This factor allows the increase in transit ridership to be equated to the number of vehicle trips reduced on the roadway. If every new transit rider was previous in a single-occupant vehicle, this percentage would be 100%, however, there will most likely be a number of new transit riders that previously carpooled or used a non-vehicle mode. In addition, some transit riders will drive to a transit stop.

Percent of transit system affected - The percentage of transit routes that are affected when travel time is reduced or wait time is reduced. This variable is not used for change in revenue miles calculations.

Total revenue miles during the off-peak - The total number of vehicle revenue miles driven during the off-peak period by transit vehicles while in service on an average day.

Total revenue miles during the peak - The total number of vehicle revenue miles driven during the A.M. and P.M. peak periods by transit vehicles while in service on an average day.

Express Bus

Average express bus trip length - The average length, in miles, of the new express bus service, one-way.

Existing headway - The average time between one transit vehicle and the next transit vehicle on the same transit route. Measured in minutes.

Existing travel time - The average travel time for a transit passenger on the existing non-express route that will be change to an express route. Measured in minutes.

Number of current transit riders on affected express bus routes - On the express bus routes with a change in service, the average number of transit riders currently using these bus routes.

Number of current transit riders on affected routes - The average number of daily transit passengers on the routes being converted to express service.

Percent of riders who can use express bus - The percent of transit riders on the existing route who will use the new express bus service.

Percent of transit ridership increase that equals the trip reduction - This factor allows the increase in transit ridership to be equated to the number of vehicle trips reduced on the roadway. If every new transit rider was previous in a single-occupant vehicle, this percentage would be 100%, however, there will most likely be a number of new transit riders that previously carpooled or used a non-vehicle mode. In addition, some transit riders will drive to a transit stop.

Revised headway - The new average time between two transit vehicles on the same transit route given a change in service. Measured in minutes.

Revised travel time - The average travel time for a transit passenger on the new express route. Measured in minutes.

Paratransit

Percent increase in off-peak transit use - The number of new transit riders resulting from the new service divided by the number of current transit riders, during the off-peak period.

Percent increase in peak transit use - The number of new transit riders resulting from the new service divided by the number of current transit riders, during both the A.M. and P.M. peak periods.

Percent of transit ridership increase that equals the trip reduction - This factor allows the increase

in transit ridership to be equated to the number of vehicle trips reduced on the roadway. If every new transit rider was previous in a single-occupant vehicle, this percentage would be 100%, however, there will most likely be a number of new transit riders that previously carpooled or used a non-vehicle mode. In addition, some transit riders will drive to a transit stop.

Light Rail

Average light rail commute trip length - The average trip length for the commuter while on the light rail vehicle. Measured in miles.

Average light rail non-commute trip length - The average trip length for passengers other than commuters while on the light rail vehicle. Measured in miles.

Percent decrease in travel time during the off-peak - The percentage decrease in average travel time for a transit passenger during the off-peak period.

Percent decrease in travel time during the peak - The percentage decrease in average travel time for a transit passenger during the A.M. and P.M. peak periods.

Percent of transit ridership increase that equals the trip reduction - This factor allows the increase in transit ridership to be equated to the number of vehicle trips reduced on the roadway. If every new transit rider was previous in a single-occupant vehicle, this percentage would be 100%, however, there will most likely be a number of new transit riders that previously carpooled or used a non-vehicle mode. In addition, some transit riders will drive to a transit stop.

Percent of transit system affected - The percentage of transit routes that are affected when travel time is reduced or wait time is reduced. This variable is not used for change in revenue miles calculations.

Bus Signal Pre-Emption

Change in off-peak travel time on affected routes - The average decrease in travel time during the off-peak period for all the affected transit routes. Expressed in minutes.

Change in peak travel time on affected routes - The average decrease in travel time during the A.M. and P.M. peak periods for all the affected transit routes. Expressed in minutes.

Existing off-peak travel time on affected routes - The average travel time during the off-peak period on transit routes that will be changed to include signal pre-emption. Express in minutes.

Existing peak travel time on affected routes - The average travel time during the two peak periods

on transit routes that will be changed to include signal pre-emption. Express in minutes.

Percent of off-peak speed decrease due to signal timing changes - The percent speed decrease for vehicles other than transit vehicles who may have increase delays during the off-peak period due to bus signal pre-emption.

Percent of peak speed decrease due to signal timing changes - The percent speed decrease for vehicles other than transit vehicles who may have increase delays during the two peak periods due to bus signal pre-emption.

Percent of transit ridership increase that equals the trip reduction - This factor allows the increase in transit ridership to be equated to the number of vehicle trips reduced on the roadway. If every new transit rider was previous in a single-occupant vehicle, this percentage would be 100%, however, there will most likely be a number of new transit riders that previously carpooled or used a non-vehicle mode. In addition, some transit riders will drive to a transit stop.

Percent of transit system affected during the off-peak - The percentage of transit routes that are affected during off-peak period when travel time is reduced or wait time is reduced. This variable is not used for change in revenue miles calculations.

Percent of transit system affected during the peak - The percentage of transit routes that are affected during the A.M. and P.M. peak periods when travel time is reduced or wait time is reduced. This variable is not used for change in revenue miles calculations.

Activity Center Shuttles

Average shuttle length - The average distance traveled by the shuttle vehicle in one trip.

Number of rides provided on shuttle - The average number of daily passengers on the new shuttle service.

Percent of trips that were previously walking - The percent of the shuttle passengers who previously walked to their destination.

Percent of shuttle trips in the peak - Of all shuttle trips on an average day, the percent of these trips made during the A.M. and P.M. peak periods.

Transit Advanced Traveler Information System

Percent increase in off-peak transit use - The number of new transit riders resulting from the new service divided by the number of current transit riders, during both the off-peak period.

Percent increase in peak transit use - The number of new transit riders resulting from the new service divided by the number of current transit riders, during both the A.M. and P.M. peak periods.

Percent of transit ridership that equals the trip reduction - This factor allows the increase in transit ridership to be equated to the number of vehicle trips reduced on the roadway. If every new transit rider was previous in a single-occupant vehicle, this percentage would be 100%, however, there will most likely be a number of new transit riders that previously carpooled or used a non-vehicle mode. In addition, some transit riders will drive to a transit stop.

Transit Shelters

Percent increase in off-peak transit use - The number of new transit riders resulting from the new service divided by the number of current transit riders, during both the off-peak period.

Percent increase in peak transit use - The number of new transit riders resulting from the new service divided by the number of current transit riders, during both the A.M. and P.M. peak periods.

Percent of transit ridership that equals the trip reduction - This factor allows the increase in transit ridership to be equated to the number of vehicle trips reduced on the roadway. If every new transit rider was previous in a single-occupant vehicle, this percentage would be 100%, however, there will most likely be a number of new transit riders that previously carpooled or used a non-vehicle mode. In addition, some transit riders will drive to a transit stop.

HOV Facilities

Freeway HOV Lanes

Increase in number of HOVs - The number of new high occupancy vehicles (vehicles with more than one occupant) as the result of new HOV lanes.

Induced number of vehicle trips on mixed-flow lanes due to additional capacity - The shifting of vehicles from the mixed-flow lanes to the HOV lanes will increase speeds on the mixed-flow lanes. If it is a congested freeway segment and there is latent demand in the area, then new vehicle trips may be made on the freeway.

Percent of maximum VMT reduction realized dut to circuity of ridesharing or access to transit - The reduction in VMT as a result of the reduction in number of trips of an average trip length will partially be offset by additional VMT incurred by the carpool vehicle due to pick-ups and drop-offs.

<u>Percent of new HOV passengers who still make a trip</u> - The percent of the new HOV passengers who drove to meet the carpool vehicle.

<u>Percent of ridesharers who previously rode transit</u> - The percent of new HOV passengers who changed from using transit to carpooling.

Arterial HOV Lanes

<u>Increase in number of HOVs</u> - The number of new high occupancy vehicles (vehicles with more than one occupant) as the result of new HOV lanes.

<u>Induced number of vehicle trips on mixed-flow lanes dut to additional capacity</u> - The shifting of vehicles from the mixed-flow lanes to the HOV lanes will increase speeds on the mixed-flow lanes. If it is a congested freeway segment and there is latent demand in the area, then new vehicle trips may be made on the freeway.

<u>Percent of maximum VMT reduction realized dut to circuity of ridesharing or access to transit</u> - The reduction in VMT as a result of the reduction in number of trips of an average trip length will partially be offset by additional VMT incurred by the carpool vehicle due to pick-ups and drop-offs.

<u>Percent of new HOV passengers who still make a trip</u> - The percent of the new HOV passengers who drove to meet the carpool vehicle.

<u>Percent of ridesharers who previously rode transit</u> - The percent of new HOV passengers who changed ffrom using transit to carpooling.

Ramp Meter Bypass for HOVs

<u>Average idling time per vehicle</u> - The average vehicle time waiting in a queue on the freeway on-ramp.

<u>Increase in number of HOVs</u> - The number of new high occupancy vehicles (vehicles with more than one occupant) as the result of new HOV lanes.

<u>Induced number of vehicle trips on mixed-flow lanes dut to additional capacity</u> - The shifting of vehicles from the mixed-flow lanes to the HOV lanes will increase speeds on the mixed-flow lanes. If it is a congested freeway segment and there is latent demand in the area, then new vehicle trips may be made on the freeway.

<u>Percent of new HOV passengers who still make a trip</u> - The percent of the new HOV passengers

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who drove to meet the carpool vehicle.

Percent of ridesharers who previously rode transit - The percent of new HOV passengers who changed from using transit to carpooling.

Employer-Based Strategies

Transit Pass Subsidy

Percent of employees offered transit passes - The percent of all employees in the area that are affected by this strategy (not only those who actual use the transit pass). This includes employees outside the urban areas and employees that commute in the off-peak hours.

Percent of transit ridership that equals the trip reduction - This factor allows the increase in transit ridership to be equated to the number of vehicle trips reduced on the roadway. If every new transit rider was previous in a single-occupant vehicle, this percentage would be 100%, however, there will most likely be a number of new transit riders that previously carpooled or used a non-vehicle mode. In addition, some transit riders will drive to a transit stop.

Percent subsidy of cost of monthly transit pass - The amount of subsidy, calculated as a percentage of the cost of a monthly transit pass, offered to employees for a monthly transit pass.

Employee Transportation Coordinator

Number of new ridesharers - The number of persons who changed their mode of transportation to ridesharing in response to this specific program during both the peak and off-peak periods.

Number of new transit riders - The number of persons who switched their mode of transportation to using transit, either bus or train, in response to this specific program during both the peak and off-peak periods.

Percent of new carpool riders that still make a trip - The percent of new passengers in carpools that drive to meet the carpool, such as to park-and-ride lot.

Number of new walkers/bicyclists - The number of individuals who changed their mode of transportation to waling or to bicycling in response to this specific program during both the peak and off-peak periods.

Percent of maximum VMT reduction realized due to circuity of ridesharing - The reduction in VMT as a result of the reduction in number of trips of an average trip length will partially be offset by additional VMT incurred by the carpool vehicle due to pick-ups and drop-offs.

<u>Percent of ridesharers who previously rode transit</u> - The percent of the new ridesharers who switched from using transit, either bus or train, to carpooling.

<u>Percent of transit ridership increase that equals the trip reduction</u> - This factor allows the increase in transit ridership to be equated to the number of vehicle trips reduced on the roadway. If every new transit rider was previous in a single-occupant vehicle, this percentage would be 100%, however, there will most likely be a number of new transit riders that previously carpooled or used a non-vehicle mode. In addition, some transit riders will drive to a transit stop.

Education/Information Dissemination

<u>Number of new ridesharers</u> - The number of persons who changed their mode of transportation to ridesharing in response to this specific program during both the peak and off-peak periods.

<u>Number of new transit riders</u> - The number of persons who switched their mode of transportation to using transit, either bus or train, in response to this specific program during both the peak and off-peak periods.

<u>Number of new walkers/bicyclists</u> - The number of individuals who changed their mode of transportation to walking or to bicycling in response to this specific program during both the peak and off-peak periods.

<u>Percent of maximum VMT reduction realized due to circuity of ridesharing</u> - The reduction in VMT as a result of the reduction in number of trips of an average trip length will partially be offset by additional VMT incurred by the carpool vehicle due to pick-ups and drop-offs.

<u>Percent of new carpool riders that still make a trip</u> - The percent of new passengers in carpools that drive to meet the carpool, such as to a park-and-ride lot.

<u>Percent of ridesharers who previously rode transit</u> - The percent of the new ridesharers who switched from using transit, either bus or train, to carpooling.

<u>Percent of transit ridership increase that equals the trip reduction</u> - This factor allows the increase in transit ridership to be equated to the number of vehicle trips reduced on the roadway. If every new transit rider was previous in a single-occupant vehicle, this percentage would be 100%, however, there will most likely be a number of new transit riders that previously carpooled or used a non-vehicle mode. In addition, some transit riders will drive to a transit stop.

Guaranteed Ride Home

Average number of guaranteed rides per day - The number of rides actually provided to employees on an average work day in response to the guaranteed ride home program.

Percent increase in alternative mode use - The number of commuters who changed their mode of transportation from driving alone to an alternative mode such as carpooling or using transit divided by the number of people who previously used an alternative mode to the single occupant vehicle.

Trip Reduction Ordinances

Average number of new telecommuters per day - The number of employees that are new to a telecommuting program, averaged over the number of days they telecommute to obtain the average number of telecommuters on any given day.

Average number of telecommuters per day - Telecommuters are those who work from home for an entire day and do not make a commute trip on that day. An individual will probably only telecommute a few days per week or month, therefore, this value is the average number of individuals that would be telecommuting on any given day, not the total number of individuals who participate in a telecommuting program.

Base average vehicle occupancy rate for affected employees - For employees affected by the TRO, the AVR that existed before the implementation of the TRO.

For employees affected, base percent that arrive in the peak - Before the trip reduction ordinance is established, the percent of commute person trips, for employees affected only, that arrive in the peak period. This variable, and the following two variables, are only necessary if the TRO shifts travel from one of the peak periods to the off-peak period.

For employees affected, revised percent that arrive in the peak - After the trip reduction ordinance is established, the percent of commute person trips, for employees affected only, that arrive in the peak period.

Occupancy of vehicles that shift from the peak to the off-peak - The TRO may include strategies, such as Flextime, that shift trips from the peak period to the off-peak period. This variable quantifies the average occupancy for those vehicles.

Percent of employees affected - The percent of all employees in the area that are affected by this strategy. This includes employees outside the urban areas and employees that commute in the off-peak hours.

Revised vehicle occupancy rate for affected employees - The new average vehicle occupancy rate (AVR) applied to affected employees that is the target for the trip reduction ordinance. In this case, AVR is defined as the number of employees that arrive at work during the peak period divided by the number of vehicles that arrive at an employment site during the peak period. In order to include the benefit of telecommuting, all telecommuters are included in the numerator; employees that arrive at work during the peak period.

Traffic Improvement Projects

Traffic Signal Timing and Coordination Improvements

Percent off-peak speed change - The average percent change in speeds during the off-peak period that are expected to occur over all of the roadways as a result of the implemented strategy.

Percent peak speed change - The average percent change in speeds during the peak period that are expected to occur over all of the roadways as a result of the implemented strategy.

Traffic Operations Center

Percent off-peak speed change - The average percent change in speeds during the off-peak period that are expected to occur over all of the roadways as a result of the implemented strategy.

Percent peak speed change - The average percent change in speeds during the peak period that are expected to occur over all of the roadways as a result of the implemented strategy.

Courtesy Patrol

Percent off-peak speed change - The average percent change in speeds during the off-peak period that are expected to occur over all of the roadways as a result of the implemented strategy.

Percent peak speed change - The average percent change in speeds during the peak period that are expected to occur over all of the roadways as a result of the implemented strategy.

Other Incident Detection & Response Programs

Percent off-peak speed change - The average percent change in speeds during the off-peak period that are expected to occur over all of the roadways as a result of the implemented strategy.

Percent peak speed change - The average percent change in speeds during the peak period that are

expected to occur over all of the roadways as a result of the implemented strategy.

Motorist Information

Increase in off-peak VMT due to longer path chosen - The increase in VMT during the off-peak period as a result of motorists changing the route to their destination after being informed of a roadway incident. Measured in miles.

Increase in peak VMT due to longer path chosen - The increase in VMT during the A.M. and P.M. peak periods as a result of motorists changing the route to their destination after being informed of a roadway incident. Measured in miles.

Off-peak trip reduction during incidents - The reduction in the number of vehicle trips in the off-peak period during a traffic incident, such as an accident, that will be expected as a result of providing travelers with information on the incident.

Peak trip reduction during incidents - The reduction in the number of vehicle trips in the peak period during a traffic incident, such as an accident, that will be expected as a result of providing travelers with information on the incident.

Intersection Improvements (Widening)

Percent off-peak speed change - The average percent change in speeds during the off-peak period that are expected to occur over all of the roadways as a result of the implemented strategy.

Percent peak speed change - The average percent change in speeds during the peak period that are expected to occur over all of the roadways as a result of the implemented strategy.

Ramp Metering

Increase in idling time per vehicle - The average increase in vehicle time waiting in a queue on the freeway on-ramp.

Number of on-ramp vehicles affected - The average daily number of vehicles that use the on-ramps that will have metering signals.

Percent peak speed change on freeway - The average percent change in speeds during the peak period that are expected to occur on the freeway as a result of ramp metering.

Reversible Lanes

Percent off-peak speed change - The average percent change in speeds during the off-peak period that are expected to occur over all of the roadways as a result of the implemented strategy.

Percent peak speed change - The average percent change in speeds during the peak period that are expected to occur over all of the roadways as a result of the implemented strategy.

Park-and-Ride Lots

Transit Oriented

Average length of transit trip from lot - The average distance that a person using transit travels from the park-and-ride lot to his or her destination.

Average utilization rate - On average for the new park-and-ride lots, the percent of available spaces that are used.

Number of non-vehicle trips to/from the lot - The number of daily trips made to or from the park-and-ride lot used an alternative mode to the passenger vehicle, such as by transit, walking, or bicycling.

Number of new park-and-ride lot spaces - The total number of new park-and-ride lot spaces provided by the project.

Percent of lot use that is commute trips - Of the vehicles that use a park-and-ride lot, the percent for which the trip is a commute trip.

Percent of lot use that is non-commute trips - Of the vehicles that use a park-and-ride lot, the percent for which the trip is not a commute trip.

Percent of lot used by existing transit riders - Of the persons using transit to travel from the park-and-ride lot, the percent who previously used transit before the lot was available.

Car/Vanpool-Oriented

Average length of carpool tips from lot - The average distance that a person in a carpool travels from the park-and-ride lot to his or her destination, probably the employment site.

Average utilization rate - On average for the new park-and-ride lots, the percent of available spaces that are used.

<u>Number of carpool passengers who previously did not drive</u> - The number of daily trips made to or from the park-and-ride lot that used an alternative mode to the passenger vehicle, such as by transit, walking, or bicycling.

<u>Number of new carpool trips</u> - The number of carpool trips using the park-and-ride lot that were previously made using a different travel mode such as drive alone vehicle or transit.

<u>Number of new park-and-ride spaces</u> - The total number of new park-and-ride lot spaces provided by the project.

<u>Number of non-vehicle trips to/from the lot</u> - The number of daily trips made to or from the park-and-ride lot used an alternative mode to the passenger vehicle, such as by transit, walking, or bicycling.

<u>Percent of lot use by previous carpoolers</u> - Of the persons using the park-and-ride lot, the percent who were carpooling previous to the opening of the lot.

<u>Percent of travel to lot during the peak</u> - The percent of daily trips to the park-and-ride lot that occurs during the A.M. and P.M. peak periods.

Bike to Park-and-Ride Program

<u>Average bicycle trip length to park-and-ride lot</u> - The average distance that a person using a bicycle travels from his or her starting point, probably the home end of a trip to the park-and-ride lot.

<u>Base percent of park-and-ride trips by bicycle</u> - The percent of trips made to a park-and-ride lot by bicycle before implementation of the bike program.

<u>Percent of lot use that is commute trips</u> - The number of trips made to the park-and-ride lot, the percent for which the trip is a commute trip.

<u>Percent of lot use that is non-commute trips</u> - The number of trips made to the park-and-ride lot, the percent for which the trip is not a commute trip.

<u>Percent of park-and-ride trips that would bicycle</u> - Of all trips to the park-and-ride lots, the percent of these trips that would be made by bicycle if facilities were provided.

<u>Total trip to the park-and-ride lots</u> - The number of trips made to the park-and-ride lots regardless of the travel mode.

Auto/Truck Restrictions

Restricted Time for Goods Delivery

Number of trucks that shift from peak to off-peak - The number of medium-duty and heavy-duty trucks that previously drove in the peak period that now drive in the off-peak period.

Auto Restricted Zones

Average length of trip within the zone - The average distance that a person travels making a trip within the auto-restricted zone.

Increased peak VMT due to driving around the zone - The additional VMT that occurs during the A.M. and P.M. peak periods due to vehicles traveling different routes to avoid the restricted zones.

Increase off-peak VMT due to driving around the zone - The additional VMT that occurs during the off-peak period due to vehicle travel that occurs to avoid the restricted zones.

Number of trips that shift to transit/walking - The number of trips made within the zone previously mode by passenger vehicle that now use transit or walking as their travel mode.

Congestion Pricing

VMT Tax

The tax per mile - The tax placed on drivers fro each vehicle mile traveled, expressed as dollars.

Tolls

Amount of toll - The cost of the toll levied on a passenger vehicle per trip, expressed in dollars.

Average daily out-of-pocket costs per vehicle - The average daily cost of driving a vehicle including gasoline, parking charges, and tolls, but excluding maintenance and purchase expenses.

Average number of times toll paid per day - For all passenger vehicle trips that pay the toll in one day, the average number of times a single vehicle pays the toll in that day.

Percent of travel affected - Of the baseline VMT, the percent of travel that includes use of toll

facility.

Rideshare Programs/Services

Regional or Neighborhood-Based Rideshare Program

Number of new ridesharers - The number of persons who carpool as a result of the rideshare program who previously used a different travel mode, including transit.

Percent of maximum VMT realized due to circuity of ridesharing - The reduction in VMT as a result of the reduction in number of trips of an average trip length will partially be offset by additional VMT incurred by the carpool vehicle due to pick-ups and drop-offs.

Percent of new carpool passengers who still make a trip - The percent of new carpool passengers who drive to a destination point to meet the carpool driver.

Percent of ridesharers who previously rode transit - The percent of new carpoolers who previously used transit.

Transportation Management Associations

Number of new ridesharers - The number of persons who carpool as a result of the rideshare program who previously used a different travel mode, including transit.

Number of new transit riders - The number of persons who switched their mode of transportation to using transit, either bus or train, in response to this specific program during both the peak and off-peak periods.

Number of new walkers/bicyclists - The number of persons who change their mode of travel to walking or bicycling in response to this program.

Percent of maximum VMT realized due to circuity of ridesharing - The reduction in VMT as a result of the reduction in number of trips of an average trip length will partially be offset by additional VMT incurred by the carpool vehicle due to pick-ups and drop-offs.

Percent of new carpool passengers who still make a trip - The percent of new carpool passengers who drive to a destination point to meet the carpool driver.

Percent of ridesharers who previously rode transit - The percent of new carpoolers who previously used transit.

<u>Percent of transit ridership increase that equals the trip reduction</u> - This factor allows the increase in transit ridership to be equated to the number of vehicle trips reduced on the roadway. If every new transit rider was previous in a single-occupant vehicle, this percentage would be 100%, however, there will most likely be a number of new transit riders that previously carpooled or used a non-vehicle mode. In addition, some transit riders will drive to a transit stop.

Vanpool Programs

<u>Average vanpool size</u> - The average number of persons in a vanpool, including the driver.

<u>Number of new vanpool passengers</u> - The number of persons who change their mode of travel to vanpooling in response to this program

<u>Percent of new passengers who still make a trip</u> - Of the vanpool passengers, the percent who drive to a destination point to meet the driver of the vanpool.

<u>Percent of vanpoolers who previously rode transit or carpooled</u> - The percent of new vanpoolers who changed their mode of travel from transit or carpooling.

Non-Motorized Facilities

Pedestrian Improvements

<u>Number of new walkers</u> - The number of persons who change their mode of travel to waling in response to the pedestrian improvements.

Bicycle Lanes, Paths

<u>Average bicycle commute trip length</u> - The average distance traveled for a commute trip, one-way, by bicycle. Measured in miles.

<u>Average bicycle non-commute trip length</u> - The average distance traveled for a non-commute trip, one-way, by bicycle. Measured in miles.

<u>Percent of commute trips that would bicycle</u> - The percentage of commute person trips that would be made by bicycling, including the increase in bicycling due to this program.

<u>Percent of non-commute trips that would bicycle</u> - The percentage of non-commute person trips that would be made by bicycling, including the increase in bicycling due to this program.

Bicycle Amenities (Lockers, Showers, Secure Storage)

Number of new bicyclists - The number of persons who change their mode of travel to bicycling in response to this specific program.

Public Education Campaign

Off-peak trip reduction - The reduction in the number of vehicle trips in the off-peak period that occur as a result of this specific program.

Peak trip reduction - The reduction in the number of vehicle trips in the peak periods that occur as a result of this specific program.

Off-peak VMT reduction - The reduction in vehicle miles traveled in the off-peak period that will be expected as a result of this program.

Peak VMT reduction - The reduction in vehicle miles traveled in the peak periods that will be expected as a result of this program.

Bicycle/Pedestrian Coordinator Positions

Number of new walkers/bicyclists - The number of persons who change their mode of travel to walking or bicycling in response to this specific program.

Vehicle Idling Controls

Drive-Through Restrictions

Average idling time per vehicle - For any single vehicle using the drive-though facility, the average time the vehicle idles. Time measured in seconds.

Average number of drive-through trips per day - For all locations affected, the average number of daily trips using the drive-through facility.

Number of sites impacted - The number of locations with drive-through facilities that will be affected by the restrictions.

Percent of trips affected - Of all the vehicles using the drive-through facility at the affected locations, the percent of these trips where idling time is eliminated.

Curbside Idling Restrictions

Average idling time per vehicle - For any single vehicle using the drive-though facility, the average time the vehicle idles. Time measured in seconds.

Average number of vehicles affected per site - For all locations affected, the average number of daily trips impacted by the program.

Number of site impacted - The number of locations affected by the restrictions.

Percent reduction in idling time for those vehicles that continue to idle - For those vehicles that continue to idle, the percent reduction in time the engine idles compared to idling time before the implementation of this restriction.

Percent of vehicles that no longer idle - For all the vehicles at the affected sites, the percent of vehicles whose engines are stopped.

Vehicle Idling Restrictions by Buses and Trucks

Average idling time per truck - For a truck at the impacted site, the average time the vehicle's engine idles. Time is measured in seconds.

Number of bus stops affected - The number of locations where buses will be restricted from idling their engines.

Number of buses arriving per bus stop per day - The total number of daily buses arriving at an average bus stop at the affected sites.

Number of loading/delivery sites affected - The number of truck delivery sites affected by the proposed restrictions.

Number of idling truck trips per day - The total number of truck trips that involve idling time to the impacted locations.

Percent of truck trips affected - Of the total number of idling trips at the affected locations, the percent of trucks whose engines no longer idle.

Reduction in bus idling time per stop - For a bus at the affected location, the average reduction in idling time for a single stop. Time is measured in seconds.

Alternative Work Schedules

Compressed Work Week

Average number of induced non-commute trips on employee's day off - The average number of non-commute trips that an employee makes on his/her day off as a result of the program that they would not have otherwise made. A trip that the employee would have made on their lunch hour if they were at work, for example, does not count as an induced trip.

Increase in number of days off per week - For those employees that do participate, the average number of days per week that they do not go to work as a result of the program. This value can be less than one if, for example, the employee works nine-hour days to obtain one day off every other week.

Percent of employees participating - The percent of the workforce that participates in a compressed work week program.

Percent of participating trips that shift out of the peak period - For the employees participating in the program, the percent of commute trips that shift from the peak period to the off-peak period. This may occur due to longer work days on the day that the employee does commute to work.

Flexible Work Hours

Percent of employees affected - The percent of the workforce that participates in the flexible hours program.

Percent of employee's trips that shift out of the peak period - For the employees involved in the program, the percent of their commute trips that shift from the peak period to the off-peak period.

Staggered Work Hours

Percent of employees affected - The percent of the workforce that participates in the staggered work hours program.

Percent of employee's trips that shift out of the peak period - For the employees involved in the program, the percent of their commute trips that shift from the peak period to the off-peak period.

Telecommunications

Home-Based Telecommuting

Percent of employees participating - The percent of the workforce that participates in a telecommuting program that is home-based..

Percent of work days employee telecommutes - For those employees that do participate, the percent of work days that they telecommute for a full day.

Satellite Work Centers

Average distance to work center - For participating employees, the average distance traveled from home to the work center. Distance measured in miles.

Percent of employees participating - The percent of the workforce that participates in a telecommuting program at satellite work centers.

Percent of telecommuters who bicycle/walk/transit to the work center - For those employees that do participate, the percent who bicycle, walk, or use transit to travel from home to the work center, thereby eliminating a vehicle trip.

Percent of work days employee telecommutes - For those employees that do participate, the percent of work days that they telecommute for a full day.

Teleconferencing

Average length of business-related trips - The average distance traveled for employees attending meetings away from the worksite. Distance is measured in miles.

Average number of employees per day per meeting - For a meeting held at a teleconferencing facility, the average number of employees attending the meeting who were already at the worksite.

Number of meetings per day using facilities - For a location with teleconferencing facilities, the average daily number of meetings held using these facilities.

Percent of meetings during the peak period - Of all the meetings conducted at the worksites, the percent that were conducted during the peak period.

Number of work sites with teleconferencing facilities - The number of employment locations that can hold meetings using teleconferencing facilities.

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Parking Management

Restricted Parking Supply

Number of vehicle trips displaced to other destination - The total number of vehicle trips that shift from the restricted parking areas to other parking locations.

Number of vehicle trips no longer made to site - The total number of vehicle trips that are eliminated as a result of restricting the parking supply.

Percent of reduced parking spaces that were long-term spaces - Of the parking spaces affected by restriction, the percent of the spaces used by vehicles parked more than 4 hours.

Percent of reduced parking spaces that were short-term spaces - Of the parking spaces affected by restriction, the percent of the spaces used by vehicles parked less than 4 hours.

Parking Charges

Average length of time parking - For non-commute parking, the average number of hours that the vehicle is parked.

Increase in daily parking charge - The average incremental increase in the fee levied for daily parking. If rates are monthly, then the monthly increase should be converted to a daily increase. Increase is measured in dollars.

Increase in hourly parking charge - The average amount that the hourly parking charge is increased. Increase is measured in dollars. The increase in daily charge should not be repeated here.

Percent of employees affected - Of all commute vehicle trips, the percent of employees that use the affected parking facilities.

Percent of non-commute travel affect - Of all non-commute vehicle trips, the percent of trips that are affected by the increase in parking charges.

Preferential Parking for Carpools and Vanpools

Average length of time parked - For non-commute parking, the average number of hours that the vehicle is parked.

Decrease in daily parking charges - The average incremental decrease in daily parking cost charged to carpools and vanpools. Measured in dollars.

Decrease in hourly parking charges - The average incremental decrease in hourly parking cost charged to carpools and vanpools. Measured in dollars.

Percent of employees affected - Of all commute vehicle trips, the percent of employees that use the affected parking facilities.

Percent of non-commute travel affected - Of all non-commute vehicle trips, the percent of trips that are affected by the decrease in parking charges.

Other Transportation Projects

Promising Technologies

Off-peak trip reduction - The reduction in the number of vehicle trips in the off-peak period that will occur as a result of this specific program.

Peak trip reduction - The reduction in the number of vehicle trips in the peak period that occur as a result of this specific program.

Off-peak VMT reduction - The reduction in VMT in the off-peak period that will be expected as a result of this program.

Peak VMT reduction - The reduction in vehicle miles traveled in the peak period that will be expected as a result of this program.

Feasible Approaches

Off-peak trip reduction - The reduction in the number of vehicle trips in the off-peak period that will occur as a result of this specific program.

Peak trip reduction - The reduction the number of vehicle trips in the peak period that occur as a result of this specific program.

Off-peak VMT reduction - The reduction in VMT in the off-peak period that will be expected as a result of this program.

Peak VMT reduction - The reduction in vehicle miles traveled in the peak period that will be expected as a result of this program.

User-Defined Strategies

Off-peak trip reduction - The reduction in the number of vehicle trips in the off-peak period that will occur as a result of this specific program.

Peak trip reduction - The reduction in the number of vehicle trips in the peak period that occur as a result of this specific program.

Off-peak VMT reduction - The reduction in the VMT in the off-peak period that will be expected as a result of this program.

Peak VMT reduction - The reduction in vehicle miles traveled in the peak period that will be expected as a result of this program.

TCM SPECIFIC EMISSIONS VARIABLES

Area type affected - Specific CM/AQ strategies might only impact the Central Business District, urban and suburban areas, or rural area though most strategies will affect all area types equally.

Average number of daily trips per vehicle - For the vehicles equipped to use the alternative fuel, the average number of daily trips made by a single vehicle.

Cold start group - Certain CM/AQ strategies will only affect the number of cold starts, such as strategies that only impact commute trips, other strategies will only affect hot starts, such as restrictions to vehicle idling, and other strategies will affect both hot and cold starts. The choices available for this variable are mixed start group (affect both cold and hot starts), 100 percent cold starts, or 100 percent hot starts. This variable only appears for the user-defined CM/AQ strategies since it has already been defined for the other strategies.

Facility type affected - Certain CM/AQ strategies will only affect travel on freeways and others may only affect travel on non-freeway though most strategies will affect travel on all facility types. The variable only appears for the user-defined CM/AQ strategies since is has already been defined for the other strategies.

Impact on CO hot spot/hot grid - Indication if the CM/AQ strategy as a specific impact on a CO

hot spot or hot grid in the Central Denver area. Response is either "yes' or "no."

Impact on PM10 hot spot/hot grid - Indication if the CM/AQ strategy has a specific impact on a PM10 hot spot or hot grid in the Central Denver area. Response is either "yes" or "no."

Number of new buses - The total number of new buses added to the fleet in response to the implemented program.

Number of new bus miles - The total number of operational transit miles added to service on a daily basis.

Number of new paratransit miles - The total number of operation paratransit miles added to service on a daily basis.

Number of paratransit vehicles - The total number of new paratransit vehicles added to the fleet in response to the implemented program.

Number of vehicles involved in the program - The total number of vehicles with modifications made to use the fuel specified by the program.

Off-peak TCM speed - The average off-peak speed for the study area before implementation of the CM/AQ strategy.

Peak TCM speed - The average speed during the two peak periods for the study area before implementation of the CM/AQ strategy.

Percent of off-peak VMT affected - Of the total vehicle miles traveled during the off-peak period, the percent affected by this program.

Percent of peak VMT affected - Of the total vehicle miles traveled during the A.M. and P.M. peak period, the percent of VMT affected by this program.

Percent reduction in CO emission rate - The average percent reduction in emission rates for carbon monoxide due to implementing this program.

Percent reduction in PM10 emission rate - The average percent reduction in emission rates for PM10 due to implementing this program.

Percent reduction in VOC emission rate - The average percent reduction in emission rates for volatile organic compound due to implementing this program.

Seasonal group - This variable only affects the set of PM10 rates to be used and whether the rates include impacts for roadway sanding during winter. The only strategies when the summer season

should be chosen are non-motorized projects when winter time travel will not be affected.

Vehicle type group - Certain CM/AQ strategies will only affect passenger vehicles, others will only affect commercial vehicles (defined as full-sized vans/pickup trucks or heavier), and one strategy only affects diesel powered vehicle. Most strategies will affect all vehicle types. This variable only appears for the user-defined CM/AQ strategies since is has already been defined for the other strategies.

APPENDIX E
WORKSHOP APPLICATIONS

CM/AQ EVALUATION MODEL
Results by Project

Project Name: Houston CBD Imporovements
TCM Category: Non-Motorized Facilities
TCM Name: PEDESTRIAN IMPROVEMENTS

Travel Impact Results

	Peak	Off-Peak	Total
Base Vehicle Trips	2,489,463	3,437,830	5,927,293
Trip Reduction	890	1,110	2,000
Pct Reduction	.0358%	.0323%	.0337%
Base VMT	21,900,000	24,700,000	46,600,000
VMT Reduction	710	884	1,594
Pct Reduction	.0032%	.0036%	.0034%
Pct Speed Change	.0000%	.0000%	

Change in Idling Time (if applicable):   0

Emissions Impact Results (Kg. per Day)

	CO	VOC	NOX	PM10
Base Emissions	882,650.2	89,094.5	145,405.4	42,205.7
Reduction	129.6	7.5	6.9	1.4
Pct Reduced	.0147%	.0084%	.0047%	.0034%

Cost-Effectiveness Results (Dollars per Kg. Reduced)

	CO	VOC	NOX	PM10
Public Sector	2.31	39.91	43.60	208.10
CM/AQ Funding	.77	13.30	14.53	69.37

Total Public Sector Cost: $ 300.00
CM/AQ Funding Requested: $ 100.00
Cost Basis Used for Criteria Weighting: Public

Criteria Weighting Results

Travel Impact Score: 0
Emissions Impact Score: 12
Cost-Effectiveness Score: 28
Early Effectiveness Score: 10

Project Rating: 50

```
                      CM/AQ EVALUATION MODEL
                       Results by Project

        Baseline Table: _B          Page:  2 of 6
     User Input Table: _D           Date:  4/11/95
       Results Table: _R            Time: 12:09 pm
    ─────────────────────────────────────────────────────────────
        Project Name: Bay Bridge Alternative
        TCM Category: Congestion Pricing
            TCM Name: TOLLS
    ─────────────────────────────────────────────────────────────
    Travel Impact Results

                          Peak        Off-Peak          Total
    Base Vehicle Trips  2,489,463     3,437,830       5,927,293
        Trip Reduction     99,579       137,513         237,092
         Pct Reduction   4.0000%       4.0000%         4.0000%

              Base VMT  21,900,000    24,700,000      46,600,000
         VMT Reduction     703,024       229,651         932,676
         Pct Reduction    3.2102%        .9298%          2.0014%

    Pct Speed Change       .0241%        .0020%

              Change in Idling Time (if applicable):      0

    ─────────────────────────────────────────────────────────────
    Emissions Impact Results (Kg. per Day)

                          CO          VOC         NOX         PM10
    Base Emissions    882,650.2    89,094.5   145,405.4    42,205.7
         Reduction     22,722.1     1,938.3     3,028.7       859.3
       Pct Reduced      2.5743%      2.1756%     2.0829%     2.0360%

    ─────────────────────────────────────────────────────────────
    Cost-Effectiveness Results (Dollars per Kg. Reduced)

                          CO          VOC         NOX         PM10
    Public Sector         .01         .15         .10         .35
    CM/AQ Funding         .00         .05         .03         .12

              Total Public Sector Cost: $      300.00
                  CM/AQ Funding Requested: $    100.00
        Cost Basis Used for Criteria Weighting: Public
    ─────────────────────────────────────────────────────────────
    Criteria Weighting Results

                     Travel Impact Score:    1
                  Emissions Impact Score:   13
                Cost-Effectiveness Score:   30
                Early Effectiveness Score:  10

                        Project Rating:     55
```

CM/AQ EVALUATION MODEL
Results by Project

Project Name: State Fleet Converstion
TCM Category: Alternative Fuels Incentives
TCM Name: PUBLIC FLEET COMPRESSED NATURAL GAS

Travel Impact Results

	Peak	Off-Peak	Total
Base Vehicle Trips	2,489,463	3,437,830	5,927,293
Trip Reduction	0	0	0
Pct Reduction	0.0000%	0.0000%	0.0000%
Base VMT	21,900,000	24,700,000	46,600,000
VMT Reduction	0	0	0
Pct Reduction	0.0000%	0.0000%	0.0000%
Pct Speed Change	0.0000%	0.0000%	

Change in Idling Time (if applicable):   0

Emissions Impact Results (Kg. per Day)

	CO	VOC	NOX	PM10
Base Emissions	882,650.2	89,094.5	145,405.4	42,205.7
Reduction	75,017.3	11,954.1	29,330.2	0.0
Pct Reduced	8.4991%	13.4173%	20.1713%	0.0000%

Cost-Effectiveness Results (Dollars per Kg. Reduced)

	CO	VOC	NOX	PM10
Public Sector	-.01	-.05	-.02	0.00
CM/AQ Funding	.01	.08	.03	0.00

Total Public Sector Cost: $ -600.00
CM/AQ Funding Requested: $ 1,000.00
Cost Basis Used for Criteria Weighting: Public

Criteria Weighting Results

Travel Impact Score: 0
Emissions Impact Score: 11
Cost-Effectiveness Score: 21
Early Effectiveness Score: 10

Project Rating: 42

CM/AQ EVALUATION MODEL
Results by Project

Project Name: Corporation Alternatives
TCM Category: Telecommunications
TCM Name: HOME-BASED TELECOMMUTING

Travel Impact Results

	Peak	Off-Peak	Total
Base Vehicle Trips	2,489,463	3,437,830	5,927,293
Trip Reduction	29,211	16,148	45,359
Pct Reduction	1.1734%	.4697%	.7652%
Base VMT	21,900,000	24,700,000	46,600,000
VMT Reduction	292,109	161,476	453,585
Pct Reduction	1.3338%	.6538%	.9734%
Pct Speed Change	.0100%	.0014%	

Change in Idling Time (if applicable):   0

Emissions Impact Results (Kg. per Day)

	CO	VOC	NOX	PM10
Base Emissions	882,650.2	89,094.5	145,405.4	42,205.7
Reduction	6,957.0	742.3	1,414.4	415.2
Pct Reduced	.7882%	.8331%	.9727%	.9837%

Cost-Effectiveness Results (Dollars per Kg. Reduced)

	CO	VOC	NOX	PM10
Public Sector	.04	.40	.21	.72
CM/AQ Funding	.01	.13	.07	.24

Total Public Sector Cost: $ 300.00
CM/AQ Funding Requested: $ 100.00
Cost Basis Used for Criteria Weighting: Public

Criteria Weighting Results

Travel Impact Score: 1
Emissions Impact Score: 12
Cost-Effectiveness Score: 30
Early Effectiveness Score: 10

Project Rating: 53

CM/AQ EVALUATION MODEL
Results by Project

Project Name: Houston Freeway Park-n-Ride Lots
TCM Category: Park-n-Ride Lots
TCM Name: TRANSIT-ORIENTED

Travel Impact Results

	Peak	Off-Peak	Total
Base Vehicle Trips	2,489,463	3,437,830	5,927,293
Trip Reduction	59	41	100
Pct Reduction	.0024%	.0012%	.0017%
Base VMT	21,900,000	24,700,000	46,600,000
VMT Reduction	7,223	5,077	12,300
Pct Reduction	.0330%	.0206%	.0264%
Pct Speed Change	.0002%	.0000%	

Change in Idling Time (if applicable):   0

Emissions Impact Results (Kg. per Day)

	CO	VOC	NOX	PM10
Base Emissions	882,650.2	89,094.5	145,405.4	42,205.7
Reduction	119.2	16.8	37.4	11.2
Pct Reduced	.0135%	.0188%	.0257%	.0266%

Cost-Effectiveness Results (Dollars per Kg. Reduced)

	CO	VOC	NOX	PM10
Public Sector	2.52	17.87	8.02	26.74
CM/AQ Funding	.84	5.96	2.67	8.91

Total Public Sector Cost: $ 300.00
CM/AQ Funding Requested: $ 100.00
Cost Basis Used for Criteria Weighting: Public

Criteria Weighting Results

Travel Impact Score: 0
Emissions Impact Score: 12
Cost-Effectiveness Score: 30
Early Effectiveness Score: 10

Project Rating: 52

CM/AQ EVALUATION MODEL
Results by Project

Project Name: Main Street Signalization Improvements
TCM Category: Traffic Improvement Projects
    TCM Name: TRAFFIC SIGNAL TIMING AND COORDINATION IMPROVEMENT

Travel Impact Results

	Peak	Off-Peak	Total
Base Vehicle Trips	2,489,463	3,437,830	5,927,293
Trip Reduction	0	0	0
Pct Reduction	0.0000%	0.0000%	0.0000%
Base VMT	21,900,000	24,700,000	46,600,000
VMT Reduction	0	0	0
Pct Reduction	0.0000%	0.0000%	0.0000%
Pct Speed Change	.1500%	.2500%	

Change in Idling Time (if applicable):   0

Emissions Impact Results (Kg. per Day)

	CO	VOC	NOX	PM10
Base Emissions	882,650.2	89,094.5	145,405.4	42,205.7
Reduction	24,861.3	2,771.4	-5,135.8	0.0
Pct Reduced	2.8167%	3.1106%	0.0000%	0.0000%

Cost-Effectiveness Results (Dollars per Kg. Reduced)

	CO	VOC	NOX	PM10
Public Sector	.01	.11	0.00	0.00
CM/AQ Funding	.00	.04	0.00	0.00

Total Public Sector Cost: $ 300.00
CM/AQ Funding Requested: $ 100.00
Cost Basis Used for Criteria Weighting: Public

Criteria Weighting Results

Travel Impact Score: 5
Emissions Impact Score: 12
Cost-Effectiveness Score: 15
Early Effectiveness Score: 10

Project Rating: 43

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